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January, 2026, volume 30
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TABLE OF CONTENTS

RESEARCH ARTICLES

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

REVIEW ARTICLE

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RESEARCH ARTICLES

Risk Management and Crop Insurance Adoption among Cocoa Farmers: Insights from Ekiti State, Nigeria

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ABSTRACT

Cocoa farming in Nigeria is increasingly threatened by production and market risks, including climate shocks, pest outbreaks, and price fluctuations. Farmers, as primary producers, often lack the resources and institutional support to effectively manage these risks, making crop insurance a potentially essential tool for protecting livelihoods. This paper examines the factors influencing cocoa farmers' adoption of crop insurance in Ekiti State, Nigeria, focusing especially on risk preferences and perceptions of insurance schemes. A total of 200 household heads were selected through multi-stage sampling across four cocoa-producing local government areas. Data on socio-demographic traits, insurance perceptions, and risk attitudes were analyzed using descriptive statistics and a binary logistic regression model. Results show that most cocoa farmers have not adopted crop insurance. Adoption was positively affected by education, household size, and debt usage, whereas membership in cooperative societies, farming experience, land ownership, and non-farm income were negatively related to insurance uptake. Notably, risk preferences did not differ significantly between insured and uninsured farmers, indicating that socio-economic factors are stronger predictors of insurance decisions. The paper concludes with policy recommendations to strengthen Nigeria's agricultural insurance system, including reforms to the Nigerian Agricultural Insurance Corporation (NAIC), the provision of better inputs, and the creation of farmer-friendly insurance products tailored for smallholders. By tackling both institutional and behavioral barriers, crop

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January, 2026, volume 30
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insurance can serve as an effective tool for improving resilience and sustainability in cocoa production.

Keywords: Cocoa production, crop insurance, farmer behaviour, Nigeria, risk management

INTRODUCTION

Nigeria is one of the world's major cocoa producers, ranking behind Côte d'Ivoire and Ghana, which dominate Africa's cocoa industry (ICCO, 2013). Cocoa has historically played a central role in Nigeria's agricultural economy, serving as both a household cash crop and a key export that brings in foreign exchange (Hamzat et al., 2006). Production averaged about 420,000 tons annually in the 1960s but dropped sharply to 170,000 tons by 1999 before rebounding to 389,272 tons in the early 2000s. Since then, output has declined again, making Nigeria the sixth-largest global producer in recent years (ICCO, 2013). The main cocoa-producing states include Ondo, Ekiti, Oyo, Osun, Edo, Ogun, and Cross River. Despite its significance, less than 10% of Nigeria's cocoa is processed domestically, which limits value addition and potential income for farmers (World Cocoa Foundation [WCF], 2012).

Globally, the cocoa sector is confronted with mounting risks that threaten both productivity and farmer welfare. Climatic variability, pest and disease infestation, and volatile international prices are among the major challenges. It is estimated that about 30% of cocoa output worldwide is lost to pests and diseases, reducing the supply available for both local and export markets (EUFIC, 1999). In Nigeria, farmers face additional challenges such as declining yields from ageing plantations, inadequate access to inputs, high production costs, and smallholder fragmentation (Babalola et al., 2016). The combination of these risks has contributed to declining production, growing economic insecurity, and increasing rural poverty among cocoa farmers (MCF, 2013). Risk is inherent in agriculture because outcomes are affected by uncertain events such as adverse weather, pest outbreaks, and price shocks (Hardaker et al., 2004). Farmers have traditionally relied on informal and semi-formal risk management strategies, including diversification, debt control, cooperative membership, and off-farm employment (Salimonu & Falusi, 2009; Alimi & Ayanwale, 2005). While these strategies provide some protection, they are often insufficient against systemic risks that affect entire communities or regions. Formal crop insurance has therefore been

advanced as an important tool to mitigate risks by indemnifying farmers against yield loss, poor prices, and climate-related shocks (Smith & Glauber, 2012).

Agricultural insurance products generally fall into three categories: named-peril products, multi-peril crop insurance (MPCI), and index-based insurance (Raviv, 1979; World Bank, 2011). In Nigeria, the Nigerian Agricultural Insurance Corporation (NAIC) was established in 1978 to promote the uptake of agricultural insurance. However, despite the potential benefits, farmer participation remains very low due to poor awareness, high premium costs, negative perceptions, and lack of trust in insurers (Giné & Yang, 2009; Seyed et al., 2010). Similar challenges have been documented across developing countries where insurance markets are underdeveloped (Smith & Glauber, 2012; Adinolfi et al., 2012).

Factors such as age, education, farming experience, farm size, debt use, land tenure, off-farm income, and risk perceptions have been identified as important predictors of insurance uptake (Barry et al., 2004; Shaik et al., 2008; Adinolfi et al., 2012). Yet, most of these studies are concentrated in developed economies or outside Africa (Rue, 2009; Brånstrand & Fredrik, 2014). Recent studies have affirmed that multiple socio-economic and structural factors shape farmers' decisions to adopt crop insurance (Sahoo & Behera, 2025; Barry et al., 2004). Variables such as education, land tenure, household size, debt burden, and cooperative membership significantly influence adoption rates. For instance, Sahoo and Behera (2025) highlight that better-educated farmers with access to credit are more likely to insure their crops, mirroring findings in Ekiti State cocoa farmers. Moreover, insurance adoption is often hindered by limited trust in insurance providers, perceived high premium costs, and a lack of understanding of insurance products (Attipoe, 2023; Giné & Yang, 2009). These challenges are compounded in settings where smallholder farmers rely heavily on cooperatives, which sometimes substitute formal insurance mechanisms. In addressing broader risk management, the United Nations Framework Convention on Climate Change (UNFCCC, 2024) advocates for integrating comprehensive risk management approaches in agrifood systems, emphasizing the critical role of risk-informed investments, technical assistance, and extension services to empower smallholders. Agricultural risk is increasingly shaped by climate variability, which threatens cocoa production significantly in West Africa (State of Africa's Environment, 2025; Christian Aid, 2025). Recent projections indicate that rising temperatures and erratic rainfall patterns could reduce suitable cocoa farming areas by up to 50% by 2050, stressing the urgency for adaptive risk mitigation strategies, including crop insurance and sustainable agricultural practices.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Within Nigeria, available studies on cocoa production have focused largely on coping strategies and marketing risks (Babalola et al., 2016; Salimonu & Falusi, 2009), while empirical research on cocoa farmers' crop insurance decisions remains scarce.

Despite the prominence of cocoa in Nigeria's agricultural exports and the increasing risks faced by smallholder farmers, there is limited empirical evidence on the determinants of cocoa farmers' uptake of crop insurance. Existing studies have either examined crop insurance in general terms (Seyed et al., 2010; Adinolfi et al., 2012) or explored farmers' coping strategies without a focus on insurance (Babalola et al., 2016; Hamzat et al., 2006). Moreover, while international literature emphasizes socio-economic and behavioral factors influencing insurance adoption (Barry et al., 2004; Smith & Baquet, 1996), few studies have contextualized these determinants within Nigeria's cocoa belt, where risks are compounded by smallholder production structures, climate change, and institutional weaknesses.

This study is therefore justified as it addresses a critical gap by examining the socio-demographic, economic, and risk-related factors influencing cocoa farmers' decisions to adopt crop insurance in Ekiti State, a major cocoa-producing region in Nigeria. By identifying these determinants, the study provides evidence that can inform policy interventions to strengthen NAIC's operations, design farmer-friendly insurance products, and promote resilience in Nigeria's cocoa sector. Ultimately, such insights are essential for enhancing farmer welfare, stabilizing production, and safeguarding the sustainability of Nigeria's cocoa industry in the face of global and local uncertainties.

MATERIALS AND METHODS

Study area

Cocoa production in Nigeria is concentrated within the humid rainforest zone, commonly referred to as the *Cocoa Belt*. This belt comprises the major producing States of Akwa Ibom, Cross River, Delta, Edo, Ekiti, Ogun, Ondo, and Oyo, which collectively form the backbone of Nigeria's cocoa economy. Among these States, Ekiti stands out as a significant contributor, producing over 40% of the cocoa output of the old Western Region.

Ekiti State, located in the southwestern part of Nigeria, has a total landmass of 6,353 km². The State is predominantly agrarian, with favourable climatic and

ecological conditions that make it particularly suited for cocoa cultivation. The climate is tropical monsoon, marked by two distinct seasons: a rainy season (April–October) and a dry season (November–March). Humidity is generally high during the rainy season but drops significantly during the Harmattan period of the dry season. Vegetation varies across the State, ranging from dense tropical forest in the southern axis to savannah vegetation in the northern peripheries. This ecological diversity not only supports cocoa farming but also sustains other forms of agriculture, further emphasizing Ekiti's status as an agriculturally endowed region.

Figure 1 highlights the risks posed by climate change on African cocoa production. Cocoa is sensitive to climate variables, and changes such as rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events threaten its cultivation. The significant risk here involves reduced yields, which not only impacts farmers' livelihoods but also the economy of countries dependent on cocoa exports. As conditions become less favorable for cocoa farming, producers face the challenge of adapting to sustain their crops and income.

Figure 2 provides insights into the predicted changes in the area suitable for cocoa production across various countries. By illustrating how simulated water-limited potential yield is expected to shift—with and without the effects of increased CO2—this figure underscores the geographical risk involved. If much of the suitable land for cocoa production diminishes due to climate change, it poses a considerable threat to food security and the economy within those regions. In summary, both figures collectively emphasize the urgent need for mitigation and adaptation strategies to manage the risks associated with climate-induced changes in cocoa production.

Data collection

The study adopted a survey design targeting cocoa farmer at the household level. Primary data were collected through the administration of a well-structured questionnaire, designed to capture both socio-economic and farm-level production characteristics of respondents.

The questionnaire comprised several modules, including Household socio-economic characteristics such as information on age, education, household size, income sources, and access to credit; Farm characteristics, including area of cocoa farms, tenure arrangements, farming experience, and labour utilization patterns

(family labour, hired labour, or cooperative labour arrangements). Other information elicited includes Production practices involving the adoption of cultural practices such as fertilizer use, pesticide application, pruning, and access to improved cocoa seedlings. Risk exposure and Insurance perception and risk preferences: farmers' perceptions of crop insurance and their risk attitudes were assessed using Likert-scale items, ranging from 1 (strongly disagree) to 5 (strongly agree). This approach enabled the researchers to gauge levels of agreement with statements related to insurance awareness, affordability, trust in insurance providers, and willingness to adopt insurance products. Pilot testing of the questionnaire was conducted before the main survey to ensure clarity and reliability of the items. Adjustments were subsequently made to improve precision and contextual relevance.

Sampling and sampling techniques

A multistage sampling technique was utilized to select respondents from various regions in Ekiti State. The process began with the selection of four local government areas (LGAs) known for their cocoa production: Irepodun/ Ifelodun, Gbonyin, Ekiti West, and Ijero. These areas were chosen specifically due to their significance in cocoa farming and the high involvement of local farming households in this crop.

Following the selection of the LGAs, the next step involved identifying two communities within each selected LGA, resulting in a total of eight communities. Randomly selected communities included Awo and Afao from Irepodun/Ifelodun, Ijan and Ilumoba from Gbonyin, Erijinyan and Aramoko from Ekiti West, and Ipoti and Odo Owa from Ijero. The final stage focused on selecting households within these communities. A method of systematic random sampling was employed, where enumerators followed a designated route. They started from one side of the road and alternated sides, selecting every third house to maintain objectivity and reduce bias in the selection process. In each household chosen, the head who managed a cocoa plantation was identified as the respondent. Through this comprehensive sampling procedure, a total of 200 cocoa farming households were successfully sampled across the eight communities. This dataset encompassed a diverse representation of cocoa farmers in Ekiti State, providing a solid foundation for analyzing various socio-economic factors, risk exposures, and the determinants influencing the uptake of crop insurance.

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January, 2026, volume 30
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Source: https://www.wur.nl/en/research-results/research-institutes/plant-research/show-wpr/climate-change-puts-african-cocoa-production-under-pressure.htm.

Figure 1. Climate change puts African cocoa production under pressure

Data analysis

The data generated from the field survey were subjected to both descriptive and inferential statistical analyses. Descriptive statistics, including measures such as means, frequencies, and percentages, were employed to summarize the socio-economic characteristics of the sampled cocoa farmers. These descriptive tools provided a useful overview of variables such as age, education, household size, land tenure, farm size, and cooperative membership, which are important for understanding the general profile of cocoa farmers in Ekiti State.

To empirically determine the factors influencing cocoa farmers' uptake of crop insurance, a binary logistic regression model was employed. The choice of the logit model is consistent with previous studies that analyze dichotomous outcomes, where the dependent variable takes two values—insured (1) and not insured (0) (Barry et al., 2004; Adinolfi et al., 2012). The logit specification enables estimation of the probability that a cocoa farmer will purchase crop insurance as a function of explanatory variables such as education, household size, farming experience, debt use, land ownership, non-farm income, and cooperative membership. Logistic regression is widely applied in agricultural economics because of its robustness in handling categorical outcomes and its ability to isolate significant determinants while controlling for confounding effects (Greene,

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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1993).

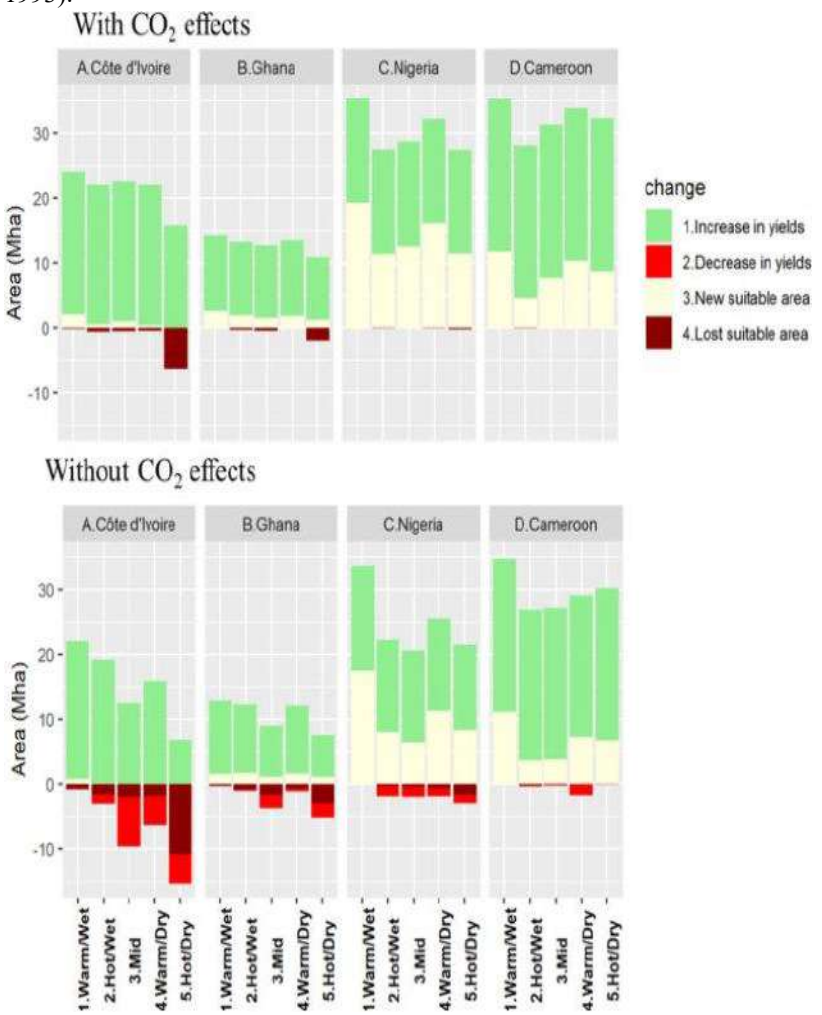

Figure 2. Predicted changes in total area suitable for cocoa production in each country where simulated water-limited potential yield is expected to change, with and without CO2 effects.

Source: https://www.wur.nl/en/research-results/research-institutes/plant-research/show-wpr/climate-change-puts-african-cocoa-production-under-pressure.htm

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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T-Test

To complement the regression analysis, an independent samples t-test was conducted to examine whether statistically significant differences exist between cocoa farmers who are insured and those who are not insured, across selected socio-economic attributes. The t-test provides a comparative assessment of group means, offering insights into whether observable differences are merely due to sampling variability or reflect genuine disparities (Newbold, 1991).

The null hypothesis tested was:

$H_0: \mu_x - \mu_y = 0$

which assumes no significant difference between the mean values of insured and uninsured farmers across each attribute. The alternative hypothesis was:

$H_1: \mu_x - \mu_y \neq 0$

which posits that the mean differences are statistically significant. The test assumes that observations are independent and approximately normally distributed within each group. The population variances σ_x^2 and σ_y^2 were estimated using the sample variances S_x^2 and S_y^2. The level of significance, α, was set at 5% (0.05), following conventional statistical standards in agricultural economics research (Newbold, 1991; Greene, 1993).

The decision rule was straightforward: if the calculated t-statistic exceeded the critical value at the chosen significance level, the null hypothesis was rejected in favor of the alternative. This approach provided a rigorous basis for determining whether insured and uninsured cocoa farmers differed significantly in terms of socio-economic and farm-level characteristics, thereby complementing the regression results with additional inferential evidence. A distribution table was employed, where the probability for the outcome is set at $\frac{\alpha}{2}$, reflecting a two-tailed test of significance (Newbold, 1991). This statistical procedure compares the mean values of an observed factor between two independent groups—farmers with insurance (X) and those without insurance (Y), to determine whether significant differences exist between them.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Logit Model

To analyze how the entire set of explanatory variables influences farmers' decisions to purchase crop insurance, a logistic regression model was employed. Logistic regression is particularly suitable for dichotomous dependent variables, as it estimates the probability of an event occurring (yes/no, success/failure) based on observed predictor variables (Greene, 1993). In this study, the dependent variable was insurance uptake, defined as:

Y = 1 if the farmer has crop insurance, 0 if the farmer does not have crop insurance

Thus, the model estimates the probability that a cocoa farmer adopts crop insurance, P(Y=1), as a function of socio-economic and farm-level characteristics. Logistic regression assumes that the probability of adoption is related to the independent variables (X) through a logistic cumulative distribution function (CDF). The general form of the model can be expressed as:

$$P(Y=1) = F(\beta'X) = \frac{1}{1+e^{-(\beta_0+\beta_1 X_1+\beta_2 x_2 \ldots..\beta_n x_n}} \quad (2)$$

Where:

P(Y=1) = probability of insurance uptake,
Y = binary dependent variable (insurance status),
β = estimated parameters (coefficients),
X = vector of independent variables (e.g., farm size, production level, age, education, debt use, cooperative membership, and risk preference).

The coefficients (β) capture the direction and strength of influence of each explanatory variable on the likelihood of insurance adoption. A positive coefficient implies that an increase in the explanatory variable raises the probability of being insured, while a negative coefficient indicates the opposite effect. Logistic regression is widely used in agricultural economics because it not only accommodates the binary nature of insurance decisions but also provides a measure of marginal effects, showing how incremental changes in explanatory variables affect the probability of insurance uptake (Barry et al., 2004; Adinolfi et al., 2012).

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RESULTS AND DISCUSSION

Descriptive analysis

Table 1 presents the descriptive statistics of the socio-economic characteristics of sampled cocoa farmers in Ekiti State, disaggregated by insurance status. The results highlight important differences between farmers who reported having crop insurance and those without. The average age of farmers with crop insurance was 51.3 years, compared with 56.4 years for those without insurance. This finding suggests that younger cocoa farmers may be more inclined to adopt agricultural innovations such as crop insurance, a trend consistent with earlier studies indicating that younger farmers are often more receptive to new technologies and risk management tools (Barry et al., 2004; Adinolfi et al., 2012). In terms of farming experience, cocoa farmers without crop insurance were generally more experienced than their insured counterparts. For example, nearly three-quarters of farmers who reported between 31 and 45 years of farming experience did not hold crop insurance. This outcome aligns with previous research suggesting that older, more experienced farmers may rely on traditional coping mechanisms or personal resilience rather than formal insurance products (Hardaker et al., 2004; Giné & Yang, 2009). It also raises questions about trust in insurance institutions, as experience with past policies—especially through the Nigerian Agricultural Insurance Corporation (NAIC)—has been associated with farmer skepticism (Hamzat et al., 2006). With respect to farm size, the majority of plantations fell within the range of 6–15 hectares, reflecting the dominance of small- to medium-scale production in the study area. Interestingly, farmers without crop insurance tended to control larger farm sizes compared with their insured counterparts. This finding appears counterintuitive, as larger farms are often associated with higher levels of risk exposure and, consequently, greater incentives to insure (Shaik et al., 2008). However, it may reflect structural constraints such as the affordability of premiums or limited access to suitable insurance products for larger commercial producers in Nigeria. Gender dynamics also reveal important patterns. Overall, 86% of cocoa farmers in the sample were male, underscoring the gender imbalance in cocoa production in Nigeria. Among insured farmers, 40% were male, while 46% of uninsured farmers were male. The relatively small difference across categories suggests that gender, while influential in access to agricultural resources, may not be a strong determinant of insurance uptake in this context. This contrasts with findings from other African settings where female farmers often face additional barriers to insurance adoption, including limited access to information and financial services (Asante et al., 2021).

Finally, the distribution of farmers across insurance categories indicates that a greater proportion of cocoa farmers (66%) did not hold insurance, compared to only 34% who reported being insured. This imbalance reflects broader national and regional trends, where adoption of agricultural insurance remains low among smallholder farmers due to high premium costs, lack of awareness, and distrust in insurance institutions (Smith & Glauber, 2012; Yusuf et al., 2024).

The analysis of household demographics shows that the mean household size for farmers without crop insurance was higher (8.2 persons) compared to 5.6 persons for insured farmers. Larger household sizes may increase consumption pressure and encourage reliance on informal coping mechanisms rather than formal risk management, a finding consistent with studies suggesting that household dependency often constrains investment in agricultural insurance (Brånstrand & Fredrik, 2014; Barry et al., 2003). Regarding land ownership status, the majority of cocoa farmers (77%) owned the land on which their cocoa was cultivated, either through purchase or inheritance, while the remaining 23% rented or leased farmland. Among landowners, 43% did not have crop insurance compared to 23% who did, whereas all farmers cultivating on rented or leased land reported having no insurance. This suggests that land tenure security may influence the likelihood of adopting crop insurance, as farmers who lack secure ownership may be less motivated to insure crops (Barry et al., 2004; Adinolfi et al., 2012).

In terms of debt use and access to credit, results show that a majority of those who borrowed capital for production were insured cocoa farmers (64%), while the remaining 36% of borrowers were uninsured. Among indebted farmers, 58% sourced loans through cooperative societies, while 30% accessed credit from the Central Bank of Nigeria's Anchor Borrower Scheme. Notably, all farmers who secured loans through the Anchor Borrower Scheme also had crop insurance, suggesting that insurance may act as a prerequisite or incentive for accessing institutional credit.

This aligns with findings from previous studies, which emphasize the complementarity between insurance adoption and credit access in agricultural risk management (Giné & Yang, 2009; Yusuf et al., 2024). Interestingly, cooperative membership showed an inverse relationship with insurance uptake. A greater proportion of uninsured cocoa farmers (60%) belonged to cooperatives compared with 40% of insured farmers.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Table-1. Socio-economic characteristics of cocoa farmers (n=200)

Variables	Insurance	No Insurance	Mean
Gender (%)			
Male	40		46
Female	6.0		8.0
Marital status (%)			
Single	3.0		4.0
Married	40	49	
Divorced	0.0	0.0	
Widowed	3.0	1.0	
Age (Mean)	51.3	56.4	
Household size (Mean)	5.6	8.2	5.9
Non-Farm income			
Yes	38		105.0
No	42	15.0	
Education (%)			9.0
Primary	42	15.0	
Secondary	10.0	4.0	
Tertiary	5.0		
No formal	12.0	38.0	
Membership of cooperative (%)			
Member	11.0	50.0	
Non-member	29.0	10.0	
Farming experience			16.0
1-15	13.0	25.0	
16-30	6.0	16.0	
31-45	11.0	30.0	
Insurance Use (%)	34.0	66.0	47.0
Land Ownership Status (%)			
Owned Land	34.0	43.0	
Rented/Lease	0.0	23.0	
Debt Use (%)	64.0	36.0	
Sources of Debt (%)			
Cooperative	28.0	30.0	
Commercial Bank	0.0	0.0	
Anchor Scheme (CBN)	30.0	0.0	
Money Lender	6.0	6.0	
Cocoa Farm Size (Ha)			5.6
1-5	2.3	1.9	
6-10	18.0	27.8	
11-15	15.3	28.0	
16-20	2.0	4.7	

Source: Author's Computation

This may imply that cooperatives serve as an alternative or substitute to insurance, providing a form of collective risk-sharing and financial support in times of shock (Salimonu & Falusi, 2009; Babalola et al., 2016). However, the overlap between cooperative participation and borrowing suggests that cooperatives also play a dual role as both informal insurance mechanisms and credit providers.

Table 2 further presents farmers' perceptions of production risks, their risk preferences, and their evaluation of crop insurance as a risk-mitigating strategy. Using an independent samples t-test, the analysis evaluated mean differences in reported risks between insured and uninsured farmers. The results show statistically significant differences in perceived risks related to drought, flooding, pest and disease incidence, lack of subsidies, input prices, weak extension services, and high production costs. These risks were considered more critical among farmers with insurance, possibly reflecting their heightened sensitivity to production shocks or their awareness of insurance as a formal risk buffer. These findings reflect the tension between formal and informal risk management strategies: while insurance is a formal safety net, farmers often rely on cooperatives, diversification, or accumulated experience as substitutes for formal insurance schemes (Adinolfi et al., 2012; Brånstrand & Fredrik, 2014).

Conversely, risks such as soil and sand drift, natural weather effects, reliance on traditional farming methods, high maintenance costs, poor productivity, and limited technical knowledge did not yield statistically significant differences between insured and uninsured farmers. This contrasts with earlier findings that identified these factors as major constraints in cocoa production (Babalola et al., 2016; Brånstrand & Fredrik, 2014). The divergence may be explained by contextual differences, suggesting that some risks are perceived as routine challenges by farmers, while others—such as climatic shocks and financial constraints—are recognized as more pressing and insurance-relevant.

Risk preferences, as presented in Table 2, were derived from farmers' responses to structured statements designed to capture their attitudes toward risk in cocoa production. The results indicate that cocoa farmers with crop insurance exhibited higher average scores across nearly all risk-preference statements compared to their uninsured counterparts. In practical terms, this suggests that insured farmers not only acknowledged the existence of risks but also demonstrated a greater willingness to engage with risk in their farming activities, possibly reflecting a more entrepreneurial orientation. Interestingly, insured cocoa farmers showed a stronger tendency to accept risk as an inherent aspect of farming and agreed with

risk-oriented statements to a significantly higher extent. This finding aligns with the expected utility theory, which suggests that risk-averse individuals adopt insurance as a means of reducing uncertainty, while those with higher risk tolerance may still insure to safeguard against catastrophic losses (Pindyck & Rubinfeld, 2005; Barry et al., 2004). The statistical analysis further revealed that the differences in mean responses between insured and uninsured farmers were statistically significant for most of the statements. However, two exceptions emerged: one, *"I like having my farm exposed to risk"*, and two, *"I strongly prefer to acquire sustainable gains rather than avoiding losses in my cocoa farm."* For these two items, no significant differences were observed, indicating that both insured and uninsured farmers shared similar attitudes.

This nuance suggests that while insurance adoption is linked to heightened risk awareness, there are certain intrinsic attitudes toward farming risks that remain consistent across groups. The analysis of insurance perceptions in Table 2 further underscores the importance of farmers' subjective evaluations of insurance products. Perceptions were shown to significantly influence the decision to adopt insurance, consistent with earlier studies that emphasize the role of trust, affordability, and product design in shaping adoption decisions (Smith & Baquet, 1996; Adinolfi et al., 2012; Yusuf et al., 2024). Significant differences were observed in most perception statements, indicating that insured farmers generally held more positive views about insurance as a viable risk-mitigation tool. However, one notable exception was the premium per hectare, which did not yield significant differences between the two groups. This suggests that while cost is an important factor, it may not be the sole determinant of insurance adoption. Other issues, such as accessibility, claim processes, and institutional credibility, appear to carry greater weight (Hamzat et al., 2006; Oladele & Obaniyi, 2023).

Taken together, the findings highlight that risk preferences and insurance perceptions are critical behavioral dimensions influencing cocoa farmers' decisions to insure. Farmers with crop insurance are generally more risk-tolerant and hold more positive views about insurance products, while uninsured farmers often substitute membership in cooperatives or informal arrangements for formal insurance. This reflects broader literature suggesting that perception gaps and institutional weaknesses, rather than cost alone, remain the major barriers to widespread adoption of agricultural insurance in developing countries (Giné & Yang, 2009; Smith & Glauber, 2012).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Table 2. Risks, risk preferences and insurance perception in cocoa production in Ekiti State

Sources of Risks/Preference/Perception	Mean – Insurance	Mean – No Insurance	T-Test
Sources of Risk			
Drought	2.3	2.1	2.49**
Flood	1.1	1.3	2.22**
Soil and sand drift	1.2	1.3	1.35e
Pests and diseases	3.5	3.3	3.78***
Natural weather effects	3.3	3.1	1.43e
Lack of subsidies on agrochemicals	2.4	3.1	2.11**
Price of inputs	3.7	3.5	4.22***
Traditional methods of farming	2.5	2.2	1.12e
Weak research and extension linkages	3.5	2.8	2.31**
High maintenance of the farm	2.6	2.3	1.54e
High cost of production	3.2	3.5	245**
Poor productivity	2.5	2.7	1.14e
Technical Capacity/knowledge in the production process	2.5	2.5	1.32e
Risk Preferences			
I like having my farm exposed to risk	2.6	2.5	1.23e
I am willing to expose myself to greater risk in order to increase the yield of my crop	3.0	2.7	2.11**
I prefer to be safe than sorry in my business	3.3	3.1	2.43**
I strongly prefer to acquire sustainable gains than avoiding losses in my cocoa farm	2.6	2.5	1.25e
I am willing to take higher risks in order to achieve a higher payoff	3.1	3.0	4.52***
Insurance Perception			
Crop insurance is important because of debt and rent payment obligations	2.4	1.8	2.31**
I am well aware of the crop insurance Provisions	3.4	2.2	2.42**
Crop insurance is an important risk-management tool in my production	3.1	1.6	2.44**
Per-hectare premium costs are very important to my crop insurance decision	3.2	3.2	2.21**
Availability of high coverage levels is important to me	3.3	2.1	2.37**
The ability to insure different acreages separately is Important	3.4	3.0	2.29**
Crop insurance is not important for me because my yield per hectare is already low	1.8	3.8	2.18**
Crop insurance provides good protection to my yield	3.5	2.2	2.49**

P value < 0.05 and * < 0.01. e=not significant

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Logit regression results

Table 3 presents the results of the binary logit regression, which estimates the likelihood of cocoa farmers adopting crop insurance based on their socio-economic and farm-level characteristics. The coefficients reflect the direction and magnitude of influence of each explanatory variable on the probability of insurance uptake. The results reveal that Age, Gender, and Farm Size (hectares) did not significantly affect the decision to adopt crop insurance. This finding suggests that insurance adoption in the study area is not necessarily dependent on demographic characteristics such as age or gender, nor on the scale of landholding. This contrasts with some earlier studies that found larger farm sizes and younger farmers to be more inclined toward insurance (Barry et al., 2004; Adinolfi et al., 2012), but aligns with more recent evidence from Nigeria and other developing countries, which emphasizes institutional and economic barriers over demographic factors (Attipoe, 2023; Yusuf et al., 2024). Out of the ten independent variables included in the model, seven emerged as significant determinants of insurance uptake:

The results, presented in Table 3, show that while Education ($\beta = 0.59$), Household Size ($\beta = 0.0029$), and Debt Use ($\beta = 0.02$) were positively significant, four other variables—Membership of Cooperative ($\beta = -4.53$), Farming Experience ($\beta = -2.51$), Land Ownership ($\beta = -2.19$), and Non-Farm Income ($\beta = -0.65$) were negative and statistically significant. The interpretation of the signs and significance levels provides important insights into the determinants of cocoa farmers' insurance adoption in Ekiti State. A positive coefficient implies that higher values of the variable are associated with an increased probability of adopting crop insurance, while a negative coefficient implies the reverse. The positive and significant effect of Education suggests that as farmers attain higher levels of formal education, their likelihood of purchasing crop insurance increases. Education enhances farmers' ability to process information, evaluate risks, and understand the benefits of formal insurance schemes. This finding is consistent with Sahoo and Behera (2025), Barry et al. (2004), and Adinolfi et al. (2012), who observed that more educated farmers are more open to sophisticated risk management strategies, including insurance. Household size also positively influenced crop insurance adoption. Larger households may face greater consumption and livelihood pressures, which increase the incentive to safeguard against production risks that could jeopardize food security and household welfare. This finding aligns with studies such as Brånstrand and Fredrik (2014),

who noted that insurance serves as a buffer against shocks that could destabilize household well-being. The result highlights how the survival instinct of farmers with larger families motivates proactive risk management through insurance. The positive significance of Debt Use indicates that indebted farmers are more likely to adopt crop insurance. This outcome is consistent with Barry et al. (2004) and Giné & Yang (2009), who argued that farmers with higher debt ratios rely more on insurance to secure loan repayment capacity and protect themselves from financial distress. In this case, crop insurance provides a safeguard for both the farmer and the lender, particularly under schemes such as the Central Bank of Nigeria's Anchor Borrower Programme, where insurance is often encouraged as a condition for accessing credit.

Conversely, Membership of Cooperative Societies was negatively associated with insurance uptake. This suggests that cooperative membership reduces the likelihood of adopting crop insurance, as farmers may substitute formal insurance with the financial and social safety nets provided by cooperatives. Similar findings have been reported in Nigeria and elsewhere, where cooperatives play a critical role in mutual aid, credit provision, and collective risk-sharing (Babalola et al., 2016; Yusuf et al., 2024). Farming Experience also exhibited a negative and significant relationship with insurance uptake, indicating that more experienced farmers are less likely to insure. This finding deviates from Barry et al. (2004), who argued that experienced farmers tend to be more positive toward insurance. In the Nigerian context, however, long-term exposure to failed or inadequate insurance schemes, such as inefficiencies within the Nigerian Agricultural Insurance Corporation (NAIC), may have bred skepticism among older, more experienced farmers (Hamzat et al., 2006; Oladele & Obaniyi, 2023).

Thus, institutional weaknesses may override theoretical expectations. Similarly, Land Ownership negatively influenced the adoption of crop insurance. Farmers who own their land outright are generally more financially secure and less vulnerable to production shocks than tenants or renters. Consequently, they perceive less need for insurance (Barry et al., 2004; Smith & Baquet, 1996). In contrast, tenant farmers with insecure land tenure face higher risks and thus stand to benefit more from insurance. Finally, Non-Farm Income was also negatively significant. Farmers who earn income from off-farm activities are less likely to adopt crop insurance, as diversification through alternative income sources stabilizes household earnings and serves as a substitute for formal insurance. This observation corroborates findings from Salimonu and Falusi (2009) and Barry et

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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al. (2003), who emphasized that non-farm income functions as an informal risk management strategy, reducing reliance on insurance products.

Table 3. Factors affecting cocoa farmers' uptake of crop insurance

Factors	Coefficient	P-Value
CONSTANT	-0.684**	0.010
Age	(0.266) 0.3456	0.507
Education	0.595** (0.274)	0.03
Household size	0.0029293*** (0.00285)	0.001
Non-Farm Income	-0.658** (0.360)	0.068
Gender	0.0763423 (0.00067)	1.19326
Membership Cooperative	-4.530*** (0.481)	0.000
Farming Experience	-2.51599***	0.0034
Owned Land	-2.19365*** (0.0012)	0.000
Debt Use	0.0206272** (0.0005)	0.048
Farm Hectare	-0.000401 (0.000002)	0.719
McFadden Pseudo- R2 = 0.0878.		

Notes: Standard errors shown in parentheses. Statistical significance levels: ***1%, **5% and *10%.

Taken together, the results suggest that financial exposure (through debt), household welfare needs, and human capital (education) drive insurance adoption, while traditional coping mechanisms (cooperatives), accumulated experience, and income diversification discourage it. These dynamics highlight the dual role of formal and informal institutions in shaping insurance adoption and underscore the need for targeted policies that integrate insurance with existing social structures, credit systems, and farmer education programs (Smith & Glauber, 2012; Attipoe, 2023).

CONCLUSION

The study revealed that cocoa farmers are exposed to multiple risks, including drought, floods, pests, diseases, and rising input costs, although some risks—such as soil erosion, sand drift, and limited technical capacity—were found not to be statistically significant in influencing production outcomes. Surprisingly, farmers' risk preferences did not differ significantly between insured and uninsured farmers. This contrasts with the expected utility theory, which suggests that risk-averse farmers should be more likely to purchase insurance to secure protection against uncertainty. However, perceptions of insurance products emerged as an important determinant of uptake. Premium affordability, in particular, was critical: risk-averse farmers expressed willingness to adopt

insurance if premiums were reasonably priced, consistent with findings in other developing economies.

The logit regression analysis identified seven critical variables influencing insurance adoption. Education, household size, and debt use had positive effects, indicating that better-educated farmers, those with larger households, and those relying on credit are more likely to adopt crop insurance. Conversely, membership in cooperatives, farming experience, land ownership, and non-farm income negatively influenced uptake.

POLICY RECOMMENDATIONS

To enhance uptake, Nigerian policymakers must adopt a holistic approach that integrates affordable insurance schemes with complementary interventions in farmer education, cooperative engagement, and institutional reform. Explicitly, the following policy recommendations are made.

1. Design of Affordable and Flexible Insurance Products,
2. Integration of Insurance with Credit Schemes,
3. Strengthening Farmer Education and Extension Services,
4. Enhancing Risk Management Beyond Insurance,
5. Leveraging Cooperatives as Insurance Gateways,
6. Promoting Cocoa as a Strategic Export Commodity:

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Adoption of Livestock Insurance among Dairy Farmers at Chitwan, Nepal

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ABSTRACT

Natural calamities, disease and pest, and unpredictable weather possess a high risk in livestock farming and cost a heavy loss to the farmers. Livestock insurance is one of the important strategies to reduce the risks related to livestock production. To assess the adoption process and impact of livestock insurance on dairy farmers, a study was conducted at Chitwan district among the 98 farmers (insured and non-insured) sampled using stratified random sampling. Descriptive statistics were used to analyze the socio-economic and demographic variables of insurer and non-insured farmers. Probit model regression was used to analyze the impact of different variables on adoption of livestock insurance. In addition, t-test was also done to compare the numeric mean value of the variables of two categories of respondent, insured and non-insured. The Probit model results revealed that the age, gender, income from livestock, awareness about insurance and awareness of subsidy on insurance have a significant (p<.05) effect on the adoption of livestock insurance. The result of Chi-square test suggests that members of a farmers group/cooperatives, subsidy, loan and members of community agents have a significant (p<.05) effect on the adoption of the livestock insurance. The study underscores the need for a strategic policy to promote livestock insurance in Chitwan district. Both the government and non-life insurance companies must prioritize enhancing farmer awareness and understanding through targeted advertising and training to establish credibility and reliability. These findings will be helpful for the improvement of different livestock insurance policy and programs implemented by different government bodies and insurance companies.

Keywords: Adoption, constraints, impact, livestock insurance, risk

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INTRODUCTION

Agriculture in Nepal possess multiple peril due to biotic and abiotic factors making this sector more prone to risk (Subedi and Dhakal, 2018). Asymmetric climate condition, increasing disease and pest infestation, natural calamities are directly threatening the farmers. Farmers in the third world countries not only have climate challenges but also the techno-economic shock due to which people in under developed countries are shifting their interest from agri-livestock to other businesses. Despite of being the major sector of GDP contribution in Nepal the risk management in the agriculture is insignificant. Although, agri-insurance sector is one of the heavily subsidies and priorities product of government of Nepal the adoption of agricultural insurance is minimal as much as it can be around 0.68% due to shortage of distribution, extension channels, knowledge and perception of the farmers. Almost half of the population of Nepal directly involved in agriculture sector; in contrast to which people area facing economic loss more than its threshold level making this industry highly vulnerable to shift towards commercialization from traditional practices.
Natural disaster risks have increased in Nepal over the past three decades, making it ahigh-risk area. Their homes were damaged, their way of life was disrupted, and they suffered significant losses. Disease outbreaks are a significant barrier for farmers engaged in who raise animal husbandry (Newar et. al, 2008).

People are constantly seeking safety, whether it be for their life or their possessions. People today are more exposed to uncertainty as a result of the rapid economic and industrial development that has occurred, therefore they are eager to have both physicalandfinancial security. Consumers are not risk-averse and favor predictableconsumption over unsafe use. This just means that risk should be taken into account when making decisions rather than being completely avoided. From the perspective ofan agricultural producer, insurance is a way for them to shift their risk to an insurance provider in exchange for a premium payment. A company that offers insurance is referred to as an insurer, insurance carrier, insurance company, or underwriter. An insured or a policyholder is a person or thing that purchases insurance.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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One of the emerging solutions to transfer agriculture and climate risk is insurance. This study aim to explore the factors of adoption of livestock insurance by milk producing farmers in Chitwan district along with the satisfaction level of dairy farmers from livestock insurance and factor associated with hindrances of adoption of the insurance.

MATERIALS AND METHODS

Study area and sample size and data collection techniques

Chitwan districts of Bagmati Province Nepal was selected purposively for this study because of availability of the highest number of commercial dairy farmers available in this area. On top of that, Chitwan is one of the highest cattle insurance policies issued district with 1, 02,997 policies (MoALD, 2022).

The primary information was collected by using the pre-tested household survey with the farmers. Also seven key informant interview survey in each local government and three focused group discussion were performed to collect more information for this study. All total 98 samples were selected for this study using stratified random sampling. . Among total farmers interviewed 49 of them were insured cattle farmers and 49 of them were non-insured who were equally distributed among the 7 municipalities of the Chitwan district. The KoBo collect toolbox software was used to collect data and MS excel was used for processing of the raw data and analyzed using SPSS. No animal were hard during this study.

Identification of determinants factors affecting decision to adopt livestock insurance

To identify factors affecting farmer's decision to adopt livestock insurance in the study area a probit regression model was used. Literature review on probit model was done to determine the factor affecting the adoption of livestock insurance (Subedi et. al, 2018). The probit model is used when a choice is to be made between two alternatives; in this study, decision to either adopt (or not adopt) livestock insurance. This statistical model defines a relationship between probability values and explanatory variables, ensuring that the probability values stay within the range of 0 and 1. This model is also adopted by Fadare et al, (2014) to study adoption of improved agricultural insurance. Different independent variable and

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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their statistical description used in this model are given in Table 1.

The following model was used to identify factors affecting adoption of the livestock insurance in the study area.

Pr (adopting livestock insurance =1) = f (b0+ b1 X1 + b2X2 + b3X3 + b4X4 + b5X5 + b6X6 + b7X7 + b8X8 + b9X9+ b10X10+ b11 X11 + b12 X12 + b13X13 + b14X14 + b15X15 + b16X16 + b17X17 + b18X18)

Where,
Pr = Probability score of adopting livestock insurance
X1= Gender of the household head (Dummy)
X2= Age of the household head (in years)
X3= Number of schooling years of the household head (in years)
X4= Cattle farming experience (in years)
X5= Major occupation of the household (Dummy)
X6= number of family members involved in agriculture
X7= LSU (livestock standard unit)
X8= Land holdings (Continuous)
X9= Credit access (dummy)
X10= Membership of organization (Dummy)
X11= Any agricultural or livestock related training (Dummy)
X12= Number of trainings received
X13= Knowledge on livestock insurance
X14= Knowledge on livestock insurance subsidy
X15= Knowledge on livestock insurance plan policies
X16= Farm productivity
X17= Number of times farm visit of agricultural technician in a year (number)
X18= Grants (dummy)
$b_1, b_2 \ldots b_{18}$ = Probit coefficient, b_0 = Regression coefficient

Hindrances associated with livestock insurance adoption

Indexing/Scaling technique was applied to construct an index for prioritizing the hindrances. Indexing has been used in several studies (Sapkota et al., 2018; Subediet al., 2019). The scaling techniques provide the direction and

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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extremity attitude of the respondents towards any proposition. Based on responded frequencies, weighted indexes were calculated for the analysis of farmer's perception on the extent ofproblems/hindrances. Farmer's perception to the different production problems/hindrances was ranked by using five-point scales. The formula used to determine the index for intensity of various problems/hindrances is:

$$I_{prob} = \Sigma \, Sifi/N$$

Where, I_{prob} = index value for severity or intensity of problem

Σ = summation

Si = scale value at i^{th} intensity

Fi = frequency of the i^{th} severity

N = total no. of the respondents

Where, I_{prob} = index, 0< | <1

+ indicates positive sign; - indicates negative sign.

Table 1. Statistical description of different variables used in the probit regression model

Variables	Description	Value	Expected sign
Age	Age of the household head	Years (in number)	+/-
Gender	Gender of the household head	Male =1, otherwise =0	+/-
Education	Number of schooling years	Years (in number)	+/-
Typology			
HH income	Household overall income	Annual income of the family (NRs.)	+
Income_Liv	Total income from the livestock sector	Annual income from the livestock sector (NRs.)	+
Aw_insu	Awareness of the household head on livestock insurance	Aware of livestock insurance policy (yes =1, otherwise =0)	+
Aw_sub/loan	Awareness of the household head on the loan and subsidy scheme provided by government	Subsidy/loan received (Yes=1, otherwise =0)	+

An Unpaired t-test were performed to compare farm income of insured and non-insured cattle farmers. In addition, chi-square test were also performed to check

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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the effect of farmer's involvement in group has any effect on buying cattle insurance.

RESULTS AND DISCUSSION

Socio-economic and demographic characteristics of the household

Livestock insurance is a very innovative and new risk management tool available to the farmers who need the conscious effort of the household head to decide to adopt or not. Age, education and experience of a head play an important role in farming. In our study the average age of the household head (HH) was 48.54 years with the majority of the HH age ranges from age 20 to 85 years in the study area. The schooling year of the household head was found to range from 0 (No formal education) up to Ph.D., which means the household head of the study area ranges from illiterate to highly educated. The mean dependency ratio in our study area was 16% meaning that 16 people out of 100 are dependent. It was revealed that age and number of educations doesn't have any significant impact in the adoption of livestock insurance ($p = .76$ & $p = .13$).

The average landholding in the study area was 0.57 hectares with the mean land holding of 0.1 ha in animal rearing. It was observed that male HH (68%) dominates the number of female HH (32%)The majority of men involvement suggests that the livestock industry is labor-intensive, with men typically serving as the family's leader (Akinola, 2014). This is might due to the patriarchal nature of Nepalese society, which has been practiced for long years. It was found that out of total sampled household heads, 16% of the household heads have agriculture as their primary occupation while, 64% of the people are engaged in livestock production sector which shows the importance of livestock in study area. The household with business, services and others as primary occupations are 8 %, 3% and 5 % respectively. Out of total household income, the main source of income from dairy production is 64 %, and 16 % comes from crop production and 20 % comes from other occupations.

Impact of economic variables with the adoption of crop insurance

Income is one of the major encouraging factors for the livestock insurance because farmers need to pay some amount as premium to the insurance company. It was found that the total household income from the livestock was found

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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significant (p <.006) in the adoption of livestock insurance in study area of Chitwan district. In terms of involvement of farmers in group, it was found that 21% respondents were involved in cooperative/farmer groups of membership and all of them have insured their livestock. Study reveals that the farmers' institutional involvement has significant effect in adoption of insurance (p < .001).

Table 2. Factors affecting adoption of the livestock insurance in Chitwan district

Variables	Coefficients	P > |z|	Standard error	dy/dx[b]	S.E[b]
Age	0.056*	0.026	0.025	0.021	0.009
Gender	-1.068*	0.054	0.553	-0.369	0.159
Education	1.186	0.102	0.726	0.446	0.245
Respondent typology	0.393	0.387	0.454	0.149	0.170
Major Source of Household	2.022***	0.001	0.615	0.687	0.146
Income from Livestock	0.440**	0.014	0.179	0.167	0.067
Awareness on Insurance	1.383*	0.030	0.638	0.508	0.191
Awareness on Subsidy Loan Scheme	2.606***	0.000	0.657	0.783	0.105

*** 1% level of significance; ** 5% level of significance, * 10% level of significance. [b]Marginal change in probability evaluated at the sample means.

Summary statistics	
Number of Observation	98
Log Likelihood	-22.75
LR Chi-Squared (8)	73.54*** Prob>chi^2 =0.000
Pseudo R^2	0.62
Predicted Probability	0.00
Goodness of fit	Pearson Chi^2 (77) = 70.45. Prob>chi^2 =0.69
Area under ROC curve	0.96

Study showed that there is a 54% increase in the likelihood that a responder will purchase livestock insurance if they are members of groups or cooperatives (Devkota et al., 2021). It was found that the insured farmers were significantly involved in taking mandatory loan and subsidy from the government (p<.001).

Factors affecting adoption of livestock insurance

A probit model regression was run to see the effect of different socioeconomic factors on the adoption of livestock insurance. The total of 9 variables were selected for the probit model in study based on pretest results. It was found that the age (p<.05) and gender (p<.01) are two of the important factors that significantly effect on the adoption of the insurance among the social factors. The gender shows negative significance means female where less adaptive for the livestock insurance compare to the male while, education showed positive significant (p<.1) effecting our study area which contradicts the findings of Kwadzo *et al*. (2013). Likewise, major source of household income (p<.01) and income from livestock (p<.05) have significant effect on the adoption of livestock insurance.

Awareness on insurance (p<.05) and insurance subsidy scheme (p<.01) have positive and significant in adoption of livestock insurance which is because of increase in their knowledge and perception towards the importance of the insurance. The probability of insurance adoption increases with the increase in awareness about the insurance (Aina and Omonona, 2012; Babalola, 2014). Awareness helped farmers to realize the need for insurance and understand the procedures of insurance.

Half of the total respondent were those people who have bought insurance for their dairy livestock, the motivation behind investing in an insurance plan was recorded and ranked using preference ranking method, from the analysis it was revealed that the risk coverage of the insurance was the number one motivation for the farmers (4.7). The satisfactory insurance policy and high premium return were given the equal importance with weighted value of 3.43. The good service of the insurance company was ranked last with the weighted mean value of 1.4.

Assessment of constraints associated with the adoption of livestock insurance in Chitwan district

The preference ranking of farmers on constraints for taking insurance revealed that one of the major reasons for farmers to not insured their livestock was people were unable to understand the product (Shrestha, 2024), as it is very new to Nepal. In addition to that, high premium cost rank second among all with the weighted value of 0.62 (Ortmann & Mohammed, 2005) followed by the delay in the claim

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

process of the insurance which is similar to the findings of (Subedi & Kattle, 2021).

Lengthy process of insurance and low payout are two major factors ranked in 4th level a similar finding from (Thapa and Bam, 2020). Among all the reasons insurance company asking for too many documents ranks last with the weighted value of 0.45 in the study area. While in a study at Nawalparasi district, it was found that the reasons for not adopting the insurance of livestock was distrust in the scheme/agency (100%), insufficient awareness (46.66%), limited ability to pay premiums (20%), complicated documentation procedures (13.3%), and delays in claim settlements (6.7%) (Ghimire et al., 2016).

Table 3. Hindrances associated with the adoption of livestock insurance in the study area

S.N.	Constraints	Index Value	Rank
1.	Farmers don't understand the product	0.71	I
2.	High premium cost	0.62	II
3.	Delay in providing claim amount	0.61	III
4.	Lengthy process of enrollment	0.57	IV
5.	Insurance company ask too many documents	0.45	V

I = least serious, II = little serious III = moderately serious IV = Serious V = most serious

It was found that 12 % of insured farmers were strongly satisfied with the premium amount followed by 34 percentage of farmers, moderately satisfied with the premium amount to be paid. Moreover, higher percentage that is 48 percentage were neutral towards the premium amount to be paid while only 6 percentage were dissatisfied with the premium amount to be paid for the insurance company. Furthermore, under two conditions, farmers were asked if they would begin or continue to purchase the premium plan. The first condition was if the premium were twice of now where 58% farmers answered yes while 42% farmers answered negative. For another condition that is if the premium amount were half of now, 76 % farmers agreed to continue the plan which align to the findings of (Devkota et al. 2021) while 24% farmers didn't agree.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Each insured farmers were asked about their feelings after investment in insurance plan and asked them to categorize their feelings among five options. The result shows that 68% of insured farmers felt good after making investment in insurance plan; 12% of insured farmers were averagely satisfied and 20% of insured farmers were completely satisfied after investing in the insurance plan. Insured farmers were asked if they made claim for compensation during investing on the insurance plan and the following result were obtained. Only 16% of farmers had made the claim for compensation while 84% of farmers didn't. From the farmers who made claim for compensation, it was known that the average amount to make the claim for compensation was NRs. 73,688 and average amount received as compensation was NRs. 87,250. The average period taken by the company to pay back the compensation was 68 days. Moreover, about 63% of farmers who made claim for compensation found it difficult to receive the compensation for loss among them half of respondent said it was very hard or hard to receive the compensation while half of respondent said the difficulty was normal or easy, a similar finding was reported by Ghimre et al. (2016). With increased knowledge of insurance, the likelihood of adopting an insurance policy rises (Akinola, 2014). A chi-square test was done to assess the awareness level of farmers who are involved in livestock insurance and those who were not. It was found that the insured farmers were aware of the insurance and the subsidy provided by the government ($p < .001$). Government subsidy (80%) is one of the motivating factors for people to insure their livestock and crops, it was asked that if the government lift off the subsidy would they even get the insurance of their livestock, and the result shows that the already insured farmers are willing to insure their animals ($p < .001$). Implementing livestock insurance as a risk management tactic is therefore highly influenced by awareness (Devkota et al., 2021).

CONCLUSION

The study looked at why dairy farmers in Chitwan do or don't get livestock insurance for their animals. It found that things like how old they are, how much education they have, how much money they make, and how much they know about insurance all affect if they get insurance for their animals or not. Farmers who are older, have more education, make more money from their animals, and know more about insurance are more likely to get it. In the study, it was found that the total land holding of the respondent, crop cultivation land and land for animal rearing has the significant effect on the insurance as explained by the probit regression.

The study also found that farmers who have support from institutions, like getting loans or help with paying for insurance, are more likely to get insurance. Farmers who already have insurance are more involved with these kinds of support than those who don't have insurance. It was also found that farmers think about risks, like diseases and problems with having babies, when they decide if they want insurance or not. And how they feel about the insurance, like if they're happy with the rules, how easy it is to get money if something happens to their animals, and how much they have to pay, affects if they want to get insurance.

The study gives suggestions to help make insurance better for farmers. It says that making sure farmers know about insurance, helping them get support from institutions, and fixing problems with how claims are settled and how much they have to pay could make more farmers want to get insurance. By doing these things, more farmers might get insurance, making the dairy farming business stronger.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Factors Affecting The Adoption of Banana Crop Insurance among Banana Farmers in Chitwan District, Nepal

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ABSTRACT

An investigation was carried out in Chitwan district of Nepal in 2021 to identify the factors affecting the adoption of banana crop insurance among banana farmers. Employing multistage purposive random sampling, 80 banana farm households were selected. Primary data were gathered through semi-structured questionnaires administered to the household head. The analysis was carried out using a binary probit model. Results revealed that the annual income of the household significantly and positively affected the adoption of banana insurance. In the present context, farm households with higher annual incomes should be targeted for the efficient adoption of insurance. Thus, it is necessary to improve the income of farmers through multiple approaches such as trainings related to agribusiness management, proper access to cost-effective input market and prices, establishment of efficient marketing channels and value addition for the better adoption. Agricultural cooperatives and farmers groups should be further strengthened to promote collective agribusiness. Subsidy on the crop insurance should be further raised and export opportunities should be explored.

Keywords: Adaptation, climate, crop, income, probit

INTRODUCTION

Climate change is a major concern nationally and globally, as it causes devastating effects on agricultural production and potential damage to property (Ghimire et al., 2016). Droughts, extreme rainfall, strong winds, and extreme temperatures are

climatic risk factors that alter trophic interactions in agroecosystems, reducing both crop productivity and quality (Ghimire et al., 2016). Climate variability and climate driven extremes have several negative impacts on the agriculture sector (FAO, 2016). FAO et al. (2015) reported natural disasters including extreme temperatures and storms, floods, drought, and pest and diseases infestation caused loss in agricultural productivity worth $10 billion in Asia. There is the prediction of an increase in heat waves and erratic rainfall patterns affecting agriculture and making developing countries more vulnerable and challenging in the future (Gouldson et al., 2016). The adoption of good agricultural practices and technologies has often been less than expected to mitigate the climate risk. In this context, farmers could adopt crop insurance to cope with climate variability and risk (Thorton et al., 2017). Crop insurance has been adopted in many developing countries to reduce the economic loss by preserving working capital, repay loans and sustain their commercial viability (De Janvry et al., 2014).

Banana became a highly commercial summer fruit in a very short period of time due to its area extension, productivity and high demand conditions, contributing 0.85% to agricultural Gross Domestic Product (GDP) in Nepal (MoALD, 2021). This crop ranks as the second major summer crop, accounting for 21% of all summer fruit production (Ranjitkar et al., 2016; Sharma et al., 2021). In the year 2019, the area of banana cultivation reached 16699 ha having production of 254161 mt with a productivity of 15.22 mt/ha (MOALD, 2020). Although Nepal may have a remarkable capacity for producing banana, there aren't many commercial banana markets, and the country currently produces relatively few of them (Bhat et al., 2011). Ineffective orchard management practices increase the likelihood of disease and pest infestation along with natural disasters occurring due to climate change are the major challenges to banana production (Adhikari, 2017).

Due to their succulent nature, banana crops are particularly vulnerable to weather-related risks including wind and hail (Ghimire et al., 2016). Due to the fleshy pseudo stem, windstorms possess the biggest issue for farmers who grow banana since they significantly reduce banana yields and cause economic loss to the farmers (Parra et al., 2001; Calberto et al., 2018). Windstorms that occur during pre-monsoon or post-monsoon periods severely impact banana farm. During 2018 in Chitwan district, powerful winds and hail devastated 88 hectares of bananas worth millions of rupees (Rimal, 2018). Around 400 hectares of banana fields in the western Terai and Nawalparasi district were destroyed by strong wind in 2005

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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(World Bank, 2009). Farmers are driven to modify their business and seek sources of non-farm income because of the significant losses they have experienced. The government has developed a number of policies and programs to help the banana farming become more commercialized. However, most of them appear to have focused primarily on policy and to have had little practical impact on the level of the farmer. Insurance is the risk management technique most commonly used in agriculture. It is a fair transfer of risk from one party to another in exchange for a premium: a small, defined loss that is assured to prevent a much larger and potentially catastrophic loss (Iturrioz, 2009). Following the implementation of the 2013 Crop and Livestock Insurance Directives, agriculture insurance was formally introduced in Nepal on January 14, 2013 (Insurance Board, 2017). In the same year, the government of Nepal provided a 50% subsidy on insurance premiums, which was later increased to 75% in 2014, then to 80% in 2021. The government has given agriculture insurance priority in its national policies, plans, projects, and budgets (Insurance Board, 2017). Adopting an insurance program encourages farmers to seek out risk and pursue commercialization, increasing banana production and income. Therefore, stakeholders and policymakers should concentrate on promoting insurance schemes for banana farming through awareness and the advantages of insurance adoption among banana growers (Dulal & Kattel, 2020). Thus, to develop mechanisms that will promote increased adoption of banana insurance and benefit farming communities, this study was done to identify the factors affecting the adoption of banana insurance among banana farmers.

MATERIALS AND METHODS

Study area

Chitwan district was selected for the study, being a key contributor to the country's banana production (Bhatta et al., 2023; MoALD, 2023). Due to its potentiality of production, the Government has established Banana Zone under Prime Minister Agriculture Modernization Project (PMAMP) and One Village One Product (OVOP) program had given priority for banana production in Chitwan. The PMAMP command area lies in Bharatpur metropolitan (ward no. 1), Ratnanagar municipality (ward no. 1-16), Khairahani municipality (ward no. 1-13) and Kalika municipality (ward no. 1-8) where the majority of the farmers are growing Malbhog followed by G9 and/or William hybrid. We selected Khairahani, Ratnanagar and Kalika Municipality to carry out the survey as large number of banana farmers have adopted the insurance policy to avoid the risk associated with

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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the weather variables as shown in Figure 1. Initial, Focus Group Discussion (FGD) and Key Informant Interviews (KII) with different stakeholders highlighted the average adoption of banana insurance in this area. Thus, this study on the adoption of banana insurance will promote sustainable development and benefit farming practices in this area.

Sampling technique and sample size

During 2021, we employed multistage sampling to select the study area and the respondent household. At first, we purposively selected the study municipalities along with wards of the Chitwan district. Later, we used stratified random sampling techniques to select the 80 respondent's households representing adopter and non-adopter of the banana insurance from the list of the 423 registered farmers provided by the PMAMP as shown in Table 1. A face to face interview was carried out using the semi-structured questionnaire to gather primary data. A pre-test was conducted using the guiding semi-structured questions to interview the first respondent. With minor adjustments made based on the feedback from the pre-test, the interview questions proved to be working well in achieving the research objectives of this study. Furthermore, KII and FGD were conducted in study municipalities including the concerned stakeholders to complement the result from the household interview.

Table 1. Selected sample size along with municipalities, wards and adoption groups

Municipality	Adopters	Non-adopters	Total
Khairahani	4	1	5
Ratnanagar	33	5	38
Kalika	12	25	37
Grand total	49	31	80

Note: Sample size calculation based on Daniel (1999)

Empirical model

Descriptive analysis and t-test was done using IBM SPSS Statistics 25. In order to determine the factors affecting the adoption of banana crop insurance, probit regression model was employed using Stata/SE 12.1. This probit model was used to identify the socio-economic factors affecting the farmers' adoption of banana crop insurance, using the functional form of probit as model Pr (Y = 1) = (X_i) where Pr (Y = 1) represents the probability of adoption of banana insurance with

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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the change in X variable. A positive estimated coefficient implies an increase in the likelihood of adoption of banana insurance. Relation between probability values and explanatory variables is established with probit model. It ensures the probability value between 0 and 1.

Let us suppose Y_i is the binary response of the banana farmers, $Y_i = 1$, if banana farmer adopts banana crop insurance, and $Y_i = 0$ if the banana farmer doesn't adopt.

If $Y_i = 1$; Pr $(Y_i = 1) = P_i$

If $Y_i = 0$; Pr $(Y_i = 0) = 1\text{-}P_i$

Where $P_i = E\ (Y = 1/X)$ represents the conditional mean of Y given certain values of X.

Model specification

The probit model specified in this study to analyze factors affecting the adoption of banana crop insurance among banana farmers was expressed as follows;

$$\Pr(Y = 1) = f(b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9 + b_{10} X_{10} + b_{11} X_{11} + b_{12} X_{12})$$

Where, Pr (Y = 1) = Probability of adoption of banana crop insurance

X_1 = Gender (dummy); X_2= Age (continuous); X_3 = Education (continuous); X_4 = Farming experience (continuous); X_5 = Farm size (continuous); X_6 = Varieties (dummy); X_7 = Source of income (dummy); X_8 = Income (continuous); X_9 = Contact with extension workers (dummy); X_{10} = Member in agricultural cooperatives (dummy); X_{11}= Member in farmers group (dummy); X_{12}= Use of ICTs (dummy)

b_0 = Regression coefficient

$b_1, b_2 \ldots\ldots\ldots\ldots b_{12}$ = Probit coefficient

The description of the variables is presented in Table 2.

RESULTS AND DISCUSSION

Descriptive statistics of the variable used in this study are presented in Table 2. Result showed that 61% of the respondents adopted banana insurance. As observed, 85% of the respondents were male. Respondents, on average, were 48.48 years of age and had 10.58 years of formal schooling. Respondents on average had 8.24 years of farming experience and annual household income of NPR 1894637.50. On average, respondents had farm size of 121.17 kattha, 21% of the respondent's cultivated G9 variety (tissue-cultured) of banana and 73% of the farm household earned income from agriculture only. Similarly, on average,

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

41% of the respondents had participation in agricultural cooperatives, 64% of the respondents have participation in farmers group and 25% of the respondents had regular contact with extension workers. On average, 31% of the respondents uses ICTs in agriculture.

Table 2. Descriptive statistics of the dependent and independent variables used in the study

Variable	Description	Mean	SD
Dependent variable			
Insurance adoption	=1 if respondent adopt banana crop insurance, 0 otherwise	0.61	0.490
Independent variable			
Gender	Gender of the respondent (1-male,0-female)	0.85	0.359
Age	Age of the respondent (year)	48.48	12.914
Education	Formal education of the respondent (year)	10.58	3.638
Farming experience	Farming experience of the respondent (year)	8.24	5.045
Farm size	Farm size (kattha)	121.17	162.602
Variety	=1 if respondent grow G9 variety, 0 otherwise	0.21	0.412
Source of income	Farm household source of income (1- agriculture only; 0- agriculture + off-farm)	0.73	0.449
Income	Annual farm household income (NPR)	1894637.50	3002187.811
Contact with extension workers	=1 if respondent have regular contact with extension workers, 0 otherwise	0.25	0.436
Member in agricultural cooperatives	=1 if respondent participate in agricultural cooperatives, 0 otherwise	0.41	0.495
Member in farmers group	=1 if respondent is member in farmers group, 0 otherwise	0.64	0.484
Use of ICTs	=1 if the respondent uses ICTs in agriculture, 0 otherwise	0.31	0.466

Source: Field survey, 2021

Mean difference of characteristics describing adopters and non-adopters of banana crop insurance

The results of differences between means of characteristics describing adopters and non-adopters of banana insurance are presented in Table 3. There was a significant difference in age, education, farming experience, farm size, income,

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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participation in agricultural cooperatives and participation in farmers group between adopters and non-adopters. Education, farming experience, farm size, income, participation in agricultural cooperatives and participation in farmers group were significantly higher for adopters compared with non-adopters. However, age was significantly higher in non-adopters compared with adopters. Additionally, there was no significant difference in other listed characteristics among adopters and non-adopters.

Table 3. Characteristics of adopters and non-adopters of banana crop insurance

Variable	Adopters (n=49)	Non-adopters (n=31)	Mean difference	t value
Gender	0.90	0.77	0.124	1.513
Age	46.04	52.32	-6.282	-2.169**
Education	11.92	8.45	3.467	4.667***
Farming experience	9.20	6.71	2.494	2.207**
Farm size	179.82	28.48	151.332	4.529***
Variety	0.27	0.13	0.136	1.453
Source of income	0.73	0.71	0.025	0.241
Income	2863775.51	362774.19	2501001.317	3.952***
Contact with extension workers	0.29	0.19	0.092	0.921
Member in agricultural cooperatives	0.53	0.23	0.305	2.794***
Member in Farmers group	0.78	0.42	0.356	3.418***
Use of ICTs	0.35	0.26	0.089	0.829

Source: Field survey, 2021

Note: ***, ** indicate significant at 1%, 5% level of significance, respectively.

Factors affecting the adoption of banana crop insurance

Table 4 shows the results of binary probit regression analysis used to identify the factors affecting the adoption of banana insurance. Marginal effect after probit was also estimated and presented in the same table. The wald test (LR chi2) has good explanatory power at 1% level. Results revealed that annual household income significantly influenced the adoption of banana insurance among banana farmers. Other mentioned variables were not significant in the adoption.

Keeping other factors constant, with the increase in annual household income by one unit, the probability of adoption of banana insurance among banana farmers increases by 93.9%. Research shows that as household income rises, the

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

likelihood of purchasing insurance products, including agricultural insurance, also increases (Subedi & Kattel, 2022; Ezekiel & Njanike, 2022).

Table 4. Probit regression analysis and marginal effect for factors affecting the adoption of banana crop insurance

Variable	Coef.	SE	p value	dy/dx	SE (dy/dx)
Gender	-0.244	0.615	0.692	-0.083	0.198
Age	0.026	0.019	0.178	0.009	0.006
Education	0.118	0.093	0.208	0.042	0.033
Farming experience	0.011	0.045	0.797	0.004	0.016
Farm size	-0.002	0.003	0.425	-0.0009	0.001
Variety	-0.314	0.626	0.615	-0.116	0.238
Source of income	-0.284	0.500	0.570	-0.098	0.166
Log(Income)	2.628***	0.786	0.001	0.939	0.298
Contact with extension workers	0.222	0.652	0.733	0.077	0.217
Member in agricultural cooperatives	-0.321	0.629	0.610	-0.115	0.227
Member in farmers group	0.531	0.521	0.308	0.194	0.192
Use of ICTs	-0.434	0.515	0.399	-0.159	0.190
Cons	-16.788	4.562	0.000		
Summary statistics Number of observation = 80 LR chi2(12) = 55.68 Prob> Chi2 = 0.0000 Pseudo R2 = 0.5212 Log likelihood = -25.570 Marginal effect after probit y=Pr(insurance) (predict) = 0.680 Goodness of fit test Number of observation = 80 Number of covariate patterns = 80 Pearson chi2 (67) = 59.03 (Prob>chi2 = 0.7452)					

Source: Field survey, 2021

Note: *** indicate significant at 1% level of significance.

Studies suggest that farmers with more financial resources are more inclined to invest in insurance, as they can better absorb the costs of premiums and potential losses (Subedi & Kattel, 2022; Ezekiel & Njanike, 2022). This financial capacity enables them to adopt risk management strategies that protect their investments in banana farming. Ginder and Spaulding (2006) reported price of insurance significantly influenced the adoption of insurance. Makki and Somwaru (2001) reported adoption of insurance depends on amount of premium. Swain and

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Hembram (2020) reported household having larger incomes are likely to adopt crop insurance. Vandeveer (2000) reported with higher income, farmers are more likely to participate in crop insurance.

CONCLUSION

Results revealed that two third of the farm households adopted insurance scheme. Adoption of banana crop insurance is significantly and positively influenced by annual household income. Thus, extension agencies of institutions and insurance companies should emphasize household having larger annual income for better adoption. Efforts should focus on enhancing the income of banana farmers through various strategies. These include providing training in agribusiness management, ensuring access to affordable input markets and fair pricing, establishing efficient marketing channels, and promoting value addition to boost farmers' earnings. Strengthening agricultural cooperatives and farmers' groups is essential to encourage collective agribusiness activities. Additionally, the government should increase subsidies for agricultural insurance and introduce minimum support prices for bananas. Exploring export opportunities and restricting imports can further prioritize and support the domestic market.

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Performance Evaluation of Chili (*Capsicum Annum* L.) Genotypes Under Mid-Hill Agro-climatic Conditions of Kirtipur, Nepal

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ABSTRACT

A study was conducted to evaluate ten chili pepper genotypes for yield performance under Preliminary trial in Kirtipur, Himalayan College of Agricultural Sciences and Technology, from March to July 2025. The genotypes, including Karma 747, Nepa Hot, Karma 777, Anna 3, Big Mama, Omega, Super Tara, Sudra, Premium, and the check variety 'Pusa Jwala', were evaluated in an open field using a Randomized Complete Block Design (RCBD) with three replications. The genotype Nepa Hot demonstrated the highest productivity (16.60 t/ha). It was an early-maturing variety, reaching 50% flowering in 47 days and 50% fruiting in 55 days. Despite having smaller fruits (length: 4.08 cm, width: 15.89 mm), its high fruit set resulted in superior yield. In contrast, Big Mama yielded the lowest (8.43 t/ha). Other promising genotypes included Super Tara, Omega, and Premium. The study identifies Nepa Hot as a prime candidate for farmer-led field trials and subsequent varietal release, promising to enhance chili productivity and sustainability in the mid-hills of Nepal, Kirtipur.

Keywords: Chili pepper, genotypes, mid-hill conditions, yield, varietal trial.

INTRODUCTION

Chili pepper (*Capsicum* spp.) is an economically important vegetable and spice crop in Nepal, yet domestic production remains insufficient to meet national demand, resulting in substantial imports of dried chili from India (MoALD, 2022; FAO, 2022). The genus *Capsicum* (Solanaceae) comprises more than 40 species, of which *C. annuum, C. chinensis, C. baccatum, C. frutescens,* and *C. pubescens* are domesticated (Barboza et al., 2022). These species exhibit extensive genetic diversity in plant architecture, fruit morphology, pungency, nutritional profile, and stress tolerance (Tripodi and Kumar, 2019).

In Nepal, chili is cultivated across a wide range of agro-ecological zones, with about 23,000 ha under cultivation and an annual production of ~185,000 metric tons in 2021 (MoALD, 2022; Poudyal et al., 2023). Despite favorable environments, national productivity (~8 t/ha) is low due to pest and disease pressures, limited availability of suitable varieties, and suboptimal cultivation practices (Poudyal et al., 2023). Although 16 varieties have been released to date, most are older types or unsuitable for hill cultivation, and more than 70% of production presently depends on costly imported hybrids (SQCC, 2021; Poudyal et al., 2023). The scarcity of high-yielding, hill-adapted genotypes represent a key constraint to increasing national production.

To address this gap, the present study evaluated ten chili genotypes—including widely cultivated local lines and the check variety 'Pusa Jwala'—under mid-hill agro-climatic conditions in Kirtipur. The objective was to assess phenological, vegetative, and yield-related traits to identify promising genotypes for subsequent farmer-participatory evaluation and potential varietal release.

MATERIALS AND METHODS

Experimental site and climate

The study was conducted during the 2025 growing season (March-July) at the research farm of Himalayan College of Agricultural Sciences and Technology (HICAST) in Kirtipur, Nepal (27.6835°N, 85.2771°E; 1350 m asl). The site experiences a subtropical climate with mean summer temperatures ranging from 20-28°C and annual precipitation of 2,812 mm.

Plant materials and experimental design

Ten chili genotypes (*Capsicum annuum* L.) were evaluated: Karma 747, Nepa Hot, Karma 777, Anna 3, Big Mama, Omega, Super Tara, Sudra, Premium, and the check variety 'Pusa Jwala'. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each plot measured 1.8 m × 1.25 m with a plant spacing of 0.5 m × 0.5 m, accommodating six plants per plot.

Crop management

Seeds were sown in a protected nursery on 1 March 2025, and seedlings were transplanted to the main field on 31 March 2025. Fertilizers were applied at a

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recommended dose of 150:120:100 kg $N:P_2O_5:K_2O$ ha^{-1}, supplemented with farmyard manure at 20 t ha^{-1}. Integrated pest management practices were implemented, including the use of yellow sticky traps for whitefly monitoring. Standard agronomic practices for irrigation, weeding, and staking were uniformly maintained across all plots.

Agronomic cultural practices

Seedlings were raised in a nursery on 1st March, 2025 and transplanted to the main field on 31 March 2025 at the specified spacing as in Table1. Irrigation, weeding, and staking were performed as needed. The recommended fertilizer ratio was 150:120:100NPK kg/ha and FYM 20t/ha. Based on this standard recommendation, the calculated fertilizer amounts per plot were 103 g of urea, divided into 47 gm as basal dose and 2 split dosages of 28 g each; 75 g of Diammonium Phosphate (DAP); and 37 g of Muriate of Potash (MOP). In addition to these fertilizers, Farm Yard Manure (FYM) at 5 kg per plot was used. After transplanting, soil was drenched with bavistin @2gm/lt. Pest and disease management was carried out following integrated pest management (IPM) principles using sticky traps for whiteflies.

Agronomic and phenological traits

Plant height (cm) and the number of primary branches were recorded from six randomly selected plants per plot at 60 and 90 days after transplanting (DAT). Collar diameter (mm) was measured at the stem base using a vernier caliper. Plant uniformity and vigor were visually assessed at 50 DAT using a 1–5 scale, where 1 represented poor/uniform growth and 5 represented excellent/vigorous growth. Leaf length, width, and petiole length (cm) were measured from five mature leaves per plot at 76 DAT.

Yield and fruit parameters

Days to 50% flowering and fruiting were recorded as the number of days from transplanting until 50% of plants per plot had at least one open flower or fruit set, respectively. At harvest (117 DAT), ten marketable fruits per plot were sampled to determine fruit length, diameter (measured at the proximal third), peduncle length (cm), and average fruit weight (g). The total number of fruits per plant was counted, and fruit weight per plant (g) was recorded. Plot yield was converted to productivity in metric tons per hectare ($t \cdot ha^{-1}$).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Data collection and analysis

Data were recorded on phenological traits (days to 50% flowering and fruiting), vegetative growth (plant height, collar diameter, leaf characteristics), and yield components (fruit size, number per plant, and weight). Total yield was recorded per plot and extrapolated to tons per hectare. Data were subjected to Analysis of variance (ANOVA) using ADEL-R software, and treatment means were compared using the Least Significant Difference (LSD) test at a 5% significance level.

RESULTS AND DISCUSSION

Significant variation was observed among the ten chili genotypes for key vegetative growth parameters (Tables 1 &2). Plant height, measured at 90 days after transplanting (DAT), showed highly significant differences ($P<0.001$). Genotypes Super Tara and Big Mama consistently exhibited the greatest plant height, reaching 110.47 cm and 96.85 cm at 90 DAT, respectively, indicating vigorous vegetative growth. In contrast, Sudra and Karma 747 were among the shortest genotypes. While greater plant height is often associated with improved light interception and photosynthetic capacity (Poorter et al., 2009), the tallest plants did not necessarily translate to the highest yields, suggesting a potential trade-off between vegetative growth and reproductive allocation.

Leaf morphological traits and stem robustness also varied significantly. Pusa Jwala and Karma 777 had the largest leaves and greatest leaf area, which can enhance photosynthetic potential. Super Tara possessed the thickest collar diameter (27.30 mm), a trait associated with better mechanical strength and vascular transport (Bosland & Votava, 2012). However, the genotype with the highest yield, Karma 777, exhibited intermediate values for these vegetative traits, indicating that optimal growth architecture for yield is not solely defined by maximum vegetative size. Larger leaves contribute to increased light interception and photosynthetic capacity, thereby enhancing plant growth and productivity (Poorter et al., 2009). However, under high-radiation or water-stressed conditions, smaller leaves can be advantageous by minimizing transpiration losses (Nicotra et al., 2011).

Phenological development and reproductive traits

The genotypes displayed a wide range in their phenological development (Table 2). Nepa Hot (47.33 and 53days to 50% respectively) followed by Anna 3 was

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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the earliest to flower and fruit (47.67and 54 days to 50%, respectively), while Super Tara was the latest (63 and 69 days). The high-yielding genotype Karma777 displayed an early to mid-season phenology (59 days to flowering, 65 days to fruiting). Early maturity is a critical adaptive trait for the mid-hills, allowing the crop to complete its key reproductive phase before the onset of unfavorable conditions (Kafle et al., 2021). The significant genetic diversity in phenology offers breeders and farmers options to select varieties suited to different growing windows.

Table 1. Effects of chili genotypes on plant height, leaf size and collar diameter

Treatment	Plant height 60DAT	Plant height 90 DAT	Leaf length (cm)	Leaf Width (cm)	Stalk length of leaf (cm)	Leaf Area (cm^2)	Collar Diameter (mm)
1 Karma 747	53.50^{cd}	79.28^{d}	7.29^{bc}	2.85^{cde}	3.00^{a}	6.99^{cde}	26.19^{b}
2 Nepa Hot	62.50^{abc}	82.61^{d}	7.64^{abc}	4.10^{a}	2.53^{ab}	9.44^{a}	20.12^{f}
3 Karma 777	58.08^{abcd}	95.11^{bc}	8.17^{ab}	3.91^{ab}	1.86^{bc}	9.45^{a}	25.78^{b}
4 Anna 3	66.56^{ab}	89.53^{bcd}	5.12^{d}	3.56^{abc}	2.36^{ab}	6.77^{de}	17.99^{h}
5 Big mama	68.17^{a}	96.85^{b}	8.19^{ab}	2.45^{e}	1.32^{c}	3.62^{f}	21.38^{e}
6 Omega	48.33^{d}	79.78^{d}	7.10^{c}	3.86^{ab}	1.93^{bc}	7.76^{b}	19.24^{b}
7 Super Tara	67.58^{a}	110.47^{a}	6.87^{c}	3.45^{abcd}	2.51^{ab}	6.58^{de}	27.30^{a}
8 Sudra	52.19^{cd}	78.25^{d}	6.80^{c}	2.77^{de}	2.77^{a}	7.56^{bc}	20.12^{f}
9 Premium	55.11^{bcd}	84.17^{cd}	7.21^{c}	3.21^{bcd}	2.35^{ab}	6.39^{e}	22.51^{d}
10 Pusa Jwala (Check)	62.39^{abc}	83.78^{cd}	8.47^{a}	3.06^{cde}	3.00^{a}	7.17^{bcd}	23.81^{c}
Grand Mean	59.44	87.98	7.29	3.32	2.36	7.17	22.44
F- test	*	***	***	**	**	***	***
StdMSE	7.25	7.17	0.56	0.42	0.46	0.35	0.25
LSD(5%)	12.44	12.30	0.96	0.73	0.8	0.6	0.42
CV%	12.20	8.15	7.65	12.72	19.68	4.87	1.10

Mean in the column followed by unlike letters indicates significant difference at P=0.05

*Note: Means with same letters are non-significant at p=0.05 by DMRT (Duncan's Multiple Range Test), *significant at 0.05% level of significance, **significant at 0.01% level of significant, ***significant at 0.001% of significance, NS- Non-Significant*

Fruit characteristics, including length, diameter, and peduncle length, showed highly significant variation (P<0.001), reflecting the diverse genetic background of the tested materials (Table 2). Pusa Jwala produced the longest fruits (10.09 cm), whereas Karma 747, despite having shorter fruits (3.6 cm) followed by Nepa

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Hot (4cm) fruit length, had the greatest fruit diameter (15.35 mm). This compact, blocky fruit type can be preferable for certain market segments.

Table 2. Effects of chili genotypes on number of primary branches, uniformity, vigor and fruit size

Treatments	Number of primary branches	Uniformity	Vigour	Days to 50% flowering	Days to 50% fruiting	Fruit length (cm)	Fruit width (mm)	Fruit peduncle length (cm)
1 Karma 747	6.40^{ab}	5.00^{a}	5.00^{a}	52.00^{d}	57.67^{de}	3.60^{d}	12.73^{abc}	3.09^{bc}
2 Nepa Hot	5.83^{bc}	4.67^{a}	5.00^{a}	47.33^{e}	53.00^{f}	4.08^{cd}	15.35^{a}	2.84^{c}
3 Karma 777	6.87^{ab}	4.00^{b}	4.00^{b}	59.33^{ab}	64.67^{ab}	7.51^{b}	7.39^{e}	3.72^{ab}
4 Anna 3	6.85^{ab}	5.00^{a}	5.00^{a}	47.67^{e}	54.00^{ef}	8.46^{b}	7.09^{e}	3.49^{abc}
5 Big mama	6.52^{ab}	4.00^{b}	5.00^{a}	53.00^{cd}	60.00^{cd}	7.85^{b}	7.91^{de}	3.33^{abc}
6 Omega	7.90^{ab}	5.00^{a}	5.00^{a}	62.00^{a}	67.67^{a}	5.18^{c}	10.51^{cd}	2.72^{c}
7 Super Tara	6.64^{ab}	5.00^{a}	5.00^{a}	62.67^{a}	68.67^{a}	4.54^{cd}	11.19^{c}	3.11^{bc}
8 Sudra	8.18^{a}	4.00^{b}	4.67^{a}	56.67^{bc}	62.33^{bc}	7.44^{b}	11.22^{c}	2.81^{c}
9 Premium	7.76^{ab}	5.00^{a}	5.00^{a}	53.00^{cd}	60.00^{cd}	5.27^{c}	14.04^{ab}	2.87^{c}
10 Pusa Jwala (Check)	4.11^{c}	4.67^{a}	4.67^{a}	50.33^{de}	56.67^{def}	10.09^{a}	11.44^{bc}	3.98^{a}
Grand Mean	6.71	4.63	4.83	54.40	60.47	6.40	10.89	3.20
F-test	*	***	**	***	***	***	***	*
StdMSE	1.28	0.24	0.27	2.31	2.62	0.90	1.57	0.47
$LSD_{0.05}$	2.20	0.42	0.46	3.96	4.50	1.55	2.70	0.80
CV%	19.13	5.26	5.49	4.24	4.34	14.12	14.44	14.62

*Note: Means with same letters are non-significant at p=0.05 by DMRT (Duncan's Multiple Range Test), *significant at 0.05% level of significance, **significant at 0.01% level of significant, ***significant at 0.001% of significance, NS- Non-Significant. Mean in the column followed by unlike letters indicates significant difference at P=0.05.*

Yield and component analysis

Yield and its components exhibited significant genetic differences, with Karma 777 emerging as a top performer (Table 3). Although the check variety Pusa Jwala recorded the highest individual fruit weight (7 g) and the highest theoretical yield (20.80 t/ha), Karma 777 achieved a comparable and statistically similar high yield (18.31t/ha) followed by Nepa Hot (17.16 t/ha).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Table 3. Effects of chili genotypes on yield parameters

Treatments	Average Fruit weight of 10 ripe fruits (g)	No of fruits per plant	Fruit Yield/ Plant (kg)	Fruit Yield (t/ha)
1 Karma 747	3.48^{de}	109.06^{d}	0.47^{bc}	12.44^{bc}
2 Nepa Hot	4.83^{cd}	207.06^{ab}	0.64^{ab}	17.16^{ab}
3 Karma 777	4.63^{cd}	160.50^{bcd}	0.69^{ab}	18.31^{ab}
4 Anna 3	2.70^{e}	187.34^{bc}	0.53^{bc}	14.13^{bc}
5 Big mama	2.50^{e}	136.91^{cd}	0.39^{c}	10.49^{c}
6 Omega	3.90^{cde}	185.98^{bc}	0.58^{abc}	15.38^{abc}
7 Super Tara	3.57^{cde}	258.51^{a}	0.56^{abc}	14.93^{abc}
8 Sudra	7.57^{a}	133.83^{cd}	0.48^{bc}	12.71^{bc}
9 Premium	5.37^{bc}	165.11^{bcd}	0.68^{ab}	18.04^{ab}
10 Pusa Jwala (Check)	7.00^{ab}	133.11^{cd}	0.78^{a}	20.80^{a}
Grand Mean	4.55	167.74	0.58	15.44
F-test	***	**	*	*
StdMSE	1.10	33.93	0.13	3.45
$LSD_{0.05}$	1.89	58.20	0.22	5.92
CV%	24.15	20.23	22.32	22.34

*Note: Means with same letters are non-significant at p=0.05 by DMRT (Duncan's Multiple Range Test), *significant at 0.05% level of significance, **significant at 0.01% level of significant, ***significant at 0.001% of significance, NS- Non-Significant. Mean in the column followed by unlike letters indicates significant difference at P=0.05.*

This highlights a key yield adaptation strategy: Karma777 compensates for its smaller fruit size with a remarkably high fruit set followed by Premium as well as Nepa Hot. This efficient partitioning of assimilates towards reproductive structures, rather than excessive vegetative growth or individual fruit size, is a hallmark of a well-adapted genotype (Wahyuni et al., 2013). Super Tara, which had the highest fruit count (258.51 per plant), achieved a strong yield (14.93 t/ha), but its later maturity and potentially larger plant structure may be less efficient than Karma 777 , Premium, and Nepa Hot's more compact and early-maturing profile. Larger fruits, are linked to greater photosynthetic translocation and are preferred for fresh markets, while smaller, lighter fruits suit the spice industry (Uwah et al. 2013). Fruit number in chili is primarily influenced by genetic makeup but is also affected by environmental factors such as nutrient availability,

soil fertility, and temperature conditions during flowering and fruiting (Bosland and Votava 2012). Genotypes that exhibit strong vegetative growth and thicker stems, such as Super Tara, tend to sustain a higher fruit load without compromising individual fruit quality. Furthermore, environmental factors such as sunlight, temperature, and nutrient management also play crucial roles in optimizing fruit set and yield (Singh et al., 2017).

Conversely, genotypes like Big Mama and Karma 747 yielded the lowest (10.49 and 12.44 t/ha, respectively), primarily due to a lower number of fruits per plant. This underscores that fruit number is a more critical determinant of final yield in this context than individual fruit weight.

CONCLUSION

The results demonstrate that Karma 777 possesses an ideal combination of traits for the mid-hill conditions of Nepal: early maturity, a high number of fruits per plant, and efficient plant architecture, culminating in high yield. Its performance suggests it is less prone to the sink-source imbalances seen in overly vigorous genotypes. The identification of Karma 777, along with other promising genotypes like Premium and Nepa Hot, provides valuable genetic resources for improving chili productivity in the region. We recommend Karma777 for immediate inclusion in farmer-participatory trials as a precursor to potential varietal release.

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Role of Commercial Cucumber on Income Generation in Kathmandu Valley

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ABSTRACT

The study was conducted to assess the commercial cucumber production and its role in income generation in Kathmandu Valley. In the study area chemical inputs were widely applied with (92.38%) using insecticides, (57.14%) using fungicides and (38.10%) were using both chemical and bio-pesticides. In terms of irrigation majority farmers depended on canal (42.46%) and tube well (35.24%) while the drip irrigation method was limited. Regarding productivity, the average cucumber yield was 740 kg per ropani and average net income was Rs 2070 resulting in a benefit cost ratio exceeding 1. Pest and disease infestation, high input cost, fluctuating market price, limited irrigation facilities and middle men exploitation were major problem in cucumber production in study area. To address these challenges, farmers must practice use of balanced input through Integrated Nutrient Management and Integrated Pest Management farmers must be trained on record keeping and benefit cost analysis for better decision making.

Keywords: Input use, pest and disease management, productivity, varieties, yield

INTRODUCTION

Being an agrarian country, Nepal has a huge potential of producing different vegetables at different regions round the year, besides various cereal, pulses and other cash crops. A vegetable is herbaceous plant, or portion of a plant that is eaten whole or in part, raw or cooked, generally with an entree or in a salad but not as a desert (Welbaum, 2015). Cucumber (*Cucumis sativus* L.), an extensively cultivated vegetable plant, belongs to the "Cucurbitaceae" family (Khanal et al., 2020). Cucumber appears to have originated in Asia, where people have grown it for sustenance for around three thousand years (Subedi et al., 2024). It is grown in almost every part of the country in an annual pattern. It is annual, warm season

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January, 2026, volume 30
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trailing vine crop, grown throughout the world under tropical and subtropical conditions (Chhetri et al., 2024). In Nepal, it is cultivated from terai to high hills, at altitudes ranging from 100 masl to 1800 masl. It is mainly cultivated for its young tender fruits, which are consumed raw as salad, and by making pickles.
Cucumber is a cash generating crop for poor farmers residing near the markets and roads and is extensively grown in low to high hill of Nepal (Dahal and Dahal, 2022). Spring-summer is considered as the normal season while the rest of the year (rainy to early-spring) is regarded as the off-season. During off season it is successfully grown under greenhouse due to its suitability to thrive under high light intensity, high humidity, high soil moisture, temperature, and fertilizers condition (Chhetri et al., 2024). Off-season greenhouse cultivation has further boosted its demand and profitability. Cucumber holds a significant economic importance with the potentiality of income generation through year round production, by cultivating during off season under plastic house (Subedi et al., 2024). It contributes by enhancing household income, livelihood, improving nutrition and promotes cucumber farming in Nepal, particularly in Kathmandu valley where the demand is high. The total area under cucumber cultivation is 10,309 ha, with production 159,625 mt and productivity 15.48 mt/ha (MoALD, 2023). Out of which Kathmandu valley, contains 505 ha of area, with production 11,223 mt and productivity 67.61 mt/ha (MoALD, 2023).

Price behavior was a problem for the farmer with the major marketing problems being price fluctuation, unawareness of price, and middlemen intervention. Import of large quantities of vegetables is also one of the constraints for cucumber production. Furthermore, diseases and pests, high price of inputs, irrigation problems, climatic uncertainty, and insufficiency of needed inputs are the major bottlenecks for cucumber production. Meanwhile, lack of marketing information, uncertainty in selling price, unmanaged marketing extension services during marketing are challenges faced by farmers for cucumber production (Khanal et al., 2020). Though it has economic and nutritional potential, limited studies have been conducted on cultivation practices and its economic scenario. Therefore this study is important as it provides insight into cucumber production to income generation and also identifies the research gap on production practices and market opportunities. It provide base for policy makers, development agencies for developing strategies and policy making. This study benefits the farmers by providing better understanding the cultivation practices and its profitability, researchers to fill the research gap.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

MATERIALS AND METHODS

The study was carried out in selected sites within the Kathmandu valley, focusing on three districts Kathmandu, Lalitpur and Bhaktapur. Kathmandu valley is in the Bagmati province in the central region of Nepal and lies at an elevation of approximately 1,300 meters above sea level. It experiences both sub-tropical and temperate climate which favor both seasonal and off- seasonal vegetable production, including cucumbers. These districts were specifically chosen due to their significant engagement in commercial cucumber farming, availability of semi-urban and peri- urban agricultural land and access to local and regional market.

Sampling technique and sample size

The study adapted purposive sampling method to select the respondents who were involved in cucumber production and could provide relevant information. This method was chosen as it allows conscious selection of farmers who meet certain criteria aligned with study objectives. A total of 105 farmers were interviewed within the study area. This number was particularly chosen for uniform representation across the three districts of the Kathmandu valley, with 35 farmers from each district i.e. Kathmandu, Lalitpur and Bhaktapur. This approach allowed the study to represent variation in farming practices across the valley while keeping the sample size manageable for collecting and analyzing the data. The farmers were selected based on certain criteria. Small scale farmers, cultivating on less than 10 ropani of land, engaged in commercial cucumber production and having at least one year of experience were the basis of criteria. These criteria assured the study focused on farmers with practical knowledge and consistent involve in cucumber production.

Data collection and analysis

Data was collected through combination of primary and secondary sources. Primary data were collected through structured interviews and questionnaire with selected participants. These tools were designed to gather detailed information on cucumber cultivation practices, input use, market price and yield. Secondary data were source from existing literature, government reports, and websites.

Descriptive statistics, such as mean, standard deviation, minimum, and maximum values, charts and graphs were computed by using Excel. Pearson correlation analysis was conducted using SPSS, focusing on the association of income, and

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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yield per ropani with key agricultural inputs such as seed rate, urea, DAP, potash, and average fertilizer use.

Additionally, an Excel Benefit-Cost Ratio (BCR) analysis was conducted to assess the economic viability of cucumber farming. By contrasting total revenue with total production costs, the BCR offers information about return on investment. The BCR is computed using the following formula:

Benefit Cost Ratio: Total Income / Total cost

A BCR value greater than 1 indicates that the farming activity is economically viable and profitable, while a value less than 1 suggests a loss.

Cropping Intensity (CI) = Gross cropped area / Net sown area X 100

CI Index = CI Index Low (150-250), Moderate (300), High (400)

Garret's ranking technique

To prioritize constraints faced by citrus farmers, Garrett's Ranking Technique (Garrett, 1961) was employed. Respondents ranked identified problems in order of perceived severity. Ranks were converted into percentage scores using:

$$Percentage\ score = 100\ Rij - 0.5/\ Nj$$

Where:

Rij= Rank given for the ith factor by the jt^{h} respondent

Nj= Number of factors ranked by the j^{th} respondent

Using Garrett's conversion table, percentage positions were transformed into scores (Garrett and Woodworth, 1969). Mean scores for each factor were calculated, ranked, and interpreted to identify the most critical constraints

RESULTS AND DISCUSSION

Socio- demographic and farm characteristics

The study revealed that among total respondents**,** 53.33% of the respondents were male, while 46.67% were female**.** The majority of respondents were under 41-50 (40.95%) followed by 31-40 (40%), 20-30 (7.62%) and above 60 (0.95%). This indicates that majority of the respondents fall between economically active age

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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group. Majority of the respondents i.e. 97.14% were primarily engaged in agriculture and remaining 0.95% was involved in other occupation. Out of the total respondents, 14.29% were illiterate, 36.19% and 30.48% had completed primary and secondary level education, and 15.24% had attained higher level education whereas only 3.81% had completed graduate-level education. The majority of farmers, 63.81%, cultivated cucumber on plots of less than 2 ropani. 24.76% cultivated between 2-4 ropani, while only 11.43% had cucumber cultivation on holdings larger than 4 ropani.

Table 1. Demographic status of respondents

Demographic characteristics	Category	Percentage
Gender	Male	53.3
	Female	46.7
Age group	20-30	7.62
	31-40	40
	41-50	40.95
	51-60	10.48
	Above 60	0.95
Occupation	Agriculture	97.14
	Abroad	1.90
	Others	1
Education	Illiterate	14.29
	Primary	36.19
	Secondary	30.48
	Higher	15.24
	Graduate	3.81
Total land under cucumber cultivation	2-4	24.76
	4+	11.43
	Less than 2	63.81

Cucumber production season

The majority of the respondents i.e. 93.3% had cultivated cucumber during spring-summer season indicating, it was the primary season for cucumber production. Conversely, only 6.67% of farmers had grown cucumbers during both the rainy and spring-summer seasons, indicating that very few farmers continued to grow cucumbers outside of the main growing season. These findings are consistent with the previous study. Spring-summer is considered as the normal season while the rest of the year (rainy to early-spring) is regarded as the off-season (Dahal and Dahal, 2022). Cucumber is widely cultivated during the summer season in low to mid hills as the main season crop and during the winter

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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under a plastic house as an offseason crop (Subedi et al., 2024). Overall, the findings showed that the study area's for cucumber production was highly seasonal, with the spring and summer being the most common growing seasons.

Varieties

During the study it was found that most of the respondents preferred using hybrid variety i.e Gorkha hybrid F1 (47%) and Brishma hybrid F1 (21%). 20% preferred using Bhaktapur local, 10% were using both hybrid and local and remaining other were found using Karma variety. When compared with previous studies, the present findings partly contrast with (Subedi et al., 2024), who reported that the majority of farmers (66.7%) cultivated Bhaktapur local cucumber, while Karma, Kamini, Pusa long green, Malini, and other varieties were grown by smaller proportions. Similarly, (Khanal and Dhakal, 2020) reported that 70% of farmers preferred Bhaktapur local, with only 5% using hybrids such as Dynasty, Beli, Kheera, Malini, and Ninja, and 25% using both types.

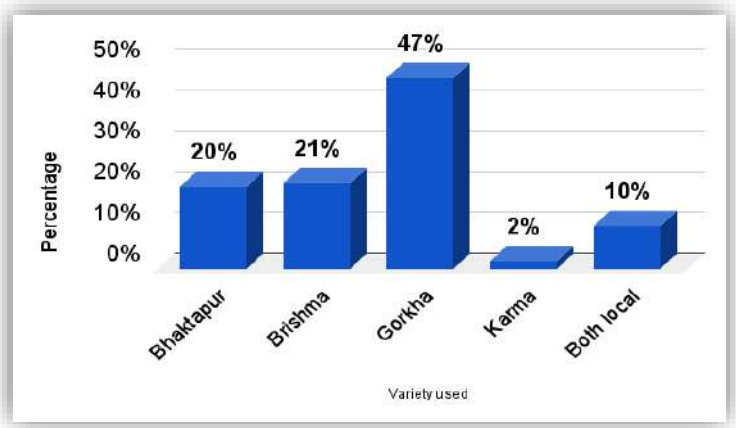

Figure 1. Varieties used by the respondents

Irrigation

From the study it was reported that 42.86% relied on tube well and 35.24% on canal irrigation. Drip irrigation was adopted by 21.90%. This suggested that while some farmers had adopted advanced drip irrigation techniques, the majority still depend on conventional method.

In contrast to these findings, Chhetri et al., (2024) reported that 100% of the respondents were cultivating cucumber inside tunnel using drip irrigation system. Drip irrigation system is more beneficial in tunnel as compared to furrow irrigation system as per the respondents of the study area. These differences may be due to several factors such as high initial cost of drip irrigation installation could be major barrier for small holder farmers in the present study. Additionally, the perceived need to invest in modern systems is diminished by the ease of access to canal irrigation and tube wells.

Nutrient source

Among the total respondents, (81.90%) used both chemical fertilizers and organic manure. 15.24% used only organic manure. However, only 2.86% of respondents reported use of chemical fertilizers, indicating that the study area did not typically rely solely on synthetic inputs.

Previous research reported that 8% of them used only organic manure, 2% of them used only chemical fertilizers and 90 % of them used both organic manure and chemical fertilizers (Gautam, 2021). Such similarities highlight that integrated nutrient management has become a widely adopted practice among cucumber growers in Nepal, mainly due to its balanced benefits for both crop yield and soil health. Similarly, (Thakuri, 2023) reported that 92% fertilizer usage rate further highlighting the widespread of integrated practices.

Fertilizer used by the respondents

Among all the respondents, 43 farmers did not use urea, while the majority did so in small to moderate amounts. Of them, 33 used between 5.1 and 10 kg, 17 used between 1 and 5 kg, and only two farmers used more than 20 kg. With 40 farmers using 1–5 kg and 5.1–10 kg per ropani, respectively, DAP was widely used; only 18 farmers did not use it at all. In contrast, only 37 farmers used potash, 39 used 1–5 kg, and 24 used 5.1–10 kg per ropani. These findings are consistent with the previous study where I was reported the recommendation of 5–6 kg of DAP, 10 kg of urea, and 2-3 kg of potash per katha, or roughly 3.5 kg of DAP, 7 kg of urea, and 2 kg of potash per ropani (Dahal and Manandar, 2020). The current study demonstrates that farmers' application of DAP (5.1–10 kg per ropani) and urea (5.1–10 kg per ropani) typically falls within or near the recommended range when compared to the previous study recommendations.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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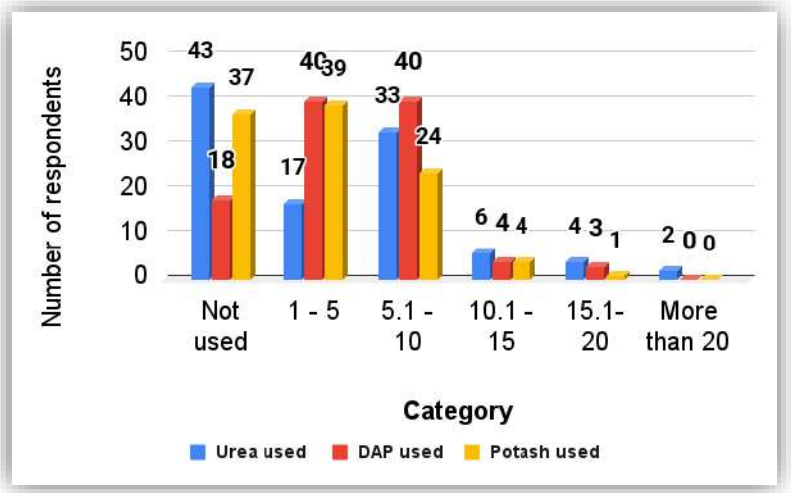

Figure 2. Fertilizer used by the respondents

Pesticides use

In the study area, 61.90% found using solely chemical pesticides whereas 38.10% of farmers reported using both chemical and biological pesticides, indicating that some level of integrated pest management was practiced but the overall adaption of bio pesticides was limited.

The present study is consistent with (Baral and Gyawali, 2025) findings where they reported that 100 % respondents used chemical pesticides while 68% reported using both chemical and biological (bio) pesticides for disease and pest management which consistent with my present findings. This study further reported that commercial vegetable farmers showed greater affinity towards chemical pesticides over bio-pesticides.

Chemical pesticides

Among the respondents, it was found that 92.38% of respondents reported using insecticides from which most of the respondents i.e. 36% used Chloropyrifos 50% + Cypermethrin 5% while other different insecticides were used by smaller proportion of respondents. Similarly 57.14% of farmers used fungicides. It was found that the most common fungicide used was Mancozeb 64% + Cymoxanil 8% WP.

This result aligned with study of (Baral and Gyawali, 2025), who noted that fungicides and insecticides are the two major used pesticides in vegetable production. From the (Maharjan, 2020) findings insecticides were most used (68%) and fungicides (22.33%) in cucumber farming, In contrast to Maharjan's finding, the percentage of farmers using pesticides in the current study is significantly higher.

Price of cucumber

The average price of cucumber paid by wholesaler was Rs 45/kg, retailer Rs 85/kg and consumer Rs 100/kg.

These findings are consistent with (Subedi et al., 2024) who also reported the average price of cucumber. In their study the average sales price of cucumber for producers was found to be Rs. 35.17 while for retailers, it was found to be Rs. 94.60.

Satisfaction level regarding market price

The study portrayed that 24.8% were satisfied with the market price whereas majority of respondents i.e. 75.24% were dissatisfied. It was due to fluctuating market price and middlemen exploitation. The study conducted by (Chhetri et al., 2024) portrayed that 33.75% of the respondents of the study area were satisfied with the market price of cucumber. 43.75% of respondents were neutral about the market price of cucumber and 22.50% of respondents were not satisfied with the market price. According to them they had to sell their cucumber in minimum price and had to face problems due to middlemen.

Production

The average production was 740 kg per ropani. From the study area, it was found that 71.43% of farmers reported a moderate yield of cucumbers, ranging from 501 to 1000 kg per ropani. Around 22% produced a low yield of 1 to 500 kg per ropani. Just 6.67% of the farmers produced a high yield of more than 1000 kg per ropani. The moderate range found in the current study is consistent with previous study (Khanal and Dhakal, 2020) where they reported an average production of 850 kg per ropani. In contrast, Chhetri et al., (2024) reported an average production of 30,020 kg per hectare, or about 1,500 kg per ropani. This falls into the high-yield category, which defined as more than 1,000 kg per ropani. These comparisons showed that although the majority of Kathmandu Valley farmers produced

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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moderate yields, better management techniques or favorable weather conditions could have facilitated for higher yields.

Economic profitability

The total average net return from cucumber in the study area was Rs 20702. The average benefit cost ratio was 1.96 (Table 2). The previous study conducted by Tiwari and Belbase, (2024) had reported an average return of Rs 1004430/ha which is approximately Rs 50,225/ropani with an average total cost of Rs 283383/ha (Rs 14,169/ropani). This demonstrates positive net returns. Similarly Chhetri et al., (2024) reported higher returns of Rs 2101400/ha (Rs 105070/ropani) and a B: C ratio of 1.41 which indicates profitability. Both studies confirmed that cucumber farming can generate significant income, but the income in the present study was lower.

Table 2. Benefit cost analysis

Average cost (NRs.)	Average gross return (NRs)	Average net profit (NRs)	B:C
20892	41476	20702	1.96

Correlation analysis

The usage of urea ($r = 0.355$, $p < 0.001$), DAP ($r = 0.341$, $p < 0.001$), and potash ($r = 0.446$, $p < 0.001$) showed a significant positive correlation with income per ropani, while their correlation with yield per ropani was also significant , urea ($r = 0.196$, $p = 0.045$), DAP ($r = 0.515$, $p < 0.001$), and potash ($r = 0.511$, $p < 0.001$) indicating that higher and balanced fertilizer use enhances both productivity and income levels.

These results are consistent with findings from Nawalparasi, where (Acharya et al., 2022) reported that the combined application of FYM and NPK under mulching conditions produced the highest cucumber yield (27.97 t/ha) and the greatest economic return with a benefit–cost ratio of 2.60. Similarly, (Adhikari et al., 2023) found that increasing urea application in Baglung improved cucumber yield, but also emphasized that balanced nutrient application is more effective than nitrogen alone. These studies reinforce the present finding that while urea contributes to productivity, phosphorus and potassium are more critical in determining both yield and profitability.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Table 3. Correlation coefficients for Mean of all variable categories (N= 105)

Particulars		Seed rate / ropani	Urea	DAP	Potash	Avg. fertilizers
Income per ropani	Pearson Correlation	0.055	.355**	.341**	.446**	.472**
	Sig. (2-tailed)	0 .577	<.001	<.001	<.001	<.001
Yield per ropani	Pearson Correlation	-0.127	.196*	.515**	.511**	.479**
	Sig. (2-tailed)	0.195	0.045	<.001	<.001	<.001
** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level						

Note: 20 ropani= 1 ha

Challenges faced by the respondents

On the basis of Garrett ranking, market price fluctuation was the most serious issue (mean score = 77), followed by high labor costs (66) and irrigation problems (67). The least serious limitation on cucumber production was seedling death with mean score 48 ranked fifth while pest attack with mean score 58 ranked fourth.

Table 4. Major challenges faced by cucumber farmers

Problems	Mean score	Rank
Market price fluctuation	77	I
Irrigation	67	II
High labor cost	66	III
Pest attack	58	IV
Seedling death	48	V

Overall the main problems found out during cucumber production included marketing difficulties, unstable market and price fluctuations, irrigation, pest and disease attack. These findings are consistent with (Chhetri et al., 2024) and (Subedi et al., 2024), who also reported unstable market, price fluctuation, irrigation, disease and pests attack as major challenges. The previous studies additionally identified problems such as marketing problem, inadequate infrastructure and high labor cost which were not significant constraint in my study area

CONCLUSION

The canal and tube well irrigation methods were dominant showing the need of modernization in water management. A small number of respondents had adapted drip irrigation method which reflected a low level of adoption of modern and efficient irrigation technologies among cucumber farmers. Farmers largely

depended on chemical inputs such as insecticides and fungicides, with limited use of bio-pesticide. The average benefit cost ratio of cucumbers for 1 ropani was 1.96 which clearly indicated that cucumber production can generate significant returns if managed effectively. However potentiality was often hindered by common problems like pest and disease infestation, fluctuating prices, high input cost, limited advances irrigation technique and middle men exploitation.

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Comparative Study of Winter and Summer Fodder Species and Their Mixtures on-Station and on-Farm Conditions

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ABSTRACT

Cultivated fodder species and cereal-legume mixtures can boost fodder supply, enhance nutritive value, and decrease reliance on crop residues, thereby helping to address the severe feed shortage faced by ruminant livestock in Nepal. This study aimed to evaluate winter and summer fodders and their mixtures under on-station conditions and verify them across diverse agro-ecological regions. In the first year, 12 winter and eight summer fodder treatments—including sole cereals, sole legumes, and mixtures—were tested in separate experiments at the National Pasture and Fodder Research Program, Khumaltar. Both winter and summer trials used a Randomized Complete Block Design with three replications. Based on first-year performance, one winter package (Oat + Berseem) and one summer package (Teosinte + Cowpea) were selected for farmers' field tests in four districts: Dhading, Kabhrepalanchowk, Banke, and Sunsari. Data on dry matter yield and related attributes were analyzed using ANOVA and Tukey's Honest Significant Difference Test at the 5% significance level. On-station results showed that sole Oat (*Avena sativa*) produced the highest ($p<0.001$) winter dry matter yield (15.63 t/ha), and the Oat + Berseem (*Trifolium alexandrium*) mixture yielded similarly (14.82 t/ha; ($p>0.05$)). Among summer fodders, Teosinte (*Euchlaena mexicana*) + Cowpea (*Vigna unguiculata*) achieved the highest yield (22.74 t/ha). In the second year's on-farm experiments, Oat + Berseem yielded the highest in Banke (14.95 t/ha) and the lowest in Kabhrepalanchowk (6.18 t/ha), while Teosinte + Cowpea also produced the best yield in Banke (27.65 t/ha). These results indicate that Oat + Berseem and Teosinte + Cowpea are suitable package options across locations for year-round fodder production to improve livestock productivity.

Keywords: Berseem, cereal–legume mixture, cowpea, oat, teosinte

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INTRODUCTION

Livestock forms a vital part of mixed crop-livestock farming systems in Nepal. Despite its essential role, the sector faces ongoing challenges from consistently low productivity, mainly caused by a significant lack of adequate, high-quality feed (FAO, 2004; Singh and Singh, 2019). This shortage shows clear seasonal patterns, with severe deficits during winter and spring. These shortages lead to lower animal performance, higher feeding costs, and a heavy dependence on low-quality crop residues and imported feed concentrates (Singh and Singh, 2019). Therefore, resolving this fodder shortage is crucial and involves boosting cultivated fodder production through the use of improved species, better mixtures, and improved management practices (Ghimire, 2025).

Among winter fodders, oats (*Avena sativa* L.) are widely cultivated for their high biomass yield, rapid growth, and broad adaptability across Nepal's diverse ecological regions (FAO, 2004; Pant *et al.,* 2022). However, a major limitation of sole cereal fodders like oats is their inherently lower crude protein and mineral content. This nutritional shortfall can be effectively addressed by intercropping with leguminous species such as Berseem (*Trifolium alexandrinum* L.) or Vetch (*Vicia* spp.). These legumes provide high protein content, improve digestibility, and enhance overall system sustainability by fixing atmospheric nitrogen (Barsila, 2018). Consequently, cereal-legume mixtures are recognized for offering a more nutritionally balanced diet for ruminants while maintaining competitive dry matter (DM) yields (Dangi, 2020; Khanal *et al*., 2020). Similarly, for summer production, tropical grasses such as Teosinte (*Euchlaena mexicana* (Schrad.) Kuntze) and Sorghum (*Sorghum bicolor* (L.) Moench) are well-suited for the Terai and mid-hills of Nepal. When intercropped with legumes like Cowpea (*Vigna unguiculata* (L.) Walp.), these systems demonstrate a synergistic potential to significantly increase both the quantity and nutritional value of fodders (Devkota *et al*., 2015; Khanal *et al*., 2020). Recent research indicates that Teosinte-Cowpea combinations, in particular, can produce superior biomass and higher crude protein levels compared to their sole crops (Khanal *et al*., 2020; Khanal *et al*., 2021).

Despite the documented agronomic potential of these fodder species, their performance is greatly affected by Nepali diverse agro-ecological conditions, including altitude, climate, and local management practices. Therefore, a systematic evaluation of these fodder systems through thorough on-station

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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screening followed by multi-location on-farm trials is a better approach to find the most resilient and suitable combinations for specific regions (Devkota *et al*., 2015). This study was conducted to address this issue by comparing promising seasonal fodders and their combinations across both on-station and on-farm environments.

MATERIALS AND METHODS

Study site

The research was carried out over two consecutive winter seasons, from November 2017 to May 2019. The first-year experiments took place at the research field of the National Pasture and Fodder Research Program (NPFRP) in Khumaltar, Lalitpur (27°39′N, 85°19′E; 1340 meters above sea level), under the Nepal Agricultural Research Council (NARC). This site is situated in Nepal's mid-hill agro-ecological regions and has a subtropical climate with cool winters and warm, humid summers. The soil is silty and moderately fertile, representative of typical fodder-growing conditions in the mid-hills.

During the second year, on-farm validation trials took place in four districts representing various agro-ecological regions of Nepal. These four sites included Kumpur village in Dhading district (2749'N and 8453'E, 667-753 masl) in the lower mid-hill region, Ryale village in Kabhrepalanchowk district (2735'N, 8527'E, and 1440-1582 masl) in the upper mid-hill region, Betahani village in Banke district (2800'N, 8142'E, and 160 masl) in the Western Terai lowland, and Inaruwa village in Sunsari district (2636'N, 8708'E, and 106 masl) in the Eastern Terai lowland.

Experimental design and crop management

During the first year, the study identified the highest-yielding winter and summer fodder crops, evaluating both sole crops and cereal-legume mixtures. The experiment was carried out using a Randomized Complete Block Design (RCBD) for each season. For the winter season, 12 fodder treatments with three replications were tested. These treatments included sole plantings of key cereals and legumes, such as Oat (*Avena sativa* L.) cv. Netra, Berseem (*Trifolium alexandrinum* L.) cv. Green gold and Illite II, Common vetch (*Vicia sativa* L.) cv. Kutilkosha-1 and Black pod, Purple vetch (*Vicia benghalensis* L.) cv. Popany, Hairy vetch (*Vicia villosa* subsp. Dasycarpa) cv. Capillo, Shaftal clover (*Trifolium resupinatum* L.) cv. Majus, Fodder pea (*Pisum sativum* L.) cv. AP2, and Garden

pea (*Pisum sativum* L.) cv. Sikkim, along with two important mixtures: Oat combined with Berseem and Oat combined with Common vetch. In the summer season, eight treatments were tested with three replications, including sole cereals—Teosinte (*Euchlaena mexicana* (Schrad.) Kuntze) cv. Makaichari-1, Sorghum (*Sorghum bicolor* (L.) Moench.) cv. Green pearl, Sama grass (*Echinochloa colona* (L.) Link), and Bajra (*Pennisetum glaucum* (L.) R. Br.) (Nutrifeed 16)—and their respective mixtures with the local Kartike Cowpea (*Vigna unguiculata* (L.) Walp.). The plot size for each experimental unit was 12 m^2, managed according to NARC recommended agronomic practices.

Based upon the first-year results, the second year study focused on the on-farm validation of the highest-performing fodder packages for both seasons. The selected treatments were the winter combination of Oat and Berseem and the summer combination of Teosinte and Cowpea, both established at a 60:40 seed ratio. These packages were evaluated through the farmers' field experiments conducted across four distinct agro-ecological regions in Nepal. Specific NARC recommended variety of Oat for the particular agro-ecological region were used for those four locations. The variety Netra was used in Dhading district, Kamadhenu in Kabhrepalanchowk, Nandini in Banke and Amritdhara in Sunsari.

The experimental design for these multi-location trials was a RCBD, where four locations were considered as treatments and each participating farmer within a site was considered a replication, with five replications (farmers) per site.

Crop establishment and management practices were standardized across all experimental sites to ensure consistency. For both seasons, sowing was done using the broadcast method. Winter fodders were sown in the second week of November, with seeding rates of 100 kg/ha for sole oat, 25 kg/ha for Berseem, 40 kg/ha for vetch, and 120 kg/ha for peas. For cereal-legume mixtures, a 60:40 seed ratio was used. Summer fodders, Teosinte and cowpea, were sown in mid-April at rates of 40 kg/ha for sole crops, with mixtures also maintaining a 60:40 seed ratio. Fertilizer applications followed NARC guidelines, with different nutrient doses for cereals, legumes, and their mixtures. Specifically, oat plots received N: P_2O_5:K_2O at 80:60:40 kg/ha, while sole-legume plots received 25:60:30 kg/ha; mixture plots received a combined dose of 60:60:40 kg/ha. For summer crops, Teosinte received 60:40:40 kg/ha, sole cowpea received 25:60:30 kg/ha, and their mixture received 60:60:40 kg/ha. In both seasons, half of the nitrogen was applied as a basal dose, with the remaining top-dressed after the first and second harvests.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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A standardized cutting management regime was followed, with the first harvest at 60 days after sowing (DAS) and subsequent cuts at 30-day intervals, resulting in three total cuts per season at a uniform height of 5 cm above the soil surface. Other management practices, including weeding, irrigation where feasible, and pest control, were carried out according to NARC recommendations.

Data collection

Data on growth and yield parameters were systematically recorded from each plot at every harvest. Growth measurements included sward height (cm), leaf length (cm), leaf breadth (cm), the number of leaves per plant, the number of tillers per plant (in case of cereals), and the number of branches per plant (in case of leguminous species). For yield estimation, the fresh weight of the fodder harvested from a one-square-meter sample area in each plot was recorded and then converted to green matter yield per hectare. To determine dry matter content, representative subsamples were oven-dried at a constant temperature of 65°C until a constant weight was achieved. The resulting dry matter percentage was then used to calculate dry matter yield in tons per hectare. In the on-farm trials, the protocol was effective in focusing on the most practical and farmer-relevant metrics, recording only sward height and dry matter yield.

Statistical analysis

All data were analyzed using Analysis of Variance (ANOVA) following RCBD procedures. Significant differences among treatment means were identified at a 5% probability level ($p < 0.05$) with Tukey's Honest Significant Difference Test. Statistical analyses were conducted using GenStat 18th Edition (VSN International, 2015).

RESULTS AND DISCUSSION

On-station experiment

The Khumaltar on-station experiment revealed highly significant differences ($p<0.001$) among winter fodder species and mixtures for growth and yield traits (Table 1). Sole Fodder Oat (cv. Netra) produced the highest ($p<0.001$) biomass among treatments (15.63 t/ha DM) and had the tallest sward and the longest leaves. This aligns with another study that identifies oat as a high-yielding,

reliable winter fodder under mid-hill conditions of Nepal (Pant *et al*., 2022). The rapid vegetative growth and higher tiller production of fodder oat are repeatedly reported as reasons for its strong biomass performance in winter-cut fodder systems (FAO, 2004; Pant *et al*., 2022).

Legumes in the experiment showed variable performance. The Common and Purple vetch produced moderate to high dried fodder biomass (10.81-11.00 t/ha) and had significantly more branching ($p<0.001$) and leaves ($p<0.001$) compared to Berseem and Peas. Such differences among legume species and cultivars are well documented. Vetch tends to grow quickly and branch extensively, which helps produce more herbage mass during winter, while some Pea varieties may be better as protein supplements rather than as bulk fodder producers (Barsila, 2018).

The Oat + Berseem mixture produced a similar ($p>0.05$) DM yield as sole Oat (14.82 t/ha), while Oat + Vetch produced a lower ($p<0.001$) cumulative DM yield (11.85 t/ha). These results align with findings from studies on Oat and legume mixtures, which report that cereal and legume blends often increase fodder nutritive value (higher crude protein, better protein-to-energy balance) while maintaining competitive total DM yields, especially when Oats are combined with legumes adapted to local winter climates (Barsila, 2018; Dangi, 2020). The mixture advantage is also due to complementarity in canopy architecture and nitrogen (N) dynamics. The legumes add N through biological fixation and improve fodder quality, while the cereal provides bulk DM (Barsila, 2018; Dangi, 2020).

For winter feeding in the mid-hills (Lalitpur) and similar environments, sole Oats are most reliable for bulk DM, but Oat + Berseem mixtures offer a practical tradeoff, with slightly less or comparable DM but better fodder protein and system sustainability (reduced inorganic N needs).

In the on-station summer fodder experiment, sole Teosinte (cv. Makaichari-1) and sorghum produced substantial dry matter (16.20 and 13.71 t/ha, respectively), while the Teosinte + Cowpea mixtures yielded the highest ($p<0.001$) dry matter (22.74 t/ha; Table 2). This pattern—higher productivity of Teosinte and significant yield increases when intercropped with legumes—is consistent with other studies that reported Teosinte responds strongly to mixed cropping with legumes, which improves both the quantity and quality of fodders (Devkota *et al*., 2017; Khanal *et al*., 2020). Khanal *et al*. (2020, 2021) also reported that the

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Teosinte + Cowpea combinations produce larger herbage mass and higher crude protein content than Teosinte grown in monoculture.

Table 1. Dry matter yield and its attributes of winter fodders and their combinations in Lalitpur

Fodder	Sward height at first cut (cm)	Leaf length at first cut (cm)	Leaf breadth at first cut (cm)	Number of leaves/plant at first cut	Number of branches or tillers/plant at first cut*	Cumulative Fodder DM yield (t/ha) from three cuts
Fodder Oat cv. Netra	57.53±4.85^{a}	32.50±5.14^{a}	1.23±0.19^{h}	6.12±0.82^{e}	4.60±0.42^{b}	15.63± 1.59^{a}
Berseem cv Green gold	13.61±3.42^{d}	5.00±2.44^{cd}	2.14±0.29^{g}	6.87±0.57^{e}	4.09±0.41^{c}	9.84±0.41^{d}
Berseem cv. Illite II	16.84±0.82^{d}	6.23±5.27^{bc}	2.57±1.08^{fg}	6.67±0.89^{e}	4.12±0.73^{c}	6.86±1.36^{f}
Common vetch cv. Kutilkosa-1	46.02±6.51^{b}	7.51±1.08^{b}	3.29±0.16^{e}	15.04±2.46^{ab}	4.67±1.18^{b}	10.81±0.95^{cd}
Common vetch cv. Black Pod	37.6±5.63^{c}	6.54±1.46^{bc}	2.94±0.42^{ef}	16.00±2.81^{a}	4.65±0.50^{b}	7.22±0.58^{f}
Purple vetch cv. Popany	46±6.56^{b}	6.74±1.59^{bc}	4.60±0.89^{bc}	14.66±2.34^{ab}	6.16±1.56^{a}	11.00±0.98^{bc}
Hairy vetch cv. Capello	62±6.55^{a}	4.63±0.48^{cd}	3.65±0.72^{d}	16.06±2.02^{a}	6.73±1.57^{a}	8.52±1.55^{e}
Saftal clover cv. Majus	46±6.05^{b}	6.46±1.28^{bc}	4.66±1.06^{b}	6.04±1.06^{e}	6.82±1.52^{a}	10.74±0.53^{cd}
Fodder pea cv. AP2	43.5±7.89^{bc}	6.36±0.73^{bc}	3.97±0.48^{cd}	13.46±2.48^{bc}	4.49±0.37^{c}	4.08±0.49^{g}
Garden pea cv. Sikkim local	45.5±4.27^{b}	7.92±1.9^{b}	5.41±0.97^{a}	10.51±2.71^{d}	4.67±0.79^{b}	4.05±0.44^{g}
Oat + Berseem clover cv. Green gold	44.62±6.28^{b}	-	-	-	-	14.82±2.72^{a}
Oat + Common Vetch cv. Kutilkosha-1	46.97±11.74^{b}	-	-	-	-	11.85±0.57^{b}
F-probability	<0.001	<0.001	<0.01	<0.001	<0.05	<0.001

*Number of tillers in case of cereals and number of branches in case of leguminous species.

Sama grass consistently yielded lower fodder dry matter (DM) in the experiment, supporting reports that some small millet-type fodders produce less DM than tall summer grasses (Animasaun *et al*., 2018). Bajra (Nutrifeed 16) and sorghum produced good biomass yields but were inferior in fodder DM yield compared to Teosinte. This result aligns with previous reports indicating that teosinte grows taller and produces more biomass under favorable climate and management

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

conditions (Khanal *et al*., 2020). The Teosinte and Cowpea mixture is recognized as the most promising summer fodder combination for maximizing DM yield in the mid-hill agro-ecologies of Nepal. The result aligns with the findings of Khanal *et al*. (2021), who reported that this mixture performs best when sowing date and fertilizer management are properly optimized.

Table 2. Dry matter yield and its attributes of winter fodders and their combinations in Lalitpur

Fodder	Sward height at first cut (cm)	Leaf length at first cut (cm)	Leaf breadth at first cut (cm)	Number of leaves/ plant at first cut	Number of tillers or branches/ plant at first cut*	Cumulative Fodder DM yield (t/ha) from three cuts
Teosenti cv. Makaichari-1	120.49±17.91^{bc}	67.86±6.71^{a}	4.22±1.32^{ab}	7.51±0.84^{a}b	6.00±0.99^{ab}	16.20±3.60^{c}
Sorghum cv. Green Pearl	160.77±17.48^{a}	63.73±2.50^{a}	4.91±1.07^{a}	6.73±1.32^{b}	5.48±1.24^{b}	13.71±2.67^{d}
Sama grass	60.73±17.83^{e}	23.79±2.53^{b}	3.97±1.06^{b}	6.07±1.37^{b}	5.09±1.22^{b}	7.75±1.37^{f}
Bajra (Nutrifeed 16)	115.87±22.08^{cd}	65.72±7.74^{a}	3.46±0.21^{b}	7.73±0.84^{a}	7.00±1.28^{a}	12.82±1.71^{d}
Teosinte cv. Makaichari-1 + Cowpea (Kartike local)	100.55±16.97^{d}	-	-	-	-	22.74±3.81^{a}
Sorghum cv. Green Pearl + Cowpea (Kartike local)	132.81±18.99^{b}	-	-	-	-	18.29±3.81^{bc}
Bajra (Nutrifeed 16) + Cowpea (Kartike local)	122.46±13.33^{bc}	-	-	-	-	18.81±2.18^{b}
Sama + Cowpea (Kartike local)	65.43±9.91^{e}	-	-	-	-	10.32±1.81^{e}
F-probability	<0.001	<0.001	<0.05	<0.001	<0.01	<0.001

*Number of tillers in case of cereals and number of branches in case of leguminous species.

On-farm experiment

Both winter (Oat + Berseem) and summer (Teosinte + Cowpea) experiments conducted on farmers' fields across four agro-ecological regions showed highly significant location effects ($p<0.001$) on sward height and fodder DM yield. The sward height and fodder DM yield of the Oat + Berseem and Teosinte Cowpea

mixtures across different cuts are shown in Figures 1 and 2, respectively. For the total fodder yield of the Oat + Berseem mixture, Banke (lower elevation) produced the highest ($p<0.001$) cumulative DM yield (14.95 t/ha), followed by Sunsari and Dhading, while Kabhrepalanchowk (higher elevation) recorded the lowest yield (6.18 t/ha; Table 3). These altitudinal and climatic gradients affecting Oat-based mixtures are also well documented in other reports. Oats and related legumes respond to warmer temperatures and longer growing periods in the Terai and lowland plains with increased sward height and higher yields from multiple cuts, whereas higher-elevation sites with cooler temperatures and shorter growing seasons generally produce less cumulative DM (FAO, 2004; Devkota *et al*., 2015; Pant *et al*., 2022). The second-cut increases in sward height at Banke and Sunsari indicate favorable mid-season regrowth related to temperature and soil fertility in these lowland areas (Figure 1). Oat + Berseem is a reliable winter package for the Terai and lower mid-hills, but at higher elevations, it may need adjustments such as later sowing, variety selection, or protected cultivation to reach similar productivity.

The Teosinte + Cowpea package produced the highest cumulative DM yield ($p<0.001$) in the farmers' field in Banke district (27.65 t/ha) during the summer season, and also performed well in Dhading (19.08 t/ha), while Kabhrepalanchowk yielded the lowest (Table 3). The trend was similar to that observed in the winter fodder mixture, indicating that lowland and warmer mid-hill sites favor heat-tolerant, tall summer fodders like Teosinte and Cowpea. Other studies in Nepal also report that Teosinte responds strongly to local climate, with much higher productivity in Terai and lowland regions when combined with legumes (Devkota *et al*., 2017; Khanal *et al*., 2020). The study shows that the Teosinte +Cowpea mixture is especially suitable for summer fodder production in the Terai and lower mid-hills, while cooler highlands may need alternative species or different management practices.

The two-year study across multiple locations demonstrates clear seasonal complementarity in fodder production. Mixtures of cereals and legumes produced superior winter biomass and the highest DM yield during summer as well. These findings support regional research recommendations advocating for location-specific fodder packages and species or variety adjustments to optimize year-round fodder supply (Khanal *et al*., 2020; Devkota *et al*., 2017; Pant *et al*., 2022; FAO, 2004).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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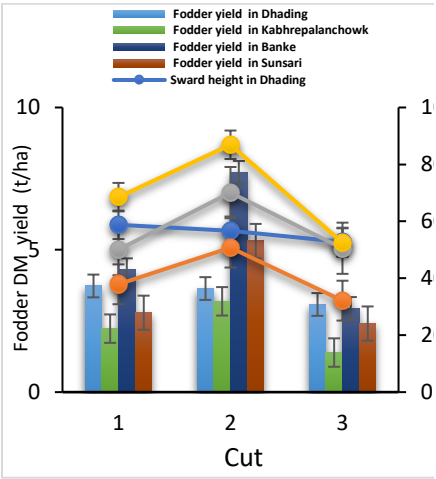

Figure 1. Sward height and fodder DM yield of Oat Berseem mixture for different cuts in the farmer field across different agro-ecological regions

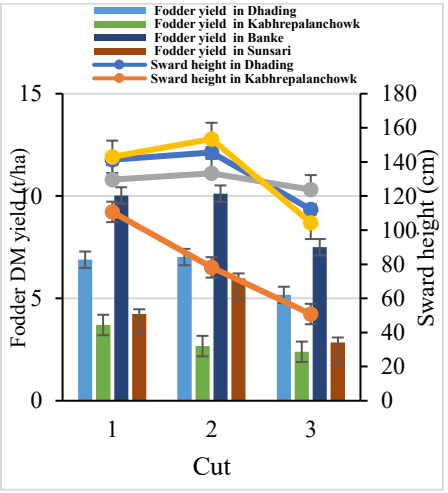

Figure 2. Sward height and fodder DM yield of Teosinte +Cowpea mixture for different cuts in the farmers' field across different agro-ecological regions.

Table 3. Fodder DM yield of Oat Berseem and Teosinte Cowpea mixtures for winter and summer in the farmers' field across different agro-ecological regions

Location	Total fodder DM yield (t/ha)*	
	Winter mixture (Oat + Berseem)	Summer mixture (Teosinte + Cowpea)
Dhading	10.45±1.28^{b}	19.08±1.28^{b}
Kabhrepalanchowk	6.18±0.68^{c}	8.96±2.68^{d}
Banke	14.95±2.96^{a}	27.65±5.06^{a}
Sunsari	11.55±1.88^{b}	13.05±1.88^{c}
F-probability	<0.001	<0.001

*Cumulative yield of three cuts

For winter, the Oat + Berseem mixture is recommended in the Terai and lower mid-hills for combined dry matter and protein benefits. For summer, the Teosinte + Cowpea mixture is best suited for the Terai and warm mid-hills, providing high summer dry matter along with improved nutritional quality in the fodders (Khanal *et al*., 2020; Khanal *et al*., 2021).

CONCLUSION

This study identified the Oat + Berseem mixture as the most suitable winter fodder package and the Teosinte + Cowpea mixture as the best summer package for different agro-ecological regions of Nepal. On-station testing confirmed their high productivity, while the on-farm study showed strong performance in lowland areas like Banke and Sunsari, with moderate yields in mid-hills and lower productivity at higher elevations. These results emphasize the importance of matching species and management practices to local climate conditions.

Adopting these cereal-legume mixtures can help bridge seasonal feed gaps, improve fodder quality, and reduce reliance on crop residues and purchased feeds. Promoting these packages more widely, along with enhancing farmer capacity, ensuring reliable seed supply, and conducting adaptive research, supports sustainable crop-livestock systems and boosts livestock productivity in Nepal.

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Variation in Species Composition and Diversity of Burnt and Unburnt Forest of *Shorea robusta*

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ABSTRACT

Forest fire is a critical ecological process that influences species composition, diversity, and regeneration dynamics. This study analyzes the impact of forest fire on the species composition and diversity of *Shorea robusta* forests in the Chure region of Butwal, Nepal, by comparing burnt and unburnt sites. Burnt areas were identified using historical fire data from ICIMOD and the Department of Forests and Environment. Vegetation was sampled using a systematic random method with 60 circular plots of 10 m, 5 m, and 1 m radii for trees, shrubs, and herbs, respectively. The burnt forest was co-dominated by *Shorea robusta* and *Lagerstroemia parviflora*, with associates including *Terminalia alata* and *Careya arborea*. In contrast, the unburnt forest was dominated by *S. robusta* and *Anogeissus latifolia*, associated with species like *Tectona grandis* and *Mallotus philippensis*. The Shannon-Wiener diversity and Margalef's richness indices were higher in the unburnt forest. However, the average density of *S. robusta* was significantly greater in the burnt forest. The findings suggest that fire plays an essential role in shaping species composition and promoting the density of *Shorea* in these forests, despite a reduction in overall diversity.

Keywords: Chure, disturbance, ecology, regeneration, species composition

INTRODUCTION

Fire is a fundamental ecological process that shapes terrestrial ecosystems worldwide (Cochrane et al., 2009). In South Asia, anthropogenic fires are frequently used as a

management tool to control vegetation growth, promote succession of certain species, and reduce wildfire risk (Bond and Van Wilgen, 1996). These fires significantly alter ecosystem functions including nutrient cycling, grass productivity, and tree recruitment (Bond and Keeley, 2005; Prior et al., 2009). Fire-induced changes in species composition represent a key ecological transformation, with burnt areas typically supporting more herbaceous vegetation due to reduced competition for resources (Keith et al., 2010). This shift reflects the replacement of fire-sensitive species by more tolerant ones through processes such as resprouting, which has been observed to be more prevalent in burnt forests (Marrinan et al., 2005).

The regeneration dynamics following fire are complex and influenced by multiple factors including grazing pressure, trampling, and tree clustering patterns (West et al., 1981). While fires release nutrients that can stimulate seedling establishment and ecosystem development (Pausas et al., 2005), they also create ecological trade-offs. High-intensity fires may damage soil tissues and reduce resprouting capacity, while heat-sensitive seeds in the soil bank may be destroyed (Keeley, 1991). Furthermore, uncontrolled fires can disrupt soil micro-flora and micro-fauna, potentially compromising decomposition processes and soil fertility (Kodandapani, 2001). The relationship between fire and forest dynamics is particularly relevant in tropical regions where tree species diversity shows substantial spatial variation (Pitman et al., 2002). Understanding how fire affects species composition and diversity in these ecosystems remains crucial for effective forest management and conservation.

Shorea robusta is deciduous timber tree endemic to South Asia, occupying about 12 million hectares and in Nepal, it primarily occupies subtropical forest zones of the Terai, Bhabar, and Dun regions, as well as the outer foothills, usually forming extensive, dominant stands (Tewari,1995). This species exhibits high ecological adaptability, occupying deciduous, semi-evergreen, and evergreen forests, influenced by local microclimate, geology, and soil conditions (Mishra et al., 2021). Widely recognized for ecological and economic value in South Asia, *S. robusta* is listed as endangered by the IUCN that supports livelihoods through timber, medicinal products, fodder, fuelwood, leaf-plates, edible seeds, and cultural uses (Kumar and Saikia, 2021). The ICIMOD fire data illustrates Chure forest of Nepal burns yearly although the frequency and intensity of fire varies with years. Therefore, this study was conducted to provide a comparative analysis of burnt and unburnt *Shorea robusta* forests in the Chure region of Butwal, Nepal. The specific objectives were to quantify and compare the species composition and diversity of trees, shrubs, and herbs between the forest stands; to assess the impact of fire on the population structure, density, and basal area of *S. robusta* and its major associated species; and to identify

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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fire-tolerant and fire-intolerant species to inform future forest management and conservation strategies in this critical ecosystem.

MATERIALS AND METHODS

Study area

This study was conducted in the Chure range of Rupandehi district, Nepal. The area lies at an altitude of 500–800 m above sea level, between 27°42'–27°44' N and 83°23'–83°30' E. Two distinct forest sites were selected for comparison: a burnt site, consisting of *Shorea robusta* forest affected by seasonal fires, and an unburnt site located to the north of the burnt area, separated by natural streams. The burnt site was identified based on historical fire data provided by ICIMOD (2020), which documented frequent fire incidents in the region during dry seasons.

Vegetation sampling A systematic random sampling approach was employed to assess vegetation composition and structure. A total of 60 circular quadrats were established across both sites with 30 for each site and approximately 30 m distance between two quadrants. Each quadrat consisted of a 10 m radius plot for trees, nested with a 5 m radius sub-plot for shrubs, and a 1 m radius sub-plot for herbs. Total studied area of brunt and unburnt forest was 188,568 sq meters and 113,140.8 sq meters respectively. Sampling was conducted in October 2020. October months is suitable for post-fire recovery, seedlings growth and sprouts which are easily visible. For all trees and saplings within the quadrats, diameter at breast height (DBH, measured at 1.37 m above ground) was recorded using a DBH tape. Plant species were identified through local names, photographic documentation, and standard taxonomic references (Polunin & Stainton, 1997).

Vegetation analysis

Field data were used to compute frequency, density, basal area, and Importance Value Index (IVI) for tree species following Zobel et al. (1987). Several diversity indices were calculated to compare community structure between sites, including the Shannon-Wiener diversity index, Simpson's dominance index, Berger-Parker dominance index, Margalef's species richness index, Pielou's equitability index, and Beta diversity (Whittaker, 1962).

Statistical analysis

Independent sample t-tests were performed using IBM SPSS Statistics (Version 25) to

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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evaluate significant differences in vegetation parameters—including diameter, basal area, height, and DBH—between burnt and unburnt forests. A significance level of $\alpha = 0.05$ was used for all statistical tests.

RESULTS AND DISCUSSION

Species composition across forest layers

A total of 71 plant species were recorded across the study sites. In the unburnt forest, we documented 22 tree, 19 shrub, and 30 herb species. The burnt forest supported a slightly different composition, with 19 tree, 18 shrub, and 32 herb species. The herb layer in the burnt forest was dominated by *Imperata cylindrica* and *Eranthemum pulchellum*, whereas the unburnt forest was characterized by species such as *Boehmeria platyphylla* and *Dryopteris filix-mas* (Figure 1A).

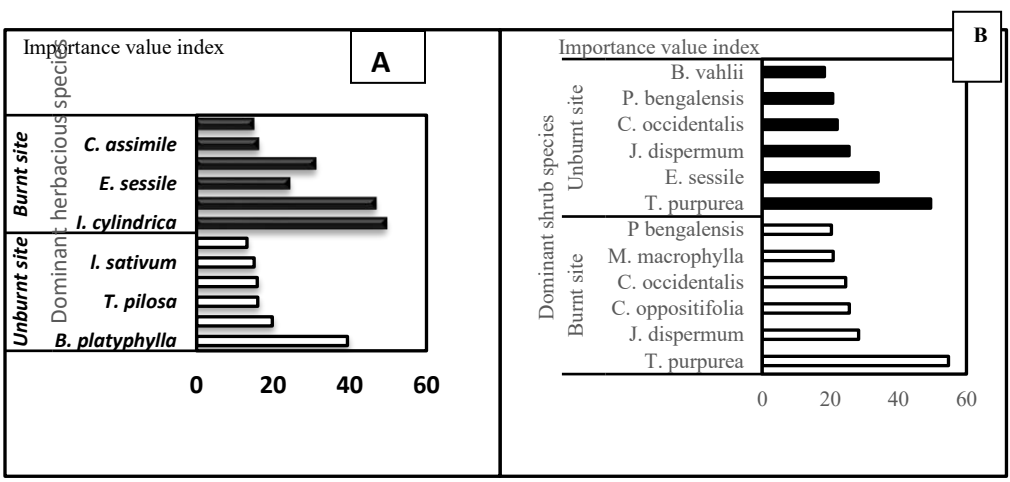

Figure 1. Importance value index of dominant herbaceous (A) and shrub species (B)

Importance Value Index (IVI) in both forest types. Four of the six dominant shrub species were common to both sites (Figure 2). The tree community showed a clear distinction between the forest types. Species such as *Mallotus philippensis*, *Tectona grandis*, and *Ficus semicordata* were recorded exclusively in the unburnt forest. Despite this, *Shorea robusta* was the dominant tree species in both forests, exhibiting the highest IVI (Figure 3).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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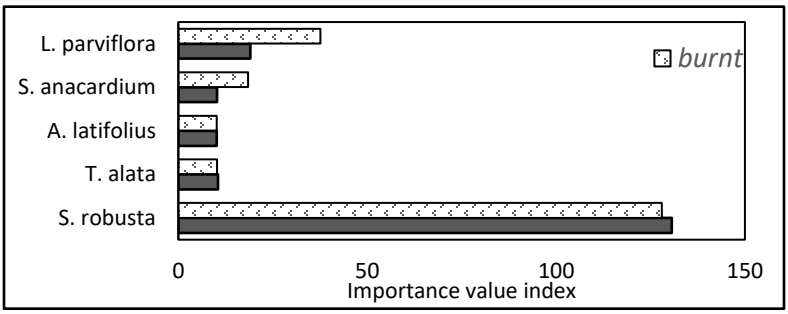

Figure 2. Importance value index of dominant tree species of both burnt and unburnt forest

Forest structure and population characteristics

The structural parameters of dominant tree species differed significantly between the burnt and unburnt forests. The average density of *S. robusta* was substantially higher in the burnt forest (1439.71 individuals/ha) compared to the unburnt forest (504.01 individuals/ha) (Figure 3A). Conversely, the basal area of *S. robusta* was greater in the unburnt forest (2.28 m²/ha) than in the burnt forest (0.80 m²/ha) (Figure 3B). Morphologically, *S. robusta* trees in the unburnt forest were taller (19.16 ± 0.24 m) and had a larger mean DBH (0.41 ± 0.11 m) compared to those in the burnt forest (height: 16.29 ± 0.21 m; DBH: 0.37 ± 0.16 m).

Diversity indices

Analysis of diversity indices revealed notable differences between the two forest conditions. The Shannon-Wiener diversity index was higher in the unburnt forest for both the tree (H = 1.80) and herb (H = 3.11) layers, indicating greater species diversity and evenness. In contrast, the shrub layer exhibited higher diversity in the burnt forest (H = 2.62) (Table 1). A similar pattern was observed for species richness. Margalef's index was higher in the unburnt forest for trees (2.94 vs. 2.34) but was comparable for shrubs and herbs across both sites. The Berger-Parker dominance index was highest for trees in the burnt forest (0.64), reflecting the strong dominance of a few species post-fire. Beta diversity, measuring the turnover of species between the sites, was highest for the tree layer ($\beta = 0.078$) and lowest for shrubs ($\beta = 0.027$), suggesting that fire had the most pronounced effect on tree species composition.

Statistical significance of fire impact

Independent sample t-tests confirmed that fire had a significant effect on key

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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vegetation parameters. The basal area and density of ecologically important species, including *S. robusta*, *Lagerstroemia parviflora*, and *Semecarpus anacardium*, showed highly significant differences ($p < 0.05$) between the burnt and unburnt forests. Furthermore, the DBH and height of *S. robusta* were significantly greater in the unburnt forest ($p < 0.05$) (Table 2).

Table 1. Diversity indices of trees, shrubs and herbs of both burnt and unburnt forests

Life form	Shannon-Wienerindex		Equitability		Concentration of Dominance		Margalef's Species richness		Berger-Parker	
	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt
Trees	1.43	1.80	0.49	1.80	0.44	0.38	2.34	2.94	0.64	0.61
Shrubs	2.62	2.35	0.90	2.35	0.08	0.08	2.44	2.45	0.17	0.18
Herbs	2.41	3.11	0.69	3.11	0.13	0.05	3.81	3.76	0.24	0.09

Table 2. Statistical comparison of structural parameters between burnt and unburnt forests

Parameters	T-value	p-value
Basal Area of *S. robusta*	6.290	0.04
Density of *S. robusta*	6.389	0.03
Basal Area of *L. parviflora*	6.489	0.01
Density of *L. parviflora*	11.41	0.00
Basal Area of *S. anacardium*	6.554	0.00
Density of *S. anacardium*	8.720	0.00
DBH of *S. robusta*	2.68	0.03
Height of *S. robusta*	8.78	0.02

Forest structure and population parameters

Significant structural differences were observed in dominant tree species between the burnt and unburnt forests. The density of *S. robusta* was nearly three times higher in the burnt forest (1439.71 individuals/ha) compared to the unburnt forest (504.01 individuals/ha) (Figure 3A). In contrast, the basal area of *S. robusta* was substantially greater in the unburnt forest (2.28 m^2/ha) than in the burnt forest (0.80 m^2/ha) (Figure 3B). Morphological measurements further revealed significant differences between sites. Trees in the unburnt forest were notably taller (19.16 ± 0.24 m) with larger DBH

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

(0.41 ± 0.11 m) compared to those in the burnt forest (height: 16.29 ± 0.21 m; DBH: 0.37 ± 0.16 m). Statistical analysis confirmed the significant impact of fire on these structural parameters (Table 2). Independent sample t-tests revealed highly significant differences ($p < 0.05$) in both basal area and density for three key species: *S. robusta*, *L. parviflora*, and *S. anacardium*. Additionally, both DBH and height of *S. robusta* showed statistically significant differences between the burnt and unburnt forests,

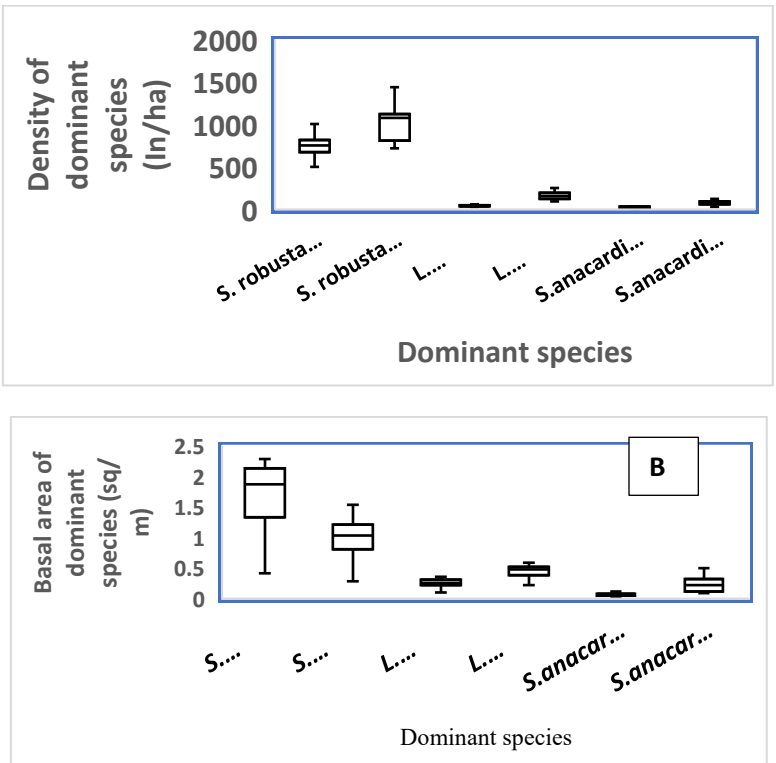

Figure 3. Comparison of densities (A) and basal area (B) of dominant tree species of burnt and unburnt forest. The box plots show the median, and 25 to 75 percentiles. Whiskers indicate maximum and minimum values.

Fire-induced changes in species composition

Results showed distinct shifts in species composition between burnt and unburnt *Shorea robusta* forests. In burnt areas, the tree layer was dominated by *S. robusta*, *Lagerstroemia parviflora*, *Semecarpus anacardium*, and *Cassia fistula*,

with *Terminalia alata*, *Careya arborea*, and *Dalbergia sissoo* as common associates. This pattern aligns with previous studies indicating that mature Sal trees exhibit considerable fire resistance once they surpass the sapling stage (Bakshi, 1957; Kumar & Thakur, 2008). The persistence of *S. robusta* following fire events supports the traditional practice of controlled burning to maintain pure Sal stands and prevent succession toward mixed broadleaved forests (Suman, 1984).

The success of *L. parviflora* in burnt areas can be attributed to its ecological adaptations as a light-demanding, drought-tolerant, and fire-resistant species (Orwa et al., 2009). In the herbaceous layer, the dominance of *Imperata cylindrica* represents a classic fire-climax community, consistent with findings from Brook (1989) and Seth (1970). The species' extensive rhizome system and high root-to-shoot ratio facilitate rapid regeneration following disturbance (Ramakrishnan et al., 1983), explaining its proliferation in frequently burnt areas.

In contrast, unburnt forests supported a more diverse tree community including *Anogeissus latifolia*, *Tectona grandis*, *Mallotus philippensis*, and *Ficus semicordata* alongside *S. robusta*. The herb layer in these undisturbed sites was characterized by moisture-preferring species such as *Boehmeria platyphylla* (Maithani et al., 1986), reflecting the more stable microclimatic conditions.

Impacts on diversity patterns

Results demonstrated reduced overall diversity in burnt forests compared to unburnt areas, particularly evident in tree and herb layers. This finding corroborates studies from various ecosystems including tropical deciduous forests in Thailand (Kafle, 2006), mixed conifer forests in California (Collins & Stephens, 2010), and juniper forests in Mexico (Harner & Harper, 1976). The observed Shannon diversity indices (1.43-3.76) fall within the range reported for similar tropical dry forests (Reddy et al., 2008; Pandey, 1992).What was their range?- Exact range was not mentioned in paper

The reduction in species richness following fire disturbance can be attributed to the elimination of early successional species that become shaded out by rapidly growing woody resprouts (Miller, 2000). However, the higher shrub diversity in burnt areas suggests variable responses across life forms, possibly due to reduced competition and increased light availability (Keith et al., 2010). This pattern of differential response across vegetation layers underscores the complex nature of fire impacts on forest ecosystems.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Structural modifications and population dynamics

Significant structural differences were observed between treatment areas, with unburnt forests supporting taller trees (19.16 ± 0.24 m) with greater DBH (0.41 ± 0.11 m) compared to burnt forests (16.29 ± 0.21 m height; 0.37 ± 0.16 m DBH). These findings support previous research by Trapnell (1959), Strang (1974), and Gandiwa (2006), indicating that repeated burning negatively affects woody plant development through top-kill and subsequent resp routing (Enslin et al., 2000; Gandiwa & Kativu, 2009).

The differential response of species to fire was particularly evident in density patterns. While fire-intolerant species like *M. philippensis* and *F. semicordata* were absent from burnt areas, fire-adapted species including *L. parviflora* and *S. anacardium* showed increased abundance. This species replacement phenomenon illustrates the filtering effect of fire on community assembly, favoring traits such as resp routing capacity and heat-resistant bark.

The significantly higher basal area in unburnt forests (2.28 m²/ha vs 0.80 m²/ha for *S. robusta*) reflects the cumulative impact of fire-free growth periods. The reduction in basal area in frequently burnt areas results from the conversion of large-stemmed individuals to multi-stemmed coppices following top-kill events (Enslin et al., 2000).

CONCLUSION

In conclusion, burnt Forest acts as an important role in management of densities *Shorea* forests. Fire is one of the major disturbances causes unbelievable loss of forest, however, fire has been considered to play positive role to stimulate fire tolerate species. Therefore, regular monitoring of this forest is necessary to manage *Shorea* and maintaining species diversity of the area as well.

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An Estimation of Greenhouse Gas Emission from Livestock in Nepal

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ABSTRACT

This study estimates and projects livestock-related greenhouse gas (GHG) emissions in Nepal between 2002 and 2022, providing crucial insights for climate change mitigation strategies. The latest secondary data on livestock population was collected from the Ministry of Agriculture and Livestock Development (MoALD) Nepal. The IPCC tier 1 methods were used to estimate emissions and forecast future trends. Studies reveal that Nepal livestock-related GHG emissions reached 28,603Gg CO_2 e /year in 2022,with buffalo accounting for 39 % of the total emissions followed by cattle and goats. In 2022, the primary sources of emissions were direct nitrous oxide (48.2%), enteric methane (44.7%), manure methane (4.5%), and indirect nitrous oxide (0.6%). Future projections indicate a potential increase in total GHG emissions by 3.06 % and 3.56% up to 2050, suggesting a growing environmental impact if current practices continue. The provincial (regional) analysis identified Koshi province as the highest emitter in 2022. This research underscores the need for effective management strategies to mitigate emissions from the livestock sector in Nepal. Further, it also recommends transitioning to the IPCC Tier 2 approach when sufficient national-level data becomes available to enhance the accuracy of future inventories.

Keywords: Climate change, enteric methane fermentation, greenhouse gas, manure methane, nitrous oxide

INTRODUCTION

Climate change is a major global challenge, and although Nepal contributes less than 0.1% of global emissions, it faces severe impacts (Herrero et al., 2016). Globally, livestock accounts for 14.5% of total GHG emissions, mainly from ruminants (Gerber

et al., 2013). Major GHGs include CO_2, CH_4, N_2O, and CFCs, with CO_2 emissions from cattle considered negligible (IPCC, 2001). Methane, contributing about 15% to global warming, is mainly produced through enteric fermentation and manure management in livestock (IPCC, 2001; Wu et al., 2024). Methane has a lifespan of 12.4 years and a global warming potential 28 times that of CO_2 over 100 years (Balcombe et al., 2018). Improper manure management, such as anaerobic storage, can further increase methane emissions.

Livestock also contributes nearly two-thirds of anthropogenic N_2O emissions and 75–80% of agricultural N_2O, which is expected to rise (FAO, 2006). In Nepal, livestock contributes 24.01% to the national GDP (MoALD, 2023). Nepal ranked 10th on the 2021 Global Climate Risk Index and could lose 2.2% of GDP annually due to climate change by 2050 (German watch, 2021; Asian Development Bank, 2021). Historical warming in Nepal between 1900–1917 and 2000–2017 was estimated at 1.0–1.3°C (World Bank, 2021).Within Nepal's agriculture sector, 54% of emissions were from enteric fermentation in 2014 (USAID, 2019). Total livestock emissions rose from 12,308 Gg CO_2-eq in 2001 to 17,665 Gg CO_2-eq in 2011 (MoFE, 2021). Country-specific enteric methane emission factors for cattle were 33 ± 7 kg CH_4/head/year for local crossbreeds and 46 ± 9 kg CH_4/head/year for international crossbreeds (Thakuri et al., 2020). Annually, Nepal produces 42,312 metric tons of CH_4, primarily from cattle (52.23%) and buffalo (36.35%) (Upreti et al., 2018).Manure is also an important source of methane, contributing about 9.3 Tg per year globally (Scheehle & Kruger, 2006). In India, enteric fermentation contributes roughly 91% of livestock methane emissions, with dairy buffalo and indigenous cattle responsible for 60% of the total (Chhabra et al., 2012). China has shown a decline in livestock-related GHG emissions from 2002–2020 due to improvements in efficiency and economic factors, and future strategies aim to promote low-carbon livestock systems (He et al., 2023). In contrast, GHG emissions in Bangladesh have increased, with methane making up the majority and enteric fermentation accounting for about 80% of emissions (Jahan, Abdul & Azad, 2013). Large ruminants can produce 200–500 liters of methane per day, and small ruminants 20–40 liters (Abdulrahman, 2020). Mitigation options include improved manure management, better feed efficiency, and optimized husbandry and genetics.

Across Asia, agriculture is increasingly affected by climate change, and Nepal faces similar challenges. Livestock are a major source of the country's GHG emissions, primarily through enteric fermentation and manure management. Accurate estimation of these emissions is crucial for understanding environmental impacts and planning

mitigation measures. Although the Ministry of Forests and Environment has been assigned to prepare Nepal's National GHG Inventory, the work has not yet begun. The goal of this study is to estimate GHG emissions from Nepal's livestock sector using the Tier 1 method. The findings will support the development of country-specific emission factors, enhance national GHG reporting, and guide climate mitigation efforts for a more sustainable livestock sector.

MATERIALS AND METHODS

Study area

GHG emission was assessed for the whole nation, Nepal, using the recent animal population as reported by the MoALD (2023) census.

Data Collection

Population data from 2002 to 2022 were used for this study were obtained from the MoALD (2023) livestock census. The main livestock categories in Nepal include cattle, buffalo, goats, sheep, pigs, and poultry.

Calculations

The IPCC Tier 1 approach was used to estimate GHG emissions. The IPCC (2006) guidelines provided the necessary parameters, including nitrogen excretion rates, emission factors for enteric fermentation and manure management, manure management systems, direct and indirect N_2O emission factors, live animal weights, and nitrogen volatilization rates. Emission factors for the warm climatic zone were applied in the analysis. Methane and nitrous oxide emissions were converted to CO_2 equivalents using global warming potentials of 25 and 298, respectively. Statistical analysis was conducted to assess long-term trends in livestock populations over the past 20 years across major categories at the national level. All calculations and analyses were performed in Excel.

Enteric methane emission

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

The enteric CH_4 emission of ruminants was calculated according to the following equation (Dong *et al.*, 2006).

$$\mathbf{CH_{4\ Enteric}} = \sum_T \frac{\mathbf{N_{(T)} * EF_{(E,T)}}}{\mathbf{10^6}} * \mathbf{25}, \frac{\mathbf{Gg}}{\mathbf{year}} \mathbf{Co_2e}$$

Where,$CH_{4\ Enteric}$ = the total CH_4 emissions for enteric fermentation of ruminants, Gg/yearCO_2e, N_T = the heads of livestock species/category T in the country, $EF_{(E,\ T)}$ = emission factor for the enteric fermentation of the livestock category "T," kg CH_4/head/year. The default $EF_{(E,\ T)}$ values for different livestock categories are presented in Table 1, according to the IPCC.

Table 1. Methane emission factors and nitrogen excretion rate of different livestock categories

Parameters	Livestock species/category (T)						
	Dairy cattle	Other cattle	Buffalo	Goat	Sheep	Poultry	Pig
$EF_{(E,T)}$	58	27	55	5	5		1
$EF_{(M,T)}$	5	2	5	0.22	0.2	0.02	6
LW	275	110	295	30	28	1.5	28
Nex	0.47	0.34	0.32	1.37	1.17	0.82	0.4

Source: U.S. Environmental Protection Agency (2006**)**

EF= enteric methane emission factor (kg/head/year CH4); $EF_{(M,T)=}$ methane emission factor for manure management (kg/head/year CH4); Nex = nitrogen excretion in manure of different livestock categories (kg/1,000 kg animal mass/day), LW= live weigh**t.**

Methane emission from the manure of animals

The manure management that contributes to CH_4 emission was calculated by the equation (Dong *et al.*, 2006):

$$\mathbf{CH_{4\ Manure}} = \sum_T \frac{\mathbf{N_{(T)} \times EF_{(M,T)}}}{\mathbf{10^6}} \times \mathbf{25}, \frac{\mathbf{Gg}}{\mathbf{year}} \mathbf{Co_2e}$$

.

where, $CH_{4\ Manure}$ – total CH_4 emissions from the different manure management systems of different livestock categories, Gg/year CO_2e; $EF_{(M,T)}$ – the emission factor of CH_4 for the manure management systems of varying livestock categories "T," kg CH_4/head/year; and N_T – heads of livestock species/category "T."

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Nitrous oxide emission

The direct N_2O emission was calculated by the equation (Dong *et al.*, 2006):

$$\mathbf{N_2O_{D(mm)}} = \sum_S\left[\left\{\sum_T\left(\mathbf{N_T} \times \mathbf{N_{ex(T)}} \times \mathbf{MS_{S,T}}\right)\right\} \times \mathbf{EF_{3(S)}}\right] \times \mathbf{298} \times \frac{\mathbf{44}}{\mathbf{28}} \times \frac{\mathbf{1}}{\mathbf{10^6}} \frac{\mathbf{Gg}}{\mathbf{year}}\ \mathbf{CO_2e}$$

where, $N_2O_{D(mm)}$ – total direct N_2O emission for the different manure management systems of different livestock categories (kg/year); $N_{(T)}$ – heads of livestock species/category "T;" $N_{ex(T)}$ – average nitrogen excretion rate of different livestock species/categories "T," kg/head/year; $MS_{(S,T)}$ – the proportion of manure managed by a manure management system "S," dimensionless; $EF_{3(S)}$ – direct N_2O-N emission factor from a manure management system "S," kg/kg N; S – manure management system; and 44/28 – conversion of N_2O-N to N_2O.

The default manure management systems ($MS_{S,T}$) and their emission factors (EF_3) are presented in Table 2 and default live weight of different livestock and N_{ex} values for Asia in Table 1 (Eggleston *et al.*, 2006). The manure management systems of goats, sheep, and poultry were taken as reported by Huque *et al.* (2017).

The indirect N_2O emission

The indirect N_2O emission was calculated by the equation (Dong *et al.*, 2006):

$$\mathbf{N_2O_{G(mm)}} = \sum_T\left(\mathbf{N_{Volatalization-MMS(T)}} \times\ \mathbf{EF_4} \times \mathbf{298} \times \frac{\mathbf{44}}{\mathbf{28}} \times \frac{\mathbf{1}}{\mathbf{10^6}}\right) \frac{\mathbf{Gg}}{\mathbf{year}}\ \mathbf{CO_2e}$$

, where,$N_2O_{G(mm)}$ – total indirect N_2O emission from different manure management of livestock, Gg/year CO_2e; $N_{Volatilizations\ -MM\ S(T)}$ – the loss of manure nitrogen of a livestock species/category "T," kg/year; EF_4 – N_2O emission factor for the deposition of nitrogen on soils and water surfaces, kg N_2O-N/kg NH_3-N and NO_x-N volatilized; and 44/28 – conversion of N_2O-N to N_2O emission.

The $N_{volatilizations\text{-}MMS(T)}$ was calculated by the following equation (Dong *et al.*, 2006):

$$\mathbf{N_{Volatalization-MMS(T)}} = \sum_S\left[\sum_T\left(\mathbf{N_T} \times\ \mathbf{N_{ex(T)}} \times \mathbf{MS_{S,T}}\right) \times \left(\frac{\mathbf{Frac_{GasMS}}}{\mathbf{100}}\right)\right] \frac{\mathbf{kg}}{\mathbf{year}}$$

where, $N_{(T)}$ – heads of livestock species/category "T;" $N_{ex(T)}$ – nitrogen excretion of a livestock species/category "T," kg/head/year; $MS_{(T,S)}$ – proportion of manure under a

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

manure management system "S," dimensionless; and $Frac_{GasMS}$ – the proportion of manure nitrogen of a livestock category "T" that volatilizes as NH_3 and NO_x under a manure management system "S" (%). The default values of EF_4 and $Frac_{GasMS}$ are presented in Table 2 and Table 3.

Table 2. Manure management system (%) and their N2 O-N emission factors

Manure management system (MS, %)	Livestock species/category							EF3	EF 4
	Dairy cattle	Other cattle	Buffalo	Sheep	Goat	Poultry	Pig		
Uncovered anaerobic lagoon	0	0	0	0	0	0	9	0	0.01
Liquid/slurry	1	1	0	0	0	0	22	0	0.01
Solid storage	0	0	0	100	100	0	16	0.005	0.01
Dry lot	0	4	4	0	0	0	30	0.02	0.01
Pasture	27	22	19	0	0	0	0	0.02	0.01
Daily spread	19	20	21	0	0	0	9	0	0.01
Anaerobic digester	1	1	1	0	0	25.5	8	0	0.01
Burn for fuel	51	53	55	0	0	0	0	0	0.01
Pit storage	0-	0-	0-	0	0	0	3	0.002	0.01
Poultry manure (without litter)	0-	0-	0-	0	0	74.4	0	0.001	0.01
Others	0	0	0	0	0	0	3	-	0.01

Source: 2006 (IPCC) Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management.

EF3 = direct N2O-N emission factor (kg/kg nitrogen excreted); EF4 = indirect N2O-N emission factor (kg N2O-N/kg NH3-N and NOx-N volatilized); and - = not reported.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 3. Default values of nitrogen volatilization in different manure management system usages

Manure management systems	FracGasMS (%)						
	Dairy cattle	Other cattle	Buffalo	Sheep	Goat	Poultry	Pig
Uncovered anaerobic lagoon	35	-	-	-	-	40	40
Liquid/slurry	40	-	-	-	-	-	48
Solid storage	30	45	-	12	12	-	45
Dry lot	20	30	-	-	-	-	
Daily spread	7	-	-	-	-	-	
Pit storage	28	-	-	-	-	-	25
Poultry manure (without litter)	-	-	-	-	-	55	
Poultry manure (with litter)	-	-	-	-	-	40	

Source: IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management.

RESULTS AND DISCUSSION

Methane emission from livestock

Tables 4 and 5 present the GHG emissions from different livestock categories through enteric fermentation and manure management. Between 2002 and 2022, buffalo contributed the highest methane emissions, followed by other cattle, goats, milking cattle, pigs, sheep, and poultry. In 2022, total emissions from enteric fermentation and manure management were estimated at 14,892 Gg CO_2e /year and 1,444 Gg CO_2e /year, respectively.

Nitrous Oxide Emission in Nepal

Table 8 presents total N_2O emissions from different livestock categories. Between 2002 and 2019, buffalo contributed the highest direct N_2O emissions from manure management, but after 2019, goats became the largest direct N_2O emitters, followed by buffalo, cattle, poultry, and sheep. Indirect N_2O emissions were highest in goats, followed by poultry, pigs, sheep, and cattle, while buffalo had zero indirect emissions. In 2022, total N_2O emissions from all livestock were 15,582 Gg CO_2e/year, with 15,582 Gg CO_2e/year from direct and 198.2 Gg CO_2e/year from indirect emissions (Tables 6-8).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 4. Enteric methane emission from different livestock categories

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Total
2002	1237	4135	5089	105	826	23	11414
2003	1262	4106	5280	104	849	23	11624
2004	1288	4103	5435	103	872	23	11824
2005	1308	4112	5612	102	894	24	12053
2006	1310	4117	5782	102	928	24	12262
2007	1318	4142	6004	102	981	25	12571
2008	1327	4168	6183	101	1017	25	12822
2009	1353	4214	6436	100	1059	26	13188
2010	1384	4215	6651	100	1106	27	13483
2011	1412	4220	6866	101	1148	28	13775
2012	1448	4216	7058	101	1189	28	14041
2013	1487	4218	7208	101	1223	29	14266
2014	1486	4198	7121	99	1272	30	14205
2015	1488	4196	7106	99	1281	30	14199
2016	1488	4237	7107	100	1373	32	14337
2017	1493	4265	7120	100	1396	33	14406
2018	1507	4277	7257	100	1456	36	14634
2019	1564	4257	7299	100	1535	37	14793
2020	1691	4248	7229	101	1601	38	14908
2021	1753	4224	7095	99	1680	40	14891
2022	1773	4178	7058	96	1749	38	14892

FracGasMS = percentage of nitrogen volatilization from managed manure of different livestock categories in different manure management systems; and - = not reported

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 5. Manure methane emission from different livestock categories

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	107	306	463	4.2	36.3	140	10.7	1067
2003	109	304	480	4.1	37.4	140	11.1	1085
2004	111	304	494	4.1	38.4	140	11.5	1103
2005	113	305	510	4.1	39.3	142	11.4	1125
2006	113	305	526	4.1	40.8	144	11.6	1144
2007	114	307	546	4.1	43.2	148	12.0	1174
2008	114	309	562	4.0	44.7	152	12.3	1198
2009	117	312	585	4.0	46.6	157	12.2	1233
2010	119	312	605	4.0	48.6	160	12.9	1261
2011	122	313	624	4.0	50.5	166	20.0	1299
2012	125	312	642	4.0	52.3	171	22.6	1328
2013	128	312	655	4.0	53.8	174	24.0	1352
2014	128	311	647	3.9	56.0	179	24.0	1349
2015	128	311	646	3.9	56.4	180	25.1	1351
2016	128	314	646	4.0	60.4	194	34.3	1381
2017	129	316	647	4.0	61.4	199	35.0	1391
2018	130	317	660	4.0	64.1	215	36.1	1426
2019	135	315	664	4.0	67.6	223	37.9	1446
2020	146	315	657	4.0	70.5	228	41.3	1461
2021	151	313	645	4.0	73.9	238	36.7	1462
2022	153	310	642	3.9	76.9	226	33.4	1444

Greenhouse gas emission

The estimated GHG emissions from livestock in Nepal for 2022 totaled 28,630 Gg CO_2e, with buffalo contributing the highest share (39%), followed by other cattle (21%), goats (23.7%), dairy cattle (10.9%), poultry (3.8%), pigs (2.8%), and sheep (1.5%). The contribution by emission type was 46.7% from enteric methane, 4.5% from manure methane, 48.2% from direct nitrous oxide, and 0.6% from indirect nitrous oxide. The provincial GHG emissions from livestock in Nepal in 2022 showed that Koshi province had the highest contribution (6,626 Gg CO2e), followed by Lumbini

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

(6,194 Gg), Bagmati (5,581 Gg), Madhesh (4,993 Gg),Sudurpaschim (3,273 Gg), Gandaki (2,853 Gg), and Karnali (2,399 Gg) .

Table 6. Indirect Nitrous oxide emission from different livestock categories

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	3.3	4.7	0	5.6	55.7	5.0	18.4	92.7
2003	3.3	4.7	0	5.6	57.3	5.0	19.2	95.0
2004	3.4	4.7	0	5.5	58.8	5.0	19.8	97.3
2005	3.4	4.7	0	5.5	60.3	5.1	19.6	98.6
2006	3.5	4.7	0	5.5	62.6	5.1	20.0	101.3
2007	3.5	4.7	0	5.5	66.2	5.3	20.6	105.7
2008	3.5	4.7	0	5.4	68.6	5.4	21.2	108.9
2009	3.6	4.8	0	5.4	71.4	5.6	21.1	111.9
2010	3.6	4.8	0	5.4	74.6	5.7	22.2	116.3
2011	3.7	4.8	0	5.4	77.4	5.9	34.5	131.8
2012	3.8	4.8	0	5.4	80.2	6.1	38.9	139.2
2013	3.9	4.8	0	5.4	82.5	6.2	41.3	144.2
2014	3.9	4.8	0	5.3	85.8	6.4	41.4	147.6
2015	3.9	4.8	0	5.3	86.4	6.4	43.2	150.1
2016	3.9	4.8	0	5.4	92.6	6.9	59.1	172.8
2017	3.9	4.8	0	5.4	94.1	7.1	60.3	175.7
2018	4.0	4.9	0	5.4	98.2	7.7	62.2	182.3
2019	4.1	4.8	0	5.4	103.6	8.0	65.2	191.1
2020	4.5	4.8	0	5.4	108.0	8.1	71.2	202.0
2021	4.6	4.8	0	5.3	113.3	8.5	63.2	199.8
2022	4.7	4.7	0	5.2	117.9	8.1	57.5	198.2

Table 7. Direct Nitrous oxide emission from different livestock categories

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	1063	2254	3404	268	2646	122	261	10018
2003	1085	2239	3532	264	2720	122	271	10233
2004	1107	2237	3635	263	2795	122	281	10441
2005	1125	2242	3754	261	2864	124	278	10648
2006	1126	2245	3867	259	2972	126	283	10878

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

2007	1133	2258	4016	260	3142	130	292	11230
2008	1141	2273	4135	258	3258	133	301	11499
2009	1163	2297	4305	256	3393	137	299	11849
2010	1190	2298	4449	256	3541	139	314	12188
2011	1214	2301	4593	257	3678	145	488	12676
2012	1245	2299	4721	258	3809	149	551	13032
2013	1279	2300	4821	258	3919	152	585	13313
2014	1277	2289	4763	252	4075	156	586	13398
2015	1279	2288	4753	252	4105	158	612	13446
2016	1279	2310	4754	256	4399	169	837	14004
2017	1283	2325	4762	256	4471	174	854	14125
2018	1296	2332	4854	256	4664	188	881	14470
2019	1345	2321	4882	255	4919	195	923	14840
2020	1454	2316	4835	257	5130	199	1007	15199
2021	1507	2303	4746	253	5383	208	895	15295
2022	1525	2278	4721	246	5602	197	815	15384

Table 8. Total Nitrous oxide emission from different livestock categories (Gg/year CO_2e)

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	1066	2259	3404	274	2701	127	279	10111
2003	1089	2243	3532	270	2777	127	291	10328
2004	1111	2242	3635	269	2854	127	301	10538
2005	1128	2247	3754	266	2925	129	298	10746
2006	1130	2249	3867	265	3034	131	303	10979
2007	1136	2263	4016	265	3209	135	312	11336
2008	1145	2277	4135	264	3326	138	322	11608
2009	1167	2302	4305	262	3464	142	320	11961
2010	1194	2303	4449	261	3616	145	336	12304
2011	1218	2306	4593	262	3756	151	522	12808
2012	1249	2303	4721	263	3889	155	590	13171
2013	1282	2304	4821	264	4001	158	626	13457
2014	1281	2294	4763	257	4161	162	628	13546

2015	1283	2292	4753	257	4191	164	655	13596
2016	1283	2315	4754	261	4492	176	896	14176
2017	1287	2330	4762	261	4565	181	914	14301
2018	1300	2337	4854	261	4762	196	943	14653
2019	1349	2326	4882	260	5022	203	988	15031
2020	1458	2321	4835	263	5238	207	1078	15401
2021	1512	2308	4746	259	5496	217	958	15495
2022	1529	2283	4721	251	5720	205	872	15582

Table 9. Total Greenhouse gas emissions from different livestock categories (Gg/year CO_2e)

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	2410	2410	8955	383	3563	291	290	18301
2003	2460	2460	9292	378	3663	290	302	18844
2004	2510	2510	9564	376	3765	291	312	19327
2005	2549	2549	9876	372	3858	295	309	19809
2006	2552	2552	10175	370	4003	299	315	20267
2007	2568	2568	10566	371	4233	308	324	20937
2008	2586	2586	10880	369	4388	315	334	21460
2009	2636	2636	11325	366	4570	325	332	22190
2010	2697	2697	11704	365	4770	331	349	22915
2011	2752	2752	12083	367	4955	345	542	23797
2012	2823	2823	12421	368	5131	354	612	24531
2013	2898	2898	12684	369	5278	361	650	25138
2014	2895	2895	12531	360	5489	370	652	25192
2015	2899	2899	12504	360	5529	375	680	25246
2016	2899	2899	12507	365	5925	402	930	25928
2017	2909	2909	12529	366	6022	413	949	26097
2018	2937	2937	12771	365	6282	447	979	26718
2019	3048	3048	12845	364	6625	463	1026	27421
2020	3295	3295	12722	367	6910	473	1120	28182

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

2021	3416	3416	12486	362	7250	495	995	28420
2022	3456	3456	12420	352	7546	468	906	28603

Future Trend of GHG in Nepal

An emission trend has been estimated up to 2050 for Nepal (Table 11). The rate of increase in annual total GHG emissions from 2002 to 2008 was 2.24% (22,592 and 25,628 Gg/year, respectively). There is a decline in GHG emissions from the year 2008-2018 by 1.98% and from 2018-2022 by 0.79%. The rate of total GHG emissions may increase to 2.77%, 3.06%, and 3.56% in the next three decades (2030–2050).

Table 10. GHG emissions from different livestock categories in different provinces of Nepal for the year 2022 *(Gg/year CO_2e)*

Provinces	Dairy cattle	Other cattle	Buffalo	Sheep	Goat	Poultry	Pig	Total
Koshi	959	1859	2029	26	1456	108	189	6626
Madhesh	554	1249	2119	3	954	81	32	4993
Bagmati	516	992	2134	41	1399	447	52	5581
Gandaki	226	280	1175	42	997	81	53	2853
Lumbini	540	1028	2975	60	1350	126	115	6194
Karnali	208	451	733	139	833	22	13	2399
Sudurpaschim	453	912	1255	43	557	40	14	3273

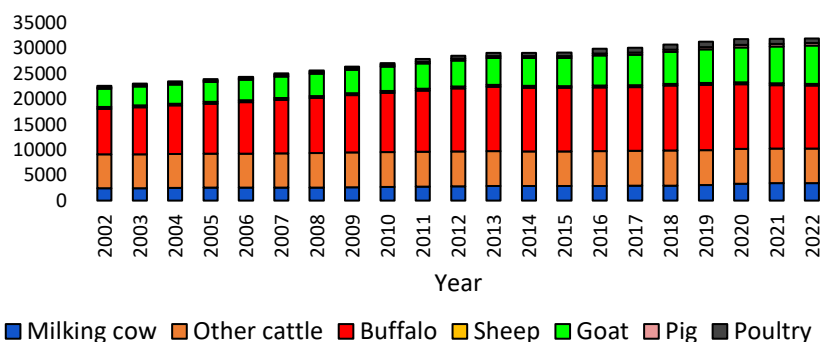

Figure 3. Total greenhouse gas emissions from livestock categories in Nepal (Gg/year CO_2e)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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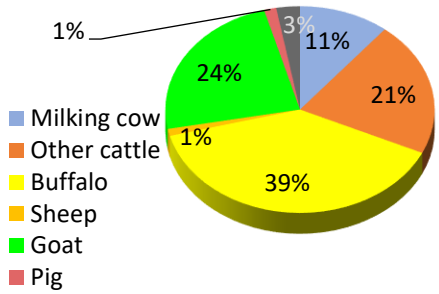

Figure 2. Share of Livestock categories in GHG emission (% CO_2e) in 2022

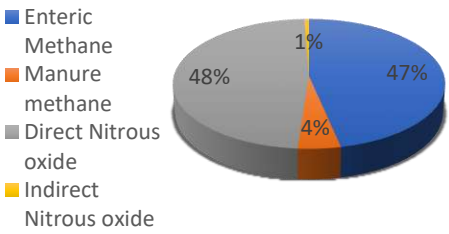

Figure 3. Share of different gases in the total GHG emission (% CO_2e) in 2022.

Table 11. GHG emissions and emission trends from different livestock categories *(Gg/year CO_2e)*

Year	2002	2008	2018	2022	2030	2040	2050
Dairy cattle	2410	2586	2937	3456	4067	4950	6025
Other Cattle	6700	6754	6931	6771	6799	6835	6871
Buffalo	8955	10880	12771	12420	14375	17156	20476
Sheep	383	369	365	352	340	326	313
Goat	3563	4388	6282	7546	11084	17278	26933
Poultry	290	334	979	906	1747	3604	7436
Pig	291	315	447	468	586	764	998
Total	22592	25628	30712	31918	38999	50915	69051
Increase		2.24	1.98	0.79	2.77	3.06	3.56

This study identified buffalo as the largest contributor to methane and GHG emissions in Nepal, reflecting the country's reliance on buffalo for dairy and meat, consistent with Bajagai (2012). While Upreti et al. (2080) reported cattle (52.2%) and buffalo (36.35%) as the main CH_4 emitters, our findings show buffalo as the highest emitter, likely due to methodological differences and Nepal's larger buffalo population. Goats and cattle are the next significant sources, similar to patterns in Bangladesh, where goats later became the leading emitters (Das et al., 2020). Nepal's annual GHG increase from livestock (2008–2018) was 1.98%, higher than Bangladesh (1.16%) and India (0.92%) (Das et al., 2020; FAO, 2021). Although total GHG emissions in Bangladesh (66,586 Gg CO_2e/year) exceed Nepal's, the difference reflects livestock

population disparities. Direct N_2O emissions (48%) dominate in Nepal due to unmanaged manure, contrasting with Europe's lower proportions (FAO, 2021). Regionally, Koshi, Lumbini, and Bagmati provinces contributed most to emissions due to high livestock density, mirroring trends in northern India and Southeast China (FAO, 2020). In 2022, enteric fermentation accounted for 47% of emissions, while direct N_2O led at 48%, a shift from 2014 (USAID, 2019) likely caused by poor manure management. Projected GHG growth in Nepal (2.77–3.56% per decade) aligns with global trends of rising emissions in developing countries due to increasing livestock demand (Herrero et al., 2016; FAO, 2023). Opportunities exist for mitigation through improved manure management, livestock feeding, and adoption of IPCC Tier 2 approaches for more accurate assessments.

CONCLUSION

Using the IPCC Tier 1 approach, the total GHG emissions from Nepal's livestock were estimated at 28,603 Gg CO2e in 2022. The contributions of enteric CH4, manure CH4, direct N2O, and indirect N2O to total emissions were 47%, 4%, 48%, and 1%, respectively. Projected GHG emissions are expected to increase at rates of 3.06% and 3.56% per year up to 2050. At the provincial level, Koshi province contributed the highest emissions (6,626 Gg CO2e), followed by Lumbini (6,194), Bagmati (5,581), Madhesh (4,993), Sudurpaschim (3,273), Gandaki (2,853), and Karnali (2,399). Developing country-specific emission factors is essential for accurately estimating GHG emissions from the livestock sector.

SUGGESTIONS

In Nepal, strategies such as extended lactation, improved nutrition, and genetic selection can reduce emissions. Implementing a robust monitoring system will help track livestock emissions and integrate mitigation measures into national climate policies. Farmer training on sustainable practices, including efficient feeding and manure management, is vital. Advanced manure management methods, such as anaerobic digestion, can capture methane for biogas production, reducing environmental impact and providing energy. These measures will support Nepal in addressing livestock emissions and achieving global climate goals, while further research on livestock GHG emissions is recommended.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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EXTENDED SPECTRUM BETA LACTAMASES (ESBL) PRODUCING *SALMONELLA* ISOLATED FROM RAW GOAT MEAT AND WATER FROM SLAUGHTERHOUSES IN CHITWAN, NEPAL

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ABSTRACT

Salmonella contamination in raw meat and water used in slaughterhouses poses a significant health risk, particularly with strains producing Extended Spectrum Beta-Lactamases (ESBL). This study aims to determine the prevalence of *Salmonella* and its ESBL activity in raw goat meat and water used in slaughterhouses, examining risk factors associated with contamination. In this cross-sectional study conducted between November 2022 and January 2023, a total of 50 raw goat meat and 50 water samples were collected from slaughterhouses in Bharatpur Metropolitan city, Nepal. Microbiological and biochemical techniques were used to identify *Salmonella* isolates, and ESBL production was confirmed by combined disc test. Risk factors, including slaughterhouse type, water quality, and cleaning practices, were analyzed using chi-square tests. *Salmonella* was isolated from 8% of meat and 44% of water samples. Among Salmonella-positive samples, ESBL activity was observed in 50% of meat and 40.9% of water samples. Significant associations were found between Salmonella presence and risk factors such as open slaughterhouse type, direct cash transactions, use of non-potable water, and lack of regular cleaning ($p < 0.05$ for each).The findings underscore the need for improved sanitation, regular cleaning, and water quality management in slaughterhouses. Implementing these measures and enhancing public awareness can mitigate *Salmonella* contamination risks and reduce the spread of antimicrobial resistance. Regulatory oversight and best practice guidelines should be developed and enforced in Nepal's slaughterhouses to protect public health and address growing antimicrobial resistance challenges.

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Keywords: Chitwan, ESBL, goat meat, Salmonella

INTRODUCTION

Raw meat, particularly goat meat, is a critical source of protein and other nutrients essential for human health. It is rich in proteins, essential fatty acids, vitamins, and minerals, making it a staple in many diets worldwide (Pereira and Vicente, 2013). However, raw meat is highly perishable due to its susceptibility to contamination by microorganisms, including pathogens like *Salmonella.* The conditions under which animals are slaughtered play a crucial role in the microbial load of meat; poor hygiene during slaughtering and improper handling can lead to significant contamination (Klaharn et al., 2022*)*. In developing countries like Nepal, the absence of modern slaughterhouses and regulated processing facilities often results in the contamination of meat with pathogenic microorganisms. Many butcher shops lack proper sanitary practices, leading to cross-contamination through tools, water, and hands (Ovuru et al., 2024). *Salmonella* is a major foodborne pathogen that causes gastrointestinal illnesses worldwide. It is a Gram-negative bacterium that can infect both humans and animals, often through contaminated food products (Lamichhane et al., 2024). The most common strains involved in foodborne outbreaks are *S. enterica* serovars Typhimurium and Enteritidis (Vencia et al., 2015). The muscles of healthy animals are usually free of pathogens; however, contamination occurs during slaughter due to contact with animal hides, gastrointestinal contents, and environmental sources (Heredia and García, 2018). This contamination can extend to the post-harvest stage during transportation and retail sale, posing a significant risk to public health (Lenzi, Marvasi and Baldi, 2021). A major concern is the increasing prevalence of antimicrobial-resistant strains of *Salmonella*, particularly those that exhibit Extended Spectrum Beta-Lactamase (ESBL) activity (Pulingam et al., 2022). ESBLs are enzymes that confer resistance to a broad spectrum of beta-lactam antibiotics, including third-generation cephalosporins (Castanheira, Simner and Bradford, 2021). This resistance limits treatment options for severe *Salmonella* infections, especially in vulnerable populations such as children and immunocompromised individuals (Kariuki et al., 2015). The improper and extensive use of antibiotics in animal agriculture is a significant factor contributing to the emergence of these resistant strains (Singh, Bhat and Ravi, 2024). This study aims to assess the prevalence of *Salmonella* and its ESBL activity in raw goat meat in Bharatpur, Nepal. The findings will contribute to understanding the contamination sources and provide insight into the public health risks associated with consuming contaminated meat.

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MATERIALS AND METHODS

Study design: This was a cross-sectional study conducted from November 2022 to January 2023 in Bharatpur Metropolitan City, Chitwan, Nepal. Chitwan, a prominent agricultural region in Nepal, is known for its substantial meat production, particularly goat and poultry, driven by a growing demand for animal protein within local and regional markets.

Study population: Samples were collected from slaughterhouses/butcher shops in 10 wards of Bharatpur metropolitan city based on convenient sampling. These shops included both open and closed premises to account for different levels of exposure to environmental contamination.

Sample size: A total of 50 samples of raw goat meat including thigh & breast meat, part of liver and heart and another 50 water samples used in slaughterhouse for different purposes like dressing, washing, cleaning etc of meats, slaughter slab, knife, chop board etc. were included in the study.

Sample collection and transportation: Raw meat samples were collected aseptically, and stored in sterile containers. Water samples, used for cleaning tools and meat, were also collected in sterile containers. All samples were transported to the Microbiology and Parasitology Laboratory, Agriculture and Forestry University (AFU), within four hours, maintaining proper cold chain conditions.

Laboratory Methods

Pre-enrichment: In the laboratory, 10 ml water samples were added to 90 ml of Selenite F broth and properly mixed. Similarly, 25 gm of meat samples were weighed, properly minced with sterile blades, and added to 225 ml of Selenite F broth. The samples were then kept at 37°C overnight under aerobic incubation.

Isolation and identification: After enrichment, the samples were inoculated into Xylose Lysine Deoxycholate (XLD) agar and incubated at 37°C for 24 hours. Identification of *Salmonella* was based on the observation of colony characteristics, Gram's staining and biochemical tests, including catalase, oxidase, indole, motility, Methyl Red Voges Proskauer, Triple Sugar Iron Agar, citrate utilization and urease production test (Makwana et al., 2015).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Antibiotic susceptibility testing (AST): Each isolate was subjected to AST by following CLSI (Clinical Laboratory Standard Institute) guidelines. Briefly, the pure culture of isolate was inoculated into nutrient broth, the turbidity of which was matched to that of 0.5 Mc Farland Standard. The suspension was then swabbed into Mueller Hinton Agar (MHA) and antibiotic discs were placed onto the swabbed agar surface. After incubation at 37°C for 24 hours, the zone of inhibition around each disc was measured and reported as susceptible, intermediate or resistant.

Detection of ESBL production: The screening test for the production of ESBL producing isolates was performed by measuring the diameters of zone of inhibition around Ceftazidime (30µg) and Ceftriaxone (30 µg)/Cefotaxime (30µg) on MHA media by disc diffusion method following CLSI guidelines. The suspected ESBL producing isolates i.e. screen test positive isolates were subjected to phenotypic confirmation by combination disc method (CLSI, 2020).

Data analysis: Data were analyzed using SPSS software (version 25). Chi-square test determined associations between contamination and risk factors, with statistical significance at $p < 0.05$.

RESULTS AND DISCUSSION

Out of 100 samples, *Salmonella* was isolated from 26 samples. The prevalence of *Salmonella* among the meat samples was 8% (4/50) and that among the water samples was 44% (22/50). Out of 26 isolates, 11 were ESBL producers (Table 1).

Table 1. Isolation of Salmonella from different samples from slaughter houses (n=100)

Source of samples	No. of samples	No. (%) of samples positive for *Salmonella*	ESBL production	
			Positive No. (%)	Negative No. (%)
Meat	50	4 (8%)	2 (50%)	2 (50%)
Water	50	22 (44%)	9 (40.91%)	13 (59.09)

Salmonella was isolated from 8% of meat samples only, 44% of water samples only and 4% of both meat and water samples. Open slaughterhouses, direct cash transactions, non-potable water, lack of regular cleaning, use of shared utensils, and improper evisceration practices were each significantly correlated with increased Salmonella contamination rates (Table 2).

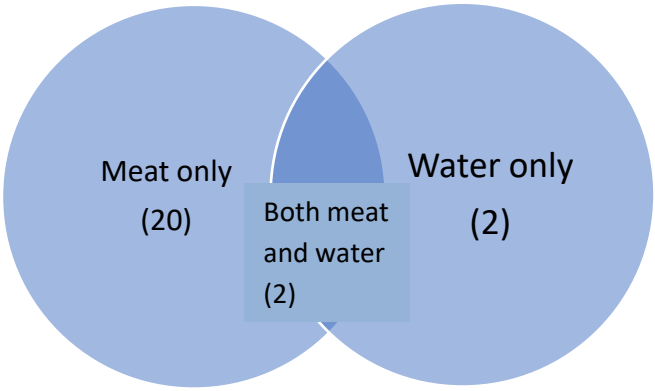

Figure 1. Venn diagram showing the number of samples positive for *Salmonella*

The high prevalence of *Salmonella* contamination observed in water samples (44%) and moderate contamination in meat samples (8%) from slaughterhouses in this study aligns with similar findings from regions with limited sanitation infrastructure. For instance, a study from India found comparable contamination rates in water sources used in slaughterhouses, highlighting the role of untreated water in spreading foodborne pathogens (Makwana et al., 2015). Studies in Nepal and India further underscore that open slaughterhouses are at elevated risk for contamination, as these environments are more exposed to environmental contaminants due to insufficient physical barriers and limited regulatory oversight (Klaharn et al., 2022; Lamichhane et al., 2024).The contamination rates here also reflect findings from lower- and middle-income countries, such as Thailand, where inadequate sanitation practices increase bacterial contamination risks in slaughterhouse environments (Klaharn et al., 2022).

Notably, our study found that non-potable water use was significantly associated with Salmonella presence, a factor similarly highlighted by Ovuru et al. in developing countries, where contaminated water is a major contributor to microbial load (Ovuru et al., 2024).Comparatively, developed countries with stricter hygiene protocols and potable water use report lower contamination rates in meat-processing facilities (Heredia and García, 2018), which suggests that enforcing potable water use and implementing sanitation controls could drastically reduce Salmonella contamination in Nepal's slaughterhouses.

The prevalence of ESBL activity (50% in meat and 40.9% in water samples) among Salmonella isolates is concerning, especially given that ESBL-producing bacteria pose

a significant public health risk due to their resistance to beta-lactam antibiotics. These findings are similar to studies from India and Bangladesh, where high levels of ESBL activity among foodborne pathogens were attributed to the widespread, unregulated use of antibiotics in livestock production (Pulingam et al.,2022; Singh, Bhat and Ravi,2024). However, this prevalence contrasts with lower ESBL rates observed in developed nations, such as the European Union, where stricter antibiotic use policies have effectively reduced antimicrobial resistance among foodborne pathogens (Castanheira, Simner and Bradford, 2021). The disparity highlights the critical need for regulatory interventions in Nepal to monitor and control antibiotic use in agriculture to limit the spread of resistant strains.

Table 2. Risk factors associated with isolation of *Salmonella* from slaughter houses

Type of slaughter house	Total number	Culture positive for *Salmonella* No. (%)	p-values
Open	30	22 (73.33)	0.0007
Closed	20	4 (20)	
Direct connection of cash between seller and customer			
Yes	30	22 (73.33)	0.0007
No	20	4 (20)	
Water used in slaughterhouses			
Potable	15	1 (6.67)	0.0002
Non-potable	35	24 (68.57)	
Regular cleaning of slaughterhouses			
Yes	15	1 (6.67)	0.0002
No	35	24 (68.57)	
Use of common utensils or knife to cut different species of meat at a time			
Yes	40	25 (62.50)	0.0088
No	10	1 (10.00)	
Follow instruction while evisceration of carcass to reduce cross contamination			
Yes	10	1 (10.00)	0.0088
No	40	25 (62.50)	

Operational practices were also significantly associated with contamination levels in this study. For instance, using common utensils across different meat types and inadequate evisceration practices both increased contamination risks, echoing findings from South Asia and Africa where cross-contamination from shared utensils is prevalent due to limited resources (Makwana et al., 2015). In contrast, developed countries with stringent food safety regulations typically report lower contamination

rates, as proper cleaning and separation protocols are followed to prevent cross-contamination (Lenzi, Marvasi and Baldi, 2021). These operational practices indicate that simple yet critical interventions, such as separate utensils for different species and strict adherence to evisceration guidelines, could lower contamination rates significantly in Nepal's slaughterhouses.

CONCLUSION

The findings underscore the need for improved sanitation, regular cleaning, and water quality management in slaughterhouses. Implementing these measures and enhancing public awareness can mitigate *Salmonella* contamination risks and reduce the spread of antimicrobial resistance. Regulatory oversight and best practice guidelines should be developed and enforced in Nepal's slaughterhouses to protect public health and address growing antimicrobial resistance challenges.

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Factors Affecting Adoption of Systematic Household Waste Management, Waste Composting and Homestead Farming in Bharatpur, Janakpur and Pokhara

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ABSTRACT

SOLID Health project of Nepal Development Society (NeDS) aimed at effective household solid waste management through 3R approach in three mega cities: Bharatpur, Janakpur and Pokhara. On which, non-organic wastes were encouraged to reuse, recycle and safe disposal, whereas organic wastes were attempted to manage through composting at household level and utilizing at homestead farming. The program was executed for around two and half years within the year 2021 to 2024. Major program interventions were capacity enhancement programs, practical demonstration and support with resources. Data were collected from 348 project intervention households through structured surveys, complemented by Focus Group Discussions and Key Informant Interviews. The achievement of the projects was comparatively analyzed with baseline information. Rooftop farming was most prevalent in Pokhara (64%), while kitchen gardening was more common in Bharatpur (71%). Overall, 81% of households across the three cities practiced either rooftop farming, kitchen gardening or both. In overall, there was around 69% percentage change in knowledge and attitude of respondents towards waste management, composting and homestead gardening as compared to baseline status. Composting practice at home was increased significantly in all three cities after project intervention, which was increased by 39% in overall. Also, there was significant adoption of reusing and recycling of the non-organic wastes rather than sending all those to municipality vehicle. Socio-demographic factors such as education level, income, and land availability were significant determinants of adoption. Households with higher education levels and larger homestead land areas showed greater likelihood of practicing kitchen gardening and rooftop farming. A combination of land

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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availability, education levels, economic factors, age group, gender and type of capacity development support approach appear to be the primary drivers behind the differences in adoption rates between three cities.

Keywords: Household waste, kitchen gardening, rooftop farming, waste composting

INTRODUCTION

Urban households in Nepal are facing increasing challenges in managing solid waste though waste bears opportunity of converting into valuable products supporting environmental and health safety. Existence of dense population in city areas, rapid urbanization, and availability of cheap use & throw non-degradable materials, lack of appropriate mass disposal facilities and delayed adoption of improved technologies are major causes of ineffective solid waste management in big cities of Nepal. While assessing the countries overall waste generation (i.e. around 1 million mt. per year), household wastes shares around 39% followed by business houses (25%), health institutions (10%), educational institutes (10%), industries (9%) and others (7%). As per 2021 census, more than 66% of total households of the country reside in municipalities. Organic (biodegradable) waste is the major part of household waste, which shares more than 65% of waste composition. Also, organic wastes are potential biomass for composting at household level that can support homestead gardening through proper utilization of limited spaces. At present condition, there exist increasing trend of urbanization due to people's migration from rural areas, which seeks reform measures against existing challenges of improved infrastructures and services like drinking water, waste management and sanitation. Integration of household waste management practices with rooftop farming and kitchen gardening has been promoted as a sustainable approach to minimize the negative impacts associated with solid waste management.

The SOLID-HEALTH project, titled "Improving public health and environmental health in Nepal through appropriate solid waste management," of Nepal Development Society (NeDS) aimed at improving household waste management undertaking 3R (Reduce, Reuse and Recycle) approach. Out of three major objectives, objective 1 focused on reducing household wastes through promoting organic waste composting, encourage homestead farming along with capacity strengthening for non-organic waste reuse and recycle. The program was executed for around two and half years within the year 2021 to 2024. This program intervention was implemented in three mega cities Bharatpur, Janakpur, and Pokhara. The project achieved some significant

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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changes in adoption of systematic household waste management through organic waste reduction at source by composting and utilizing at homestead farming. Key project interventions were capacity enhancement programs, practical demonstration and support with resources. Support was focused on waste segregation, composting practices, and the adoption of homestead farming (kitchen gardening and roof top farming) techniques. For effective training delivery, Training of Trainers (ToT) was provided to selected community members, who delivered orientation to other members to expand the knowledge and skill. In addition, project provided material support (compost bin/chamber) and home based guidance on reuse and recycle of non-organic waste timely.

MATERIALS AND METHODS

This study examines the factors influencing adoption of improved household waste management, composting and compost utilization at homestead greenery. The project was evaluated during year 2024 to measure the impacts against baseline status. Though there were multiple outcomes against all project objectives, this research paper is confined only for objective 1 outcome. The findings are drawn from the quantitative and qualitative analysis of the project's impact assessment research. The outcome of this research is evidence-based findings from the project impact assessment survey of the SOLID-HEALTH Project. Standardized questionnaires were used for the quantitative survey at household level. Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) with various stakeholder groups were conducted along with interview guides. Purposive Sample survey was employed for the household survey, in which the sample size of 348 was surveyed across Bharatpur, Pokhara, and Janakpur. Purposive sampling was used to identify participants for FGDs.

Table 1. Total number of households surveyed in the study areas

Metro/Sub-Metro City	Total No. of HHs surveyed
Bharatpur	108
Janakpur	118
Pokhara	122
Total	**348**

The data were statistically analyzed to identify the key determinants that encourage or hinder households from implementing organized waste segregation, composting of organic waste, and the integration of homestead farming include awareness, knowledge, access to resources, and socio-economic conditions. The level of changes

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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in response to such factors and intercity differences are discussed in this research article. The OECD DAC method was applied to measure the level of changes in knowledge, behavior and practice. Based on frequency of responses to different strengths of changes, percentage analysis was made to those parameters.

RESULTS AND DISCUSSION

Comparison of adoption rates in three cities

Objective 1 of the Solid Health project focused on primary management of solid waste at household level and successive utilization of compost from organic waste home-based gardening. The project interventions like capacity and skill enhancement approaches, practical demonstration and material support have put significant impact in various aspects, which are discussed hereafter.

Change in Knowledge and Attitude

Percentage change in **knowledge and attitude** of respondents towards waste management before and after the training (ToT and Orientation on waste composting, kitchen gardening and roof top farming) is around 69% (overall). As per the response, the most percentage change observed was in Janakpur followed by Pokhara. There was found positive impact of program with such changes seeking continuation of the project to gain subject matter specific changes in the future.

Table 2. Percentage change in knowledge and attitude of respondents

City	Average % change in knowledge and attitude	N
Bharatpur	55.12	108
Janakpur	79.97	118
Pokhara	70.07	122
Total	**68.79**	**348**

Source: Field Survey, 2024

State of adoption of solid waste management practices

While reviewing the data analysis outcomes, biodegradable waste management has become more systematic after project interventions. In overall, 80% respondents are composting organic wastes at home. Though compost bins are more used in Janakpur,

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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composting activates highly exist in Bharatpur and Pokhara. As compared to baseline there is significant change in adoption of management practices for both degradable and non-degradable waste management (Table 3). Non-degradable waste was found to be more re-used and recycled (sale to collectors/recycling units). These practices were more adopted in Bharatpur and Pokhara. In Janakpur, the project improved the status at higher proportion as compared to baseline status.

Table 3. Practices for management of bi-degradable waste

Management of biodegradable waste					
Option	Result from	Bharatpur	Janakpur	Pokhara	Grand Total
Composting- pit, pile, ring, bin)	After project	82%	73%	84%	80%
	Baseline	63%	7%	53%	41%
Management of Non-biodegradable waste					
Sending to Municipality Waste Vehicle	After project	81%	67%	89%	79%
	Baseline	95%	89%	93%	92%
Reuse	After project	82%	5%	94%	60%
	baseline	10%	2%	15%	9%
Recycle	After project	65%	0%	56%	40%
	Baseline	3.50%	1.30%	1.80%	2.20%

Source: Field Survey, 2024

Adoption of kitchen gardening and roof top farming practices

While reviewing the increment percentage of HHs adopting kitchen gardens and roof top farming, there is slight increment (as compared to baseline status) with roof top farming. The increment is homogenous covering all cities. Table 3 illustrates the percentage of adoption of roof top farming, kitchen garden and either of both practices.

Table 4 indicates that in overall, 81 percent respondents practiced either roof top farming or kitchen gardening or both. Of them, 57% practiced sole kitchen gardening, which is highest in Bharatpur followed by Pokhara and Janakpur. In Pokhara, 94% practice either kitchen gardening or rooftop farming, showing the highest adoption rate among the three cities.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Table 4. Percentage of HHs practicing rooftop farming, kitchen gardening or both

Assessment	City			Total
	Bharatpur	Janakpur	Pokhara	
After project execution	34%	39%	64%	46%
Baseline	30%	26%	63%	41%
Percentage of practice (kitchen garden, rooftop farming or both): post project				
Particular	City			Total
	Bharatpur	Janakpur	Pokhara	
Either of one or both (Kitchen garden or roof top)	82%	66%	94%	81%
Kitchen Garden	71%	42%	58%	57%

Source: Field Survey, 2024

Roll model households

There were role model households in all cities in terms of best practice of solid waste management, composting and homestead gardening. Pokhara had highest number of role model households (20) which were successful to adopt and implement the best practices after participating in the Solid Health program of NeDS. Also, an impressive number of participants (14) were produced in Janakpur followed by Bharatpur (10). Those households were successful examples, from which other community members could gain knowledge and empowerment for household level sanitation and greenery maintenance.

Factors affecting adoption rates

A fundamental prerequisite for adoption is awareness and understanding of the new practice. If individuals are unaware of a practice composting or don't understand its benefits of reduced waste, improved soil, they are unlikely to adopt it. Training and support programs were directly interrelated with these factors. Also, there are some non-project intervention factors which resulted in creating variations in adoption rates in three cities, which have been discussed hereunder.

Land availability and ownership

Pokhara respondents had the least homestead land areas, which may have driven higher adoption of rooftop farming (64%) compared to other cities. Janakpur

respondents owned smaller areas of land due to the dense urban setting, which could explain their lower overall adoption rate (66%) for kitchen gardening or rooftop farming. Bharatpur respondents had the highest land ownership, which may have facilitated higher adoption of kitchen gardening (71%).

Education and income

Bharatpur had a higher rate of literacy and education, with more respondents having higher secondary and bachelor's level education. Janakpur had a lower overall education level, with more respondents having only basic literacy or lower secondary education. Education level was found to be strongly associated with adoption of rooftop farming and kitchen gardening. Households with higher secondary or above education were more likely to adopt sustainable roof top farming practices. While analyzing the average comparison of yearly income values in three cities, there was significant difference found with Cities. Following is the F test result (mean comparison) and the analytical database:

Table 5. Mean comparison of the yearly gross income of respondents groups

Interaction	Degree of freedom	F value	Significance (95%)
Annual income * City	2	38.089	.000
City	Mean annual income (NPR)	N	Std. Deviation
Bharatpur	597685	108	341485
Janakpur	561305	118	580388
Pokhara	1062049	122	516525
Total	748144	348	544178

Source: Field Survey, 2024

There is higher level of significant difference (P=<0.05), the table has shown that average annual income is higher (almost at double level) in Pokhara than that of Bharatpur and Janakpur, which are not significantly different. The survey found that higher incomes enabled greater investment in sustainable homestead farming and safe roof top farming practices.

Gender and age group

The age groups of 35-54 range were the utmost participants' group in the program. In each city, more than 85% practitioners were female members. Engagement of such age group indicated that mature female members were active in the project.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Table 6. Age group and gender of respondents

Particulars	Labels	Bharatpur %	Janakpur %	Pokhara %
Age group (Yr)	35-44	41	39	27
	45-54	34	16	40
Gender	Female	86%	99%	91%
	Male	14%	1%	9%

Source: Field Survey 2024

Project's capacity enhancement approach

Project's interventions had mutual connections and benefits such as: composting reduced waste volume and farming/gardening supported degradable waste management along with improvement in knowledge and skill. As per the respondents, there were three major changes due to composting and homestead farming, which were: "Appropriate waste management" followed by "Increase in knowledge and skill" and "Increased productivity of crops". During qualitative survey, ToT recipient members and some active respondents mentioned that they had increased productivity of crops from kitchen garden or roof top farming. In overall, 51 respondents realized increased crop productivity due to technological improvement (Table 7). Hence ToT approach was an effective activity within the project interventions.

Table 7. Changes due to training on composting and homestead farming

City	Benefits/achievements from training on rooftop farming, composting, bio pesticides and others		
	Increment in knowledge and skills	Appropriate waste management)	Increased productivity of crops)
Bharatpur	88	75	8
Janakpur	56	112	2
Pokhara	119	104	41
Total	263	291	51

Source: Field Survey, 2024

CONCLUSION

The Solid Health project of NeDS boosted systematic household waste management along with increased adoption of waste segregation, composting and homestead gardening in three mega cities of Nepal. It has also positively contributed for increased food security and health & environmental safety. The findings and recommendations

provide a roadmap for improving and sustaining adoption in the future. The adoption of improved waste management and homestead food production practices was influenced by multiple factors. Education, income, and land availability are the primary factors influencing adoption of improved household waste management, rooftop farming, and kitchen gardening. Project interventions that combine technical training, resource provision, and awareness rising were effective in overcoming structural barriers.

For long-term sustainability, municipal governments should integrate these practices into local waste management policies, provide continuous support for training, and incentivize households to adopt waste-to-resource approaches.

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Drivers of The Organic Mushroom Market in Kathmandu Valley: A Dual-Perspective Analysis of Consumer Willingness-To-Pay and Producer Viability

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ABSTRACT

The demand for safe and organic food is rising in urban Nepal, but the market for organically grown mushrooms remains underdeveloped. Understanding consumer behavior and producer readiness is crucial for market development. This study aimed to assess mushroom consumption patterns, awareness, access disparities, and willingness to pay (WTP) for organic mushrooms in Kathmandu Valley, integrating perspectives from both consumers and producers. A mixed-methods approach was employed. Data were collected from 150 consumers through a structured online survey and from 10 producers/traders via in-person interviews. Analysis involved descriptive statistics, chi-square tests, binary logistic regression, and cost-benefit analysis. A vast majority (94.7%) of respondents consumed mushrooms, primarily driven by taste and nutritional value. Awareness of organic mushrooms was high (88%) and significantly associated with education level ($p<0.05$). Social networks and social media were the primary information sources. While access to conventional mushrooms was widespread, 45% of consumers were willing to pay a premium for organic varieties. Logistic regression confirmed awareness as a critical determinant of WTP (Odds Ratio = 7.67, $p=0.001$). On the supply side, 70% of producers expressed willingness to adopt organic methods, and cost-benefit analysis indicated moderate profitability (Average B: C Ratio = 1.49), though challenges like price fluctuations and pests were common. This study highlights that there is significant potential for an organic mushroom market in Kathmandu Valley. Realizing this potential requires integrated strategies focusing on consumer education, establishing trustworthy certification, and providing targeted support to producers to overcome operational challenges.

Keywords: Awareness, consumer behavior, cost-benefit analysis, organic mushrooms, sustainable agriculture

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INTRODUCTION

Nepal's diverse agroecology supports a rich myco-biota, with over 400 recorded mushroom species, of which more than 100 are edible (Adhikari, 2014). Historically foraged from the wild, mushroom cultivation has gained momentum over recent decades, transforming into a recognized agricultural subsector (Poudel,2018). As heterotrophic organisms, mushrooms efficiently convert lignocellulosic waste from agriculture and forestry into nutritious food, representing a promising avenue for sustainable intensification and the circular economy (Chávez, 2019, and Sapkota, 2022). Globally, mushroom production has seen a sixfold increase in the last twenty years, with China dominating the market (FA0,2021). The global mushroom market was valued at approximately USD 62.3 billion in 2023 and is projected to grow at a CAGR of 9.1%, reaching around USD 136.9 billion by 2032 (Devochkina,2024). This growth is driven by rising consumer awareness of their health benefits, which include bioactive compounds like polysaccharides, peptides, and phenolic compounds (Devochkina,2024).

Despite Nepal's rich biodiversity of over 1,150 mushroom species, commercial cultivation is limited to about five species, with oyster mushrooms (*Pleurotus ostreatus*) constituting 86% of production (Raut,2019). While this sector offers significant income-generation potential for farmers, Acharya and Tiwari (2021), commercial expansion remains restricted, and participation in mushroom cultivation remains low (Acharya and Dhungel,2021). Nepal is concurrently experiencing rapid urbanization, particularly in the Kathmandu Valley, the nation's economic hub (Timsina,2022, and Khatri,2024). This urbanization drives changes in dietary patterns, with a growing urban middle class showing increased interest in health-conscious and safe food products (Singh and J.D., 2024). However, the conventional cultivation of mushrooms often involves unregulated pesticide use, raising public health concerns (Dhakal,2024). Organically grown mushrooms present a safer alternative but face considerable market barriers, including low consumer awareness, absent certification mechanisms, and underdeveloped supply chains (Khanal 2020; Regmi 2023). Furthermore, access to such premium products is often inequitable, disproportionately affecting peri-urban and low-income populations *(*Mishra et al., 2024). While previous studies in Nepal have explored general organic food consumption (Regmi, 2023; Aryal, 2009) and examined the profitability of mushroom enterprises Phuyal (2023), a critical gap exists in understanding the specific market dynamics for organic mushrooms, particularly the interplay between consumer awareness, WTP, and producer economics. This study aims to fill this gap by providing a dual-perspective

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analysis of the potential for organic mushrooms in the Kathmandu Valley. Specifically, it investigates: (1) mushroom consumption patterns and access, (2) awareness and determinants of WTP for organic varieties, and (3) the economic viability and challenges of production from the farmers' perspective.

MATERIALS AND METHODS

Study Area: The study was conducted in the Kathmandu Valley, comprising three districts: Kathmandu, Lalitpur, and Bhaktapur. As the country's most urbanized and populous region, it serves as the primary market for premium and organic food products, making it an ideal site for this investigation.

Research design and sampling: A cross-sectional, mixed-methods design was employed. The consumer sample, while stratified, was relatively small (n = 150), yet it provided a meaningful and balanced representation of respondents across the three districts. The final sample size was determined through a combination of Cochran's sample size formula for large populations and practical feasibility considerations.

Cochran's formula was applied as follows:

$$n_0 = Z^2 \times p \times q / e^2$$

Where:
- n_0 = required sample size for an infinite population
- Z = Z-value (1.96 for 95% confidence level)
- p = estimated population proportion (0.5 assumed for maximum variability)
- q = 0.5
- e = margin of error (0.08 or 8%)

Substituting the values:

$$n_0 = (1.96^2 \times 0.5 \times 0.5) / 0.08^2$$
$$= (3.8416 \times 0.25) / 0.0064$$
$$= 0.9604 / 0.0064$$
$$\approx 150.06$$

The sample was proportionally allocated according to the Central Bureau of Statistics (CBS) 2021 population data: 101 from Kathmandu, 27 from Lalitpur, and 22 from Bhaktapur. For the producer survey, a purposive sampling method was used to identify and interview 10 active mushroom producers/traders within the valley to gain in-depth qualitative and economic data.

Pilot testing: Before the final survey, a pilot test was conducted with 10 respondents from Kathmandu Valley. The purpose of the pilot test was to evaluate the clarity, relevance, and reliability of the questionnaire, as well as to identify any ambiguities or difficulties faced by respondents. Feedback from the pilot study was carefully reviewed, and minor modifications were made to the wording and sequencing of questions to improve comprehension and minimize bias. Primary data were collected between April and July 2025. Consumer data were gathered primarily through a structured online questionnaire administered via Google Forms, distributed through social media and community networks. To mitigate digital bias, this was supplemented with 10 in-person interviews with producers and traders, which also provided insights into supply-side dynamics. The consumer questionnaire covered sections on socio-demographics, consumption patterns, access and availability, awareness of organic mushrooms, and willingness to pay. The producer interview guide focused on production costs, revenues, challenges, and perceptions of the organic market. Secondary data were sourced from the CBS, the Ministry of Agriculture and Livestock Development (MoALD), FAO reports, and relevant peer-reviewed literature.

Data analysis : Quantitative data from consumers were coded, cleaned, and analyzed using SPSS (Version 26) and Microsoft Excel. Analysis included:

- **Descriptive statistics** to summarize socio-demographic and consumption variables.
- **Chi-square tests** to examine associations between categorical variables (e.g., income and price sensitivity).
- **Binary Logistic Regression** to identify factors influencing WTP for organic mushrooms. The dependent variable was WTP (willing = 1, not willing = 0). Key independent variables included awareness, education, and income.
- **Ranking Analysis** using an index value to prioritize factors influencing consumer purchase decisions.
- **Geographic Information System (GIS)** tools were used to map and visualize the spatial distribution and accessibility of organic mushrooms across urban and peri-urban areas of Kathmandu, Lalitpur, and Bhaktapur.

Producer data were analyzed using a cost-benefit analysis to calculate the Benefit-Cost (B:C) ratio for different mushroom varieties. Total cost included substrate, spawn, utilities, packaging, and other operational costs; family labor was excluded.
The Benefit-Cost Ratio (B: C Ratio) was calculated using the formula:

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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B:C Ratio=Total Revenue (NPR)/Total Cost (NPR)

Ethical considerations and limitations: Verbal informed consent was obtained from all participants before data collection. The study acknowledges several limitations. The consumer sample, while stratified, is modest and was primarily collected online, which may underrepresent segments of the population with limited digital access, potentially introducing selection bias. The producer sample is small and not representative of all producers in the valley. Furthermore, WTP was measured through stated preference, which may not accurately reflect actual market behavior. These limitations restrict the generalizability of the findings and should be taken into account when interpreting the results.

RESULTS AND DISCUSSIONS

Socio-demographic profile and mushroom consumption patterns

The study involved 150 respondents from Kathmandu Valley. Nearly half of the respondents were aged 18–25, with progressively smaller proportions represented in older age groups. The gender distribution was relatively balanced, with males comprising 55% and females 44% of the sample. Educational attainment was generally high, as the majority held a bachelor's degree (44.7%) or a master's degree and above (30.7%). Students formed the largest occupational group (45.3%), followed by individuals in government or private service (30.7%). Household income varied, though most respondents reported earnings between NPR 20,000 and 60,000 per month. In terms of location, two-thirds of participants resided in Kathmandu District, with the remainder from Lalitpur and Bhaktapur. Overall, the sample reflects a relatively young, educated, and urban population.

The vast majority of respondents (94.7%) were mushroom consumers, confirming their widespread popularity in the urban market of Kathmandu Valley, consistent with its status as a major consumption hub in Nepal (Aryal,2009). Button mushrooms (*Agaricus bisporus*) were the most commonly consumed (76.4%), followed by oyster mushrooms (53.5%), reflecting established production and market supply patterns (Raut,2019). In this study, 94.7% of respondents reported consuming mushrooms, indicating a very high prevalence of mushroom consumption in the Kathmandu Valley. This aligns with earlier studies identifying Kathmandu as a key urban market where awareness, demand, and consumption of mushrooms have grown steadily (Aryal, 2009). National assessments similarly note increasing production and rising

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urban uptake of commonly cultivated species such as button and oyster mushrooms. Consumption frequency was moderate; 44% consumed mushrooms 2-3 times per month, while only 2.7% were daily consumers (Table 2).

Table 1. The sociodemographic profile of survey respondents

Variables	Characteristics	n	Percentage (%)
Age	<18	7	4.7
	18-25	72	48
	26-35	21	14
	36-45	18	12
	46-60	19	12.7
	Above 60	13	8.7
Gender	Female	66	44
	Male	83	55
	Other	1	1
Education	No formal education	4	2.6
	Primary	6	4
	Higher secondary	27	18
	Bachelor	67	44.7
	Master's or Higher	46	30.7
Occupation	Students	68	45.3
	Private/Government Service	46	30.7
	Business	15	10
	Teacher	9	6
	Other	12	8.1
Income	20k–40k	47	31.3
	40k–60k	42	28
	60k–80k	26	17.3
	80k–1 Lakh	18	12
	Above 1 Lakh	17	11.4
Location	Kathmandu	101	67
	Lalitpur	27	18
	Bhaktapur	22	15

Source: Field Survey, 2025

This pattern suggests that mushrooms are predominantly perceived as a supplementary vegetable or a culinary ingredient for variety, rather than a dietary staple. This

indicates significant potential for market growth through campaigns promoting their nutritional benefits and culinary versatility to increase consumption frequency.

Table 2. Frequency of mushroom consumption (N=150)

Frequency	Frequency (N)	Percent)
Rarely	39	26
2-3 times/month	66	44
Weekly	27	18
2-3 times/week	14	9.3
Daily	4	2.7
Total	150	100

Source: Field Survey, 2025

A Likert-scale analysis revealed that taste was the primary driver of consumption (Mean=3.25), whereas mushrooms were less commonly perceived as a regular part of the diet (Mean=2.49) or a meat substitute (Mean=2.34). This aligns with global studies, such as (Predanócyová et al., 2023) in Slovakia, which also found sensory preference to be the leading motivator, surpassing health and environmental concerns. These results provide insight into consumer attitudes toward mushroom consumption in the Kathmandu Valley, suggesting that while mushrooms are valued for taste, they are not yet widely perceived as a dietary staple or meat substitute.

Access, availability, and perceived barriers

Access to conventional mushrooms was not a major constraint, with 95.3% of respondents reporting easy access. The most common purchase sources were local markets (61.9%), street vendors (57.1%), and direct purchases from farmers (55.8%), highlighting the critical role of informal, trust-based channels in the fresh produce sector. Supermarkets were used by 48.3%, while online purchases were minimal (12.9%), reflecting the nascent stage of digital food retailing in Nepal, a sector hampered by challenges like limited trust, quality concerns, and underdeveloped logistics (Parajuli,2024). The most significant barrier to consumption was high price (67.6% of cases), followed by taste preferences (53.5%) and distrust in sellers (39.4%). A chi-square test found no significant association between income level and being limited by high price ($p > 0.49$), indicating that cost sensitivity is a universal concern across income groups for this non-staple food item. This finding is supported by Owusu and Dekagbey (2020), who identified price as a major factor influencing the purchase of edible mushrooms, with consumers across income brackets demonstrating sensitivity to price points.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Awareness of organic mushrooms and their influence on willingness to pay

Awareness of organically grown mushrooms was high (88%), which is a positive indicator for market potential. Friends and family (32%) and social media (26.7%) were the dominant sources of awareness. A significant association was found between the respondents' education level and their source of awareness ($\chi^2 = 38.79$, $p = 0.029$), with more highly educated individuals relying more on social networks and digital media. This underscores the need for formal, accessible public education campaigns to reach a broader demographic beyond the highly educated, who currently benefit from informal knowledge transfer. These patterns are supported by Rokaya and Pandey (2024) found that social media and interpersonal networks are critical channels for organic product awareness in Nepal. A key finding of this study is the powerful role of awareness in shaping WTP. Overall, 58% of consumers were willing to pay a premium for organic mushrooms, with 40.7% willing to pay a 5% premium and 28.7% willing to pay 10% more. Binary logistic regression identified awareness as the most significant predictor of WTP (Table 4). Consumers aware of organic mushrooms were 7.67 times more likely to be willing to pay a premium ($p=0.001$). This robustly demonstrates that knowledge is a primary lever for market creation and aligns with studies in similar contexts, such as Shrestha and Baral (2009), which found that awareness of health and safety benefits significantly increased WTP for organic products in Nepal.

Willingness to pay for organic mushrooms

The survey findings show a generally positive consumer attitude toward paying a premium for organically grown mushrooms. Among 150 respondents, 58% reported willingness to pay more, while 26% expressed conditional interest. Only 16% were unwilling to pay extra, indicating limited price sensitivity. These results align with previous studies in Nepal, such as Regmi (2023), which reported strong consumer support for premium pricing on organic produce, particularly among individuals with higher awareness, education, and income levels.

Table 3. Chi-Square test results for the association between education level and medium of awareness about organic mushrooms

Test	Value	df	Sig.
Pearson Chi-Square	38.793	24	0.029
Likelihood Ratio	44.165	24	0.007

Source: Field Survey, 2025

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Table 4. Logistic regression of awareness on willingness to pay a premium

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Awareness	2.037	0.585	12.112	1	0.001	7.668
Constant	-1.447	0.556	6.779	1	0.009	0.235

Source: Field Survey, 2025

The survey results indicate that a clear majority of respondents (128 of 150; 85.4%) are willing to pay a premium for organically grown mushrooms, while 22 (14.7%) are unwilling. The willingness is concentrated at modest levels: 61 (40.7%) would pay 5% more, 43 (28.7%) would pay 10% more, 14 (9.3%) would pay 20% more, and 10 (6.7%) would pay over 20% extra. (Note: the previously reported figure of 58% was from an earlier draft and is incorrect; the table-based totals above are the accurate values.) These findings demonstrate broad openness to modest price increases, with only a small segment prepared to pay substantially higher premiums.

Table 5. Respondents' willingness to pay a premium for organic mushrooms

Willingness to Pay (Premium)	Frequency (N)	Percent (%)	Valid Percent (%)	Cumulative Percent (%)
None at all	22	14.7	14.7	14.7
5% more	61	40.7	40.7	55.3
10% more	43	28.7	28.7	84
20% more	14	9.3	9.3	93.3
More than 20%	10	6.7	6.7	100
Total	150	100	100	—

Source: Field Survey, 2025

When ranking purchase factors for organic mushrooms, consumers prioritized packaging, organic labeling, and appearance, while taste and price were ranked lowest. This indicates that in the context of organic products, consumers value cues that signal safety, quality, and credibility above basic attributes like taste and cost. This finding contrasts with the general consumption motive (where taste was primary) and suggests that trust-building through certification and presentation is paramount for the organic segment. Empirical evidence from other studies supports this; for instance, Predanócyová et al. (2023) also found that trust-related factors like packaging were highly valued.

Health benefits were identified as the primary determinant for purchasing organically grown mushrooms (30.7%), followed by taste (24%) and organic certification (20.7%). Support for local farmers (10.7%) and considerations of sustainability or food

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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safety (14%) were less influential, indicating that personal health and sensory attributes predominantly drive consumer decisions in the Kathmandu Valley. These findings are consistent with previous studies in Nepal. Regmi (2023) identified health, taste, freshness, environmental considerations, and certification as key predictors of WTP, influenced by education and income. Khanal (2020) noted willingness to pay for health and safety benefits, despite cost and information barriers, while Aryal (2009) highlighted certification, perceived health and quality, and taste as major factors in Kathmandu Valley.

Table 6. Ranking of factors influencing consumer preference for organic mushrooms

Factor	1st	2nd	3rd	4th	5th	6th	Index Value	Rank
Packaging	31 (20.7%)	19 (12.7%)	26 (17.3%)	28 (18.7%)	27 (18.0%)	19 (12.7%)	0.602	1
Organic Label	27 (18.0%)	26 (17.3%)	29 (19.3%)	20 (13.3%)	22 (14.7%)	26 (17.3%)	0.598	2
Appearance	25 (16.7%)	26 (17.3%)	27 (18.0%)	22 (14.7%)	27 (18.0%)	23 (15.3%)	0.59	3
Freshness	25 (16.7%)	28 (18.7%)	18 (12.0%)	28 (18.7%)	24 (16.0%)	27 (18.0%)	0.579	4
Taste	20 (13.3%)	22 (14.7%)	27 (18.0%)	33 (22.0%)	25 (16.7%)	23 (15.3%)	0.567	5
Price	22 (14.7%)	29 (19.3%)	23 (15.3%)	19 (12.7%)	25 (16.7%)	32 (21.3%)	0.564	6

Source: Field Survey, 2025

Note: 1st-Most Important to least important

Producer perspectives, economic viability, and market challenges

The survey of 10 producers revealed that oyster mushroom cultivation was most prevalent. The majority (70%) were willing to adopt organic methods, and 60% perceived a growing demand for organic products, signaling a readiness on the supply side to respond to market signals. Major production challenges included pests/diseases (30%), price fluctuations (20%), and substrate availability (20%). These constraints are consistent with broader literature on smallholder agriculture in Nepal Raut (2019) and Acharya and Tiwari (2021) and point to areas where technical and market support are urgently needed to enhance sustainability and reduce risks.

Table 7. Perceived risk factors in mushroom production

Production Challenge	Frequency (N)	Percent (%)
Pest/disease	3	30
Price fluctuation	2	20
Substrate issues	2	20
Climate instability	2	20
Labor shortage	1	10
Total	10	100

Source: Field Survey, 2025

Table 8. Production cost and revenue analysis of sample farms (N=10)

S.N	Mushroom Type	Land Size (Ropani)	Total Cost (NPR)	Total Revenue (NPR)	B: C Ratio
1	Oyster	2	37,000	67,716	1.83
2	Button	3	71,000	116,708	1.64
3	Shiitake	4	103,000	67,203	0.65
4	Oyster	1.8	32,500	55,302	1.7
5	Button	2	51,500	81,567	1.58
6	Shiitake	5	115,000	79,772	0.69
7	Oyster	2.5	41,500	74,385	1.79
8	Oyster	1.5	30,000	46,940	1.56
9	Button	2.5	60,500	93,367	1.54
10	Oyster	3	45,500	86,185	1.89

Source: Field Survey, 2025

Cost-benefit analysis showed that oyster and button mushroom production was profitable, with B: C ratios ranging from 1.56 to 1.89 and 1.54 to 1.64, respectively (Table 7). In contrast, shiitake cultivation was less economically viable (B: C ratios of 0.65 and 0.69) due to higher input costs and longer cultivation cycles. The average B: C ratio across all farms was 1.49, indicating moderate profitability and confirming the economic feasibility of mushroom cultivation as noted in previous studies (Phuyal,2023). The low profitability of shiitake highlights how variety selection is critical for financial sustainability and that targeted technical and financial support would be needed to commercially scale such premium varieties.

These findings suggest that oyster and button mushrooms offer relatively stable economic returns, whereas improvements in production efficiency and cost management are needed to enhance the viability of shiitake farming.

CONCLUSION

Based on the empirical findings of this study, the development of a viable organic mushroom market in Kathmandu Valley is contingent upon the establishment of a robust regulatory and educational framework. The identified causal relationship between consumer awareness and willingness-to-pay (OR = 7.67) necessitates the implementation of science-based public outreach programs and a standardized, verifiable organic certification protocol to reduce information asymmetry and build market confidence. Concurrently, supply-side interventions must focus on enhancing technical efficiency through the dissemination of integrated pest management strategies and optimized substrate formulation to improve benefit-cost ratios. Strengthening market linkages and developing risk-mitigation financial instruments are crucial to ensuring sector resilience and facilitating the transition to a sustainable, knowledge-driven organic mushroom production system.

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Adoption of Good Beekeeping Practices Among Beekeepers in Chitwan District, Nepal

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ABSTRACT

The adoption of Good Beekeeping Practices is widely recognized as essential for enhancing productivity, sustainability, and commercial success in the beekeeping industry. In Nepal, despite the sector's strong potential to support rural livelihoods, its growth remains constrained by reliance on traditional methods. This study investigates the extent of Good Beekeeping Practices adoption and explores the socioeconomic factors influencing their use among beekeepers in Chitwan, one of the country's leading honey producing districts. A mixed-methods approach was employed, combining a survey of 57 randomly selected beekeepers with qualitative insights from focus group discussions and key informant interviews conducted within the Prime Minister Agriculture Modernization Project (PMAMP) area. Data were analyzed using descriptive statistics and a binary logit regression model. Findings reveal a 59.6% adoption rate of Good Beekeeping Practices. Core practices such as the use of protective gear, appropriate apiary site selection, and maintenance of colony handling (64.9%) and feeding honey-pollen mixture (52.6%) were less common. Regression results indicate that age and the number of beehives negatively influenced adoption, whereas annual income from beekeeping, off-farm income, and honey production were positive and significant. The study concludes that financial capacity and economic resilience are key to encouraging the adoption of better practices. It suggests that efforts to increase profitability and diversify income are essential for modernizing the sector.

Keywords: Age, colony, income, production, regression

INTRODUCTION

Beekeeping is a significant part of rural households' incomes and economies in Nepal (Devkota, 2020). Despite economic growth, bee keeping is also essential for raising agricultural productivity, and biodiversity via the pollination services (Gupta et al.,

2014). Nepal has the capacity to produce around 10,000 tons of honey every year (Bhattarai et al., 2021). Honey is the primary output of bee keeping. Along with honey, various bee products are royal jelly, propolis, bee bread, bee venom, beeswax can be obtained from bee industry (Aryal et al., 2015). Beekeeping is an economically viable, socially acceptable, and environmentally sound business. Beekeeping is associated with the cultural as well as the economic history of Nepal. Five economically important Apis species found in Nepal are *Apis cerana*, *Apis mellifera*, *Apis florea*, *Apis dorsata*, and *Apis laboriosa* (Shrestha & Shrestha, 2000). All four species except Apis mellifera, are indigenous to Nepal. In Nepal, Apis mellifera and A. cerana make up 22% and 78% of all domestic bee species respectively (Kafle, 2019). In the Terai region, Apis mellifera are raised extensively, although Apis cerana are more common in the hills. The government and non-governmental organizations have worked hard to promote this bee species to boost the production of honey (Taylor, 2014). Since Bee Keeping is a non-land-based business with multipurpose output, demand for it has been rising dramatically in Nepal (Bista & Shivakoti, 2001).

The problems associated with beekeeping in Nepal are a shortage of bee flora, pesticide poisoning, and no access to improved apian materials for keeping bees (Devkota et al., 2022). In beekeeping, good management practices constitute several techniques that enhance honey production, improve hive health, and ensure sustainability. An essential component of successful honey production is low-cost technology combined with appropriate feeding, mite, and other pest control (Bista et al., 2015). Those who wish to start a beekeeping business must manage artificial feeding during the harsh winter and rainy seasons and provide management as needed (Bista & Shivakoti, 2001). In off-season honey bee colony management, a low dosage of sugar syrup combined with 30g pollen was appropriate, since it also aids in a high rate of flight activity (Suroj, 2006). A study revealed that feeding bees banana syrup during the off-season can save the cost of sugar feeding by more than 50% (Neupane & Thapa, 2005). Good Management Practices (GMPs) in beekeeping operations are important for optimizing efficiency and productivity (Danieli et.al., 2023). GMPs thus play a critical role in the maintenance of the genetic quality of a bee colony and are also engaged in the control of diseases and pests, which will determine the sustainability of the undertaking in the long run (Oldroyd & Thompson, 2006). The adoption rate of GMPs, however, is not uniform and has varying factors. Generally, innovations in beekeeping are adopted in stages, with early adopters leading the way, to be followed by others as the benefits become more evident (Bhandari & Kattel, 2020). This speed of adoption is influenced by factors such as the availability of resources, financial constraints, and the level of education and training among the

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available beekeepers. The Agricultural Development Strategy (ADS) 2015-2035 underscores the importance of advancing scientific beekeeping through the adoption of quality standards, promotion of modern technologies, strengthening of extension networks, enhancement of honey value chains, and assurance of food safety and competitiveness. Within this framework, beekeeping is identified as a key enterprise for commercialization, biodiversity conservation, and improved management practices to boost productivity, sustainability, and market access MoAD, (2016).

Chitwan district is recognized as one of Nepal's most promising regions for beekeeping, owing to its rich bee flora and abundant pasture resources among 30 districts nationwide (FNBK, 2012). The district's potential is significant, with beekeeping offering greater revenue opportunities compared to traditional crop farming (Bhattarai et al., 2021). However, productivity and the processing of hive products remain constrained by reliance on traditional methods. Against this backdrop, the present study was undertaken to assess the adoption of good beekeeping practices among beekeepers in Chitwan. By examining the extent of adoption and the socioeconomic factors influencing it, the study aims to inform targeted interventions that can strengthen beekeeping practices and unlock the district's full potential.

MATERIALS AND METHODS

Study area: The study was carried out in Rapti Municipality, located in the eastern part of Chitwan district, Nepal, in 2024. Research activities focused on beekeeping practices within the Prime Minister Agriculture Modernization Project (PMAMP) command area, covering wards 1-6 and 10-13 of the municipality.

Sampling technique and sample size: The target population comprised 151 registered beekeepers in the study area. Using Daniel (1999) sample size determination formula, a sample of 57 beekeepers was selected. Respondents were chosen through random sampling to reduce selection bias and ensure the findings could be generalized to the wider population.

Data collection: A mixed-methods approach was employed to collect both qualitative and quantitative information. Primary data were gathered using three instruments. First, household surveys with a semi-structured interview schedule were administered to the heads of 57 selected beekeeping households. Second, Focus Group Discussions (FGDs) were conducted with farmers to gain deeper insights into community-level practices and challenges. Third, Key Informant Interviews (KIIs) were held with officials from government institutions (including PMAMP and the Agricultural

Knowledge Centre), representatives of non-governmental organizations (NGOs), and members of farmers' groups and cooperatives. In addition, secondary data were obtained from institutional reports and scientific journal articles, which helped contextualize the study and refine the definition and review of Good Beekeeping Practices.

Variables and measurement: The adoption of Good Beekeeping Practices served as the dependent variable and was measured as a binary outcome. Beekeepers were classified as adopters (1) if their Good Beekeeping Practices was greater than or equal to the mean value, and as non-adopters (0) if their score fell below the mean. Ten independent variables were selected to examine their influence on Good Beekeeping Practices adoption. These included a combination of continuous and categorical (dummy) variables, as summarized in Table 1.

Data analysis: The data were examined using both descriptive and inferential statistical techniques. Descriptive statistics, including the mean and standard deviation (SD), were applied to summarize and present the characteristics of the study variables. To identify the factors influencing the adoption of Good Beekeeping Practices, a binary logit regression model was employed. This approach allowed for the assessment of how socioeconomic and management variables affected the likelihood of adoption among beekeepers. The logit model is expressed as;

$$Zi = \ln [Pi/(1-Pi)] = a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5 +b_6X_6+ b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10}+U$$

Where: Pi = Probability of adoption and non-adoption of Good Beekeeping Practices.
Pi = 1 indicates adoption
Pi = 0 indicates non-adoption
Dependent variable:
Zi = Probability of adoption of Good Beekeeping Practices

Independent variables:
X_1 = Age (Continuous); X_2 = Gender (Dummy); X_3 = Education (Dummy); X_4 =Farming experience (Continuous); X_5 = Beehives (Continuous); X_6 = Production (Continuous); X_7 = Pollination services (Dummy); X_8 = Off-farm income (Dummy); X_9 = Annual income (Continuous); X_{10} = Training (Dummy)
a = Intercept
b_1 to b_{10}= Regression coefficients of the dependent variables
U = Error term

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RESULTS AND DISCUSSION

Descriptive statistics: The descriptive statistics of variables is presented in Table 1. Results revealed that 59.6% of respondents have adopted Good Beekeeping Practices, equal to or higher than mean. The average age of respondents is 47.12 years. Among sampled respondents, 94.7% were men and 5.3% were women in the surveyed area. Only 24.6% of respondents have higher education. On average, respondents have 9.6 years of beekeeping experience. The average number of beehives owned is 68.05. The average annual honey production is 1838.1 kg. Approximately 80.7% of respondents provide pollination services. About 73.6% of households have on-farm income sources. The average annual income from beekeeping is NPR 441,105.3. Approximately 77.1% of respondents have received training in beekeeping.

Adoption status of good beekeeping practices: The survey of 57 beekeepers indicates a widespread adoption of Good Beekeeping Practices. A majority of respondents (84.2%) preferred apiary sites that were clean, open, and dry, while 80.7% selected locations that were free from pollutants yet easily accessible. Fresh running water near the apiary was considered important by 73.7% of beekeepers, and 82.5% valued the presence of windbreaks and early sunlight exposure. Similarly, 80.7% favored sites with abundant floral resources.

Proper spacing between rows and hive boxes was maintained by 73.7% of respondents, and 78.9% reported adopting general hygiene measures and conducting periodic colony inspections.84.2% people checked the colonies periodically for any abnormalities or changes in the behavior of bees. The use of smokers and protective gear was common (85.9%), although only 64.9% practiced gentle colony handling. Isolation of diseased colonies was reported by 75.4% of beekeepers. Feeding practices varied: 52.6% used honey-pollen mixtures, while 59.6% relied on sugar syrup. Artificial food was fed by 38.6% people. The use of stainless steel of food-grade plastic tools was noted among 73.7% of respondents. Migration of colonies during non-flowering periods was adopted by 70.2% and 68.4% closed hive entrance gates in the evening.

The same proportion (68.4%) managed weak colonies and avoided pesticide use during critical periods. 66.7% people managed the colonies to prevent swarming and extracted honey frequently during the season. Overall, the findings suggest a strong commitment to effective beekeeping practices, though areas such as gentle handling and specific feeding methods present opportunities for further improvement.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Table 1. Descriptive statistics of the variables

Variable	Description	Mean	SD
Dependent variable			
Adoption	=1 if respondent adopt Good Beekeeping Practices equal to or higher than mean, 0 otherwise	0.596	0.4946
Independent variable			
Age	Age of the respondent (year)	47.12	9.70
Gender	Gender of the respondent (=1 if male, 0 female)	0.947	0.225
Education	=1 if respondent has higher education (grade 12 above), 0 otherwise	0.246	0.434
Experience	Beekeeping experience of the respondent (years)	9.61	6.67
Number of beehives	Number of beehives by the respondent	68.05	101.60
Annual production	Annual production of honey (kgs)	1838.1	3468.77
Pollination services	=1 if respondent provides pollination services ,0 otherwise	0.807	0.398
Off-farm income	=1 if household receive off-farm income,0 otherwise	0.736	0.442
Income	Annual income from beekeeping (NPR)	441105.3	709939.8
Training	=1 if respondent has received training ,0 otherwise	0.771	0.423

Source: Field Survey, 2024

Age: Age was found to have a negative and statistically significant effect on the adoption of Good Beekeeping Practices. With each additional year, the likelihood of adopting improved practices decreased by approximately 18%, indicating that older beekeepers are less inclined to embrace new management approaches. This trend may be attributed to resistance to change, reliance on established habits, and a preference for traditional methods over newer, evidence-based techniques. Furthermore, older individuals may have limited exposure to recent advancements or technologies that support modern beekeeping. Similar findings were reported by Serebrennikov et al. (2020). In this study, the average age of non-adopters was higher than that of adopters, reinforcing the observation that younger farmers are more likely to adopt innovative practices (Andaregie & Astatkie, 2021).

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January, 2026, volume 30
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Factors affecting the adoption of good beekeeping practices: Table 3 presents the factors influencing the adoption of Good Beekeeping Practices. The significant variables are discussed below:

Table 2. Good beekeeping practices among beekeepers

S.N.	Practices	Frequency (n=57)
1	Site at clean, open, dry place	48 (84.2)
2	Site away from the power station, brick kilns, highways, and train tracks but easily accessible road	46 (80.7)
3	Fresh running water available near an apiary	42 (73.7)
4	Windbreaks	47 (82.5)
5	Site receives early morning and afternoon sunshine	47 (82.5)
6	Site with rich flora nearby	46 (80.7)
7	Row to row and box to box distance is 10 and 3 feet, respectively	42 (73.7)
8	Adoption of the general colony and personal hygiene in an apiary	45 (78.9)
9	Check the colonies periodically for any abnormalities or changes in the behavior of bees	48 (84.2)
10	Use of smoker, protective dress and veil during inspection of colonies	49 (85.9)
11	Handling of colonies; gently, avoid jerks and crushing bees	37 (64.9)
12	Isolate diseased colonies from healthy ones and handle them separately	43 (75.4)
13	The mixture of honey and pollen with water to feed bees	30 (52.6)
14	Provide percent sugar syrup without mixing honey in ca lean shallow vessel and provide fresh water near a colony	34 (59.6)
15	Artificial food	22 (38.6)
16	Use of honey extractor, containers, and other tools/equipment made from stainless steel/ food grade plastic	42 (73.7)
17	Migration during non-availability of flora	40 (70.2)
18	Close the entrance gates in the evening	39 (68.4)
19	Unite weak worker colonies and control predatory wasps, ants, frogs, lizards, etc.	39 (68.4)
20	Manage the colonies to prevent swarming and extract honey frequently during the season	38 (66.7)
21	Avoid spraying of pesticides during the flowering of the crop and peak foraging time	39 (68.4)

Source: Field Survey, 2024

Note: Figure in the parentheses indicates percentage.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Number of beehives: The number of beehives showed a negative and marginally significant effect on the adoption of Good Beekeeping Practices. Each additional hive reduced the likelihood of adoption by approximately 1.7%. A larger number of hives may hinder the adoption of new practices due to resource constraints and management complexity. Beekeepers managing many colonies often prioritize maintaining existing operations rather than experimenting with innovative methods. Abeje et al. (2017) observed that older beekeepers, particularly those above 47 years, tend to maintain fewer modern hives, largely due to concerns about the challenges of colony management. This suggests that the perceived complexity of handling a greater number of hives may discourage the adoption of modern techniques. Moreover, applying time-consuming procedures across numerous colonies can be difficult, leading to slower uptake of improved management practices (Al-Ghamdi et al., 2017).

Annual production: Annual honey production exhibited a positive and marginally significant effect on Good Beekeeping Practice adoption. Higher production levels slightly increased the probability of adopting improved practices. Greater honey yields reflect stronger resource availability and financial stability, enabling beekeepers to experiment with and implement new techniques. Beekeepers with more successful operations are often more willing to inset in innovations that enhance productivity. Evidence shows that increased honey yields among those following good management practices reinforce the link between improved practices and higher output (Tubene et al., 2023). Furthermore, a positive and substantial correlation between honey production and the use of modern hives supports the view that rising output encourages the adoption of better management techniques (Affognon et al., 2015).

Off-farm income: Having an off-farm source of income significantly increased the likelihood of adopting Good Beekeeping Practices by approximately 60.9%. Off-farm income provides a stable and reliable revenue stream, enabling farmers to invest in improved management techniques for their beekeeping operations. This additional financial support allows beekeepers to overcome resource constraints and implement practices that enhance productivity and sustainability (Teferi & Wassie, 2020).

Annual income from beekeeping: Annual income from beekeeping was positively and significantly associated with Good Beekeeping Practices adoption. For each increase in income, the probability of adopting improved management practices rose by about 97.3%. Higher annual income offers financial stability, allowing beekeepers to invest in new technologies and practices. This economic cushion supports experimentation and adoption without financial risk. The findings also highlight the

differences between beekeepers and non-beekeepers in terms of skills and resource endowments, suggesting that greater revenue from beekeeping encourages the uptake of better management techniques (Abro et al., 2022).

Table 3. Logit regression analysis on factors affecting the adoption of good beekeeping practices

Variables	Coef.	St. Err.	P value	Dy /dx	St. Er (dy /dx)
Age	-0.083**	0.041	0.046	-0.180	0.009
Gender	0.311	1.401	0.824	0.071	0.330
Education	-0.454	0.827	0.583	-0.102	0.190
Experience	0.226	0.062	0.7116	0.005	0.014
Number of beehives	-0.078*	0.043	0.073	-0.017	0.008
Annual production	0.002*	0.001	0.097	0.0004	0.0003
Pollination services	-2.461	1.496	0.100	-0.370	0.145
Source of income	2.831**	1.117	0.011	0.609	0.178
Income	4.475**	2.114	0.034	0.973	0.438
Training	-0.188	0.978	0.847	-0.040	0.204
Cons	-18.567	9.731	0.056		

Summary statistics: Number of obs. = 57; LR chi2 =22.72; Prob>chi2 =0.0118; Pseudo R2 =0.2955; Log likelihood = -27.081773
Note: *, ** indicate significant at 10%, 5%, level of significance, respectively.
Source: Field Survey (2024)

CONCLUSUION

This study examined the adoption of Good Beekeeping Practices in Chitwan, Nepal, revealing a sector in transition. Overall adoption was moderate at 59.6%, with strong uptake of basic practices such as the use of protective gear, site selection, and colony hygiene. However, more advanced techniques including gentle colony handling and supplemental feeding were adopted less consistently, highlighting a gap that must be addressed to improve colony health and productivity in the long term. Logit model underscored the importance of socioeconomic factors. Annual beekeeping income and off-farm income had a strong positive influence, demonstrating that financial capacity is a key driver of adoption. In contrast, age showed a significant negative effect, suggesting generational resistance to change and reliance on traditional methods. Similarly, the number of beehives was negatively associated with adoption, indicating that scalability and management complexity can hinder consistent application of Good Beekeeping Practices in larger operations. For policymakers and development practitioners, these findings emphasize the need for economically empowering and

demographically targeted interventions. Efforts to modernize Nepal's beekeeping sector, as outlined in the Agricultural Development Strategy, should prioritize profitability, financial resilience, and tailored extension services. Supporting diversified income streams and designing hand-on programs for older beekeepers and large-scale operators will be critical. By focusing on these strategies, Nepal can accelerate the transition toward a more productive, sustainable, and commercialized beekeeping industry.

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Invitro Efficacy of Different Chemical Fungicides against *Fusarium* Spp. in Potato

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ABSTRACT

This study was carried out at the National Plant Pathology Research Center (NPPRC), Khumaltar, Lalitpur to evaluate the efficacy of different chemical fungicides against *Fusarium* spp. causing dry rot in potato (*Solanum tuberosum* L.) leading to considerable post-harvest losses. The experiment was conducted using the poisoned food technique in PDA media under laboratory condition. Five fungicides including Samradhi (Mancozeb 75% WP), Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG), M-Control (Chlorothalonil 75% WP), G-Tuphan (Dimethomorph 50% WDG) and Sectin (Fenamidone 10% + Mancozeb 50% WDG) were tested at concentrations of 50 ppm, 100 ppm and 200 ppm in a Completely Randomized Design with four replications. Findings revealed that all fungicides inhibited the mycelial growth of *Fusarium* spp., with variations among concentrations and observation days. Samradhi (Mancozeb 75% WP) and Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) were the most effective fungicides, providing 100% mycelial inhibition from day 1 to day 5 at all concentrations tested. Moderate inhibition was recorded with M-Control (Chlorothalonil 75% WP), ranging from 51.31% at 50 ppm on day 1 to 61.70% at 200 ppm on day 5. G-Tuphan (Dimethomorph 50% WDG) also showed moderate suppression, increasing from 35.20% at 50 ppm on day 1 to 59.62% at 200 ppm on day 5. Sectin (Fenamidone 10% + Mancozeb 50% WDG) showed the lowest efficacy, with inhibition values ranging from 34.21% at 50 ppm on day 1 to 47.32% at 200 ppm on day 5. The results indicate that Samradhi (Mancozeb 75% WP) and Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) are highly effective in suppressing *Fusarium* spp. under laboratory conditions. Field-level validation is essential before recommending these fungicides for integration into potato dry rot management practices.

Keywords: Disease management, dry rot, mycelial growth inhibition, poisoned food technique, post-harvest losses

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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INTRODUCTION

In Nepal, potato (*Solanum tuberosum* L.) is considered an important food crop with high economic and nutritional value (MoALD, 2022). Potato ranks fifth in global production after paddy, maize, wheat, and sugarcane, with China and India being the major producers (FAOSTAT, 2022). Originating from the Peruvian-Bolivian Andes, potatoes are now cultivated worldwide under diverse climatic conditions (Singh et al., 2020). China is the largest producer globally, contributing over 93 million metric tons, followed by Germany, Russia, Ukraine, India, and the United States, highlighting the widespread geographic distribution of potato cultivation.

In Nepal, agriculture is a key sector that contributes to food security, employment, and income generation. Out of the total land area of 147,181 square kilometer, agricultural land comprises 41,275.54 square kilometer of which 21% (3,091 ha) is cultivated and 7% (1,030 ha) remains uncultivated (MoALD, 2022). Potato is cultivated on 203,812 ha with an annual production of 3,487,816 tons, ranking second in production and sixth in cultivated area after paddy, maize, wheat, oilseeds, and lentils (Nandwani et al., 2021). Nepal is also among the top 20 countries in per capita potato consumption (Subedi et al., 2019).

Potato production in Nepal is affected by several fungal diseases, among which dry rot caused by *Fusarium* spp. is a major post-harvest problem, resulting in significant economic losses worldwide (Mortensen & Bullard, 2025). Fusarium dry rot affects tubers during storage and seed pieces after planting. Annual crop losses due to dry rot are estimated between 6 to 25 percent (Chełkowski, 1989), with over 60% of stored tubers potentially affected (Carnegie et al., 1990). The disease is characterized by necrotic dry lesions that often develop through wounds such as cuts or bruises. Infected tubers frequently rot from the center (Sandipan et al., 2016). Fusarium dry rot develops optimally under high relative humidity and temperatures of 15-20°C. Multiple species of *Fusarium* are responsible for the disease, with *Fusarium sambucinum* (teleomorph *Gibberella pulicaris*) being the most common, while *F. solani* var. *coeruleum* and *F. avenaceum* also contribute. Globally, thirteen *Fusarium* species are reported to cause potato dry rot (Cullen et al., 2005).

Management of Fusarium dry rot is challenging due to its soil-borne nature, infection through wounds, and limited curative measures. Cultural practices such as crop rotation are often ineffective against this disease (Bojanowski et al., 2013). Chemical control using fungicides remains a widely adopted strategy; however, over-reliance on

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

chemicals can lead to fungicide resistance, environmental hazards, and potential health risks. In-vitro evaluation of fungicides provides a controlled approach to screen for effective treatments against *Fusarium* spp., thereby guiding efficient disease management strategies and reducing unnecessary chemical application in the field.

MATERIALS AND METHODS

Study area

The research was conducted at National Plant Pathology Research Centre (NPPRC) which is one of the seven plant science disciplinary of National Agricultural Research Institute (NARI) under Nepal Agricultural Research Council (NARC) located in Khumaltar, Lalitpur district of Nepal.

Materials used

All laboratory equipment, chemicals, media, and pure culture were obtained from the National Plant Pathology Research Centre, NARC. Hot pan, autoclave, incubator, hot air oven, laminar air flow, weighing balance, compound microscope, micropipette, forceps, needles, corn borer, Bunsen burner, conical flasks, Petri plates, and parafilm were among the main equipment. Potato Dextrose Agar, 70% alcohol, streptomycin, and five commercial fungicides were utilized.

Preparation of test pathogen

A pure culture of *Fusarium* sp. was provided by the Plant Pathology Laboratory. To obtain the test pathogen, a pure culture of *Fusarium* spp. isolated from potato tubers affected with dry rot obtained from Dhanusha district was sub-cultured on PDA and incubated at 25°C for seven days.

Pathogen identification

The isolate produced soft, fluffy, white mycelium with pinkish-purple centers on PDA. Macroconidia were large, sickle-shaped and multi-celled; microconidia were single-celled, oval to elliptical, clustered under the microscope.

In Vitro evaluation of fungicides

PDA preparation

One liter of distilled water was used to prepare 40 grams of PDA. After preparing 1.5 L of medium, it was heated to 200℃ using a magnetic stirrer, split into 100 ml conical flasks, covered, plugged, and autoclaved for 20 minutes at 121°C.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Fungicides tested

Five fungicides viz Samradhi (Mancozeb 75% WP), M-Control (Chlorothalonil 75% WP), G-Tuphan (Dimethomorph 50% WDG), Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG), and Sectin (Fenamidone 10% + Mancozeb 50% WDG) were evaluated at three different concentrations of 50, 100, and 200 ppm using the poisoned food technique.

Preparation of fungicide-amended PDA

Cooled autoclaved media were amended with fungicides. As quantities were less than 1 g, stock solutions were prepared in 1 ml distilled water before mixing with PDA. Streptomycin (0.05 g) was added to prevent bacterial contamination. Each 90 mm Petri plate received 20 ml of poisoned medium and was left to solidify overnight in a laminar flow cabinet.

Pathogen inoculation

Poisoned PDA plates were left overnight in a laminar air flow cabinet. A 5mm cork borer was used to cut and transfer 7 days old *Fusarium* spp. mycelium to the center of each plate. Plates were sealed with parafilm to prevent contamination. Four replicates were maintained for each treatment and a control plate was also maintained on fungicide free PDA media. All plates were incubated at 25°C in an incubator.

Research design

A total of sixteen treatments were assessed, including five chemical fungicides and a control treatment. Four replications of each treatment were used in Randomized Complete Block Design (RCBD experiment. The fungicidal efficacy was evaluated using the poisoned food method.

Data recording

After the inoculation, data collection started 24 hours later. For five days in a sequence, measurements of the pathogen's growth were taken every day. Two lines were drawn through the center of each plate, vertical (V) and horizontal (H), and the average was calculated to determine the colony diameter.

Data analysis

All the recorded data were compiled in MS Excel (2016). Percent inhibition of mycelial growth over the control was calculated using the formula by Vincent (1947):

Growth inhibition (%) = C-T/C*100

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

where:
C = colony diameter of *Fusarium* spp. in control (mean of both diagonals)
T = colony diameter of *Fusarium* spp. in treatment (mean of both diagonals)
Statistical analysis was performed using R-Studio through one-way ANOVA, and treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

Efficacy of fungicides against mycelial growth of *Fusarium* spp. by poisoned food method

Using the poisoned food method, five fungicides were evaluated in vitro for their ability to inhibit the mycelial growth of *Fusarium* spp. at three different concentrations. From Day 1 to Day 5, the coefficients of variation for each fungicide were 10.88%, 14.74%, 11.53%, 10.63%, and 9.17%, all of which inhibited growth relative to the control. The control exhibited the greatest growth, rising from 3.04 cm on Day 1 to 7.86 cm on Day 5, and it was statistically different from all other treatments. At all concentrations of 50, 100, and 200 ppm, Samradhi M-45 (Mancozeb 75% WP) and Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) totally inhibited growth, maintaining it at zero centimeters. G-Tuphan (Dimethomorph 50% WDG) showed moderate inhibition, with 2.3 cm growth at 100 ppm on Day 5, though 200 ppm showed slightly reduced efficacy. M-Control (Chlorothalonil 75% WP) produced consistent moderate inhibition with Day 5 growth between 3.01 cm (200 ppm) and 3.16 cm (50 ppm). Sectin (Fenamidone 10% + Mancozeb 50% WDG) was less effective, allowing 5.03 cm (50 ppm) to 4.14 cm (200 ppm) growth on Day 5. Overall, Samradhi (Mancozeb 75% WP) and Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) were most effective, followed by moderate efficacy of G-Tuphan (Dimethomorph 50% WDG) and M-Control (Chlorothalonil 75% WP) while Sectin (Fenamidone 10% + Mancozeb 50% WDG) showed comparatively lower suppression.

The effectiveness of different fungicides against *Fusarium* spp. was observed over a 5-day period, and the results showed clear differences among the fungicides and their concentrations. Samradhi (Mancozeb 75% WP) proved to be the most reliable treatment, achieving complete 100% inhibition at 50, 100, and 200 ppm throughout all five days. Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) performed equally well, maintaining 100% inhibition from the beginning to the end of the experiment at

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

every concentration tested. M-Control (Chlorothalonil 75% WP) provided a moderate level of suppression, with inhibition increasing slightly from 59.79% at 50 ppm to 61.70% at 200 ppm by Day 5

Table 5. Results of poisoned food technique showing mycelium growth of pathogen

Fungicides	Mean mycelial growth (cm)				
	Day1	Day2	Day3	Day4	Day5
Control	3.04^{a}	4.01^{a}	6.14^{a}	7.25 ^{a}	7.86^{a}
Dimethomorph 50% WDG 50 ppm	1.96^{c}	2.43^{bc}	2.61^{de}	2.75^{d}	2.83^{e}
Dimethomorph 50% WDG 100 ppm	1.76^{d}	2.03^{de}	2.03^{f}	2.18^{e}	2.3^{f}
Dimethomorph 50% WDG 200 ppm	2.30^{b}	2.68^{b}	2.69^{d}	2.93^{d}	3.25^{d}
Mancozeb 75% WP 50 ppm	0 ^{g}	0 ^{f}	0 ^{g}	0 ^{f}	0 ^{g}
Mancozeb 75% WP 100 ppm	0 ^{g}	0 ^{f}	0 ^{g}	0 ^{f}	0 ^{g}
Mancozeb 75% WP 200 ppm	0 ^{g}	0 ^{f}	0 ^{g}	0 ^{f}	0 ^{g}
Fenamidone 10% + Mancozeb 50% WDG 50 ppm	2 ^{c}	2.53^{bc}	3.68^{b}	4.35^{b}	5.03^{b}
Fenamidone 10% + Mancozeb 50% WDG 100 ppm	1.7^{de}	2.21^{cd}	3.17^{c}	3.73^{c}	4.21^{c}
Fenamidone 10% + Mancozeb 50% WDG 200ppm	1.56^{ef}	2.06^{de}	3.02^{c}	3.65 ^{c}	4.14^{c}
Tebuconazole 50% + Trifloxystrobin 25% WG 50 ppm	0 ^{g}	0 ^{f}	0 ^{g}	0 ^{f}	0 ^{g}
Tebuconazole 50% + Trifloxystrobin 25% WG 100 ppm	0 ^{g}	0 ^{f}	0 ^{g}	0 ^{f}	0 ^{g}
Tebuconazole 50% + Trifloxystrobin 25% WG 200 ppm	0 ^{g}	0 ^{f}	0 ^{g}	0 ^{f}	0 ^{g}
Chlorothalonil 75% WP 50 ppm	1.48^{f}	1.84^{e}	2.56^{de}	2.78^{d}	3.16^{de}
Chlorothalonil 75% WP 100 ppm	1.44^{f}	1.84^{e}	2.45^{de}	2.83^{d}	3.1^{de}
Chlorothalonil 75% WP 200 ppm	1.41^{f}	1.72^{e}	2.33^{ef}	2.7^{d}	3.01^{de}
SEM(+-)	0.06	0.11	0.11	0.12	0.11
LSD	0.18	0.31	0.31	0.33	0.31
CV	10.88	14.74	11.53	10.63	9.17
F test	201.99	201.38	188.34	199.79	199.28
Grand Mean	1.16	1.46	1.91	2.19	2.43
P value	<0.001	<0.001	<0.001	<0.001	<0.001

CV: Coefficient of variation, LSD: Least significant difference, Means followed by the same letter in a column are not significantly different by Duncan's multiple range test, SEM: Standard error of the mean, cm is centimeters

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

. G-Tuphan (Dimethomorph 50% WDG) showed varied results, with the best performance at 100 ppm (41.42% to70.79%), which was better than at 50 ppm and 200 ppm, though still less effective than the top treatments. Sectin (Fenamidone 10% + Mancozeb 50% WDG) was the least effective in this study.

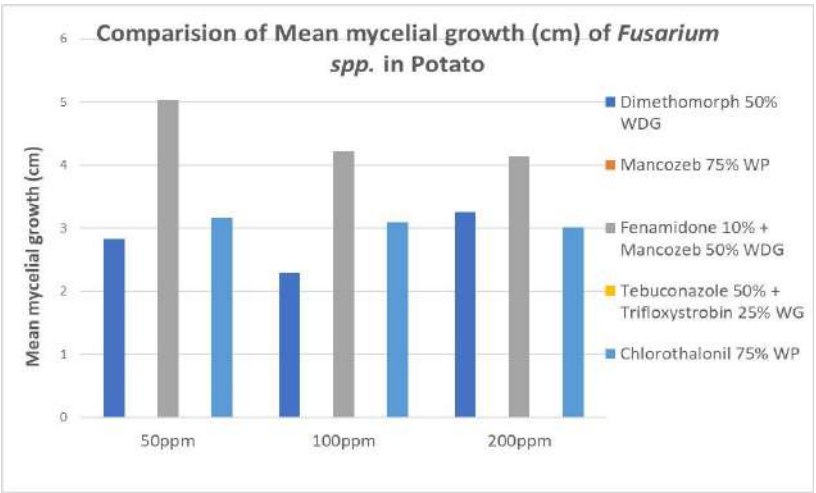

Figure 4. Bar graph showing percent growth of *Fusarium* spp. at different concentrations of chemical fungicides (Day 5), NPPRC, Lalitpur, 2025

Effect of commercial fungicides on the inhibition percentage of *Fusarium* spp.

Even at 200 ppm, inhibition reached only 47.32% on Day 5, and the lowest values (34.21% to 36.0%) were recorded at 50 ppm, indicating limited ability to suppress pathogen growth. Overall, Samradhi (Mancozeb 75% WP) and Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) stood out as the most effective fungicides, delivering complete and consistent inhibition of *Fusarium* spp. M-Control (Chlorothalonil 75% WP) and G-Tuphan (Dimethomorph 50% WDG), particularly at 100 ppm, offered moderate control, while Sectin (Fenamidone 10% + Mancozeb 50% WDG) showed comparatively weak performance under in vitro conditions.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 2. Result of poisoned food technique showing mycelial growth inhibition percentage

Fungicides	Mycelial growth inhibition (%)				
	IP Day1	IP Day2	IP Day3	IP Day4	IP Day5
Control	0.00	0.00	0.00	0.00	0.00
Dimethomorph 50% WDG 50ppm	35.2^{e}	39.61^{de}	57.50^{c}	62.15^{c}	63.95^{c}
Dimethomorph 50% WDG 100ppm	41.42^{de}	49.44^{bc}	66.89^{b}	69.83^{b}	70.79^{b}
Dimethomorph 50% WDG 200 ppm	24.20^{f}	32.95^{e}	56.09^{cd}	58.60^{d}	59.62^{c}
Mancozeb 75% WP 50 ppm	100.00	100.00	100.00	100.00	100.00
Mancozeb 75% WP 100 ppm	100.00	100.00	100.00	100.00	100.00
Mancozeb 75% WP 200 ppm	100.00	100.00	100.00	100.00	100.00
Fenamidone 10% + Mancozeb 50% WDG 50 ppm	34.21^{e}	36.90^{de}	40.06^{f}	40.00^{e}	36.00^{f}
Fenamidone 10% + Mancozeb 50% WDG 100 ppm	44.07^{cd}	44.88^{cd}	48.37^{e}	48.55^{d}	46.43^{e}
Fenamidone 10% + Mancozeb 50% WDG 200 ppm	48.68^{cd}	48.57^{bc}	50.81^{de}	49.66^{d}	47.32^{e}
Tebuconazole 50% + Trifloxystrobin 25% WG 50 ppm	100.00	100.00	100.00	100.00	100.00
Tebuconazole 50% + Trifloxystrobin 25% WG 100 ppm	100.00	100.00	100.00	100.00	100.00
Tebuconazole 50% + Trifloxystrobin 25% WG 200 ppm	100.00	100.00	100.00	100.00	100.00
Chlorothalonil 75% WP 50 ppm	51.31^{bc}	54.11^{b}	58.30^{c}	61.65^{cd}	59.79^{c}
Chlorothalonil 75% WP 100 ppm	52.63^{b}	54.11^{b}	60.09^{c}	60.96^{cd}	60.55^{c}
Chlorothalonil 75% WP 200 ppm	53.61^{b}	57.10^{b}	62.05^{bc}	62.75^{cd}	61.70^{c}
SEM(+-)	2.6	2.9	1.9	1.7	1.5
LSD	7.3	8.1	5.4	4.9	4.3
CV	8.3	8.9	5.6	4.9	4.4
Grand Mean	61.5	63.6	68.7	69.6	69.1
P value	<0.001	<0.001	<0.001	<0.001	<0.001

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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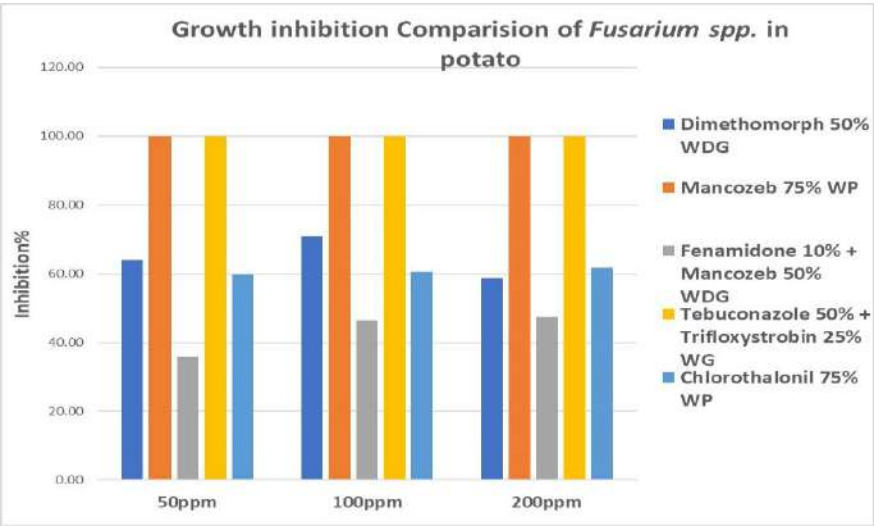

Figure 2. Bar graph showing the percent of inhibition of *Fusarium* sp. by various fungicides at different concentrations

CONCLUSION

By performing an in-vitro assessment of various fungicides against *Fusarium* spp., causative agent of potato dry rot, the results revealed that the tested fungicides at different concentrations (50, 100, and 200 ppm) using the poison bait technique had distinct variations in inhibitory efficacy. Samradhi (Mancozeb 75% WP) and Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) were the most effective treatments, continuously achieving 100% suppression of mycelial growth across all concentrations and observation days. Other fungicides, such as M-Control (Chlorothalonil 75% WP) and G-Tuphan (Dimethomorph 50% WDG), provided moderate inhibition and might be used as alternatives. On the other hand, Sectin (Fenamidone 10% + Mancozeb 50% WDG) shown relatively lesser efficacy. Crucially, the study determined economical ways to manage potato dry rot by identifying fungicides that effectively suppress the disease even at low concentrations. These results serve as a basis for the selection of effective fungicides and offer important data for upcoming field testing and integrated disease control strategies.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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SUGGESTIONS

For the long-term and sustainable control of *Fusarium* spp. integrated management strategies that combine chemical fungicides with cultural techniques (such as crop rotation, the use of healthy seed tubers, and appropriate storage conditions) can be suggested.

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Effect of Different Media on Growth of Cauliflower Seedling

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ABSTRACT

The growing medium plays a significant role in the quality and performance of vegetable seedlings. Therefore, this study was undertaken to investigate the effect of media on the growth of cauliflower (Brassica oleracea var. botrytis) seedlings. The experiment was conducted inside a plastic house at the Spices Crop Development Center (SCDC), Panchkhal, Kavrepalanchowk, Nepal, from August to September 2020. The seven media types used in this study include pure cocopeat, peatmoss, vermicompost, and soil, cocopeat plus peatmoss (1:1 by volume), cocopeat plus vermicompost (1:1 by volume), and soil plus compost (1:1 by volume). The experiment was conducted under RCBD with seven treatments and three replications. Data on germination percentage, number of leaves, shoot length, shoot diameter, shoot fresh weight, root length, and root fresh weight were recorded and analyzed using ANOVA in RStudio. Results indicated that there were significant differences among media for the germination percentage, shoot diameter, and shoot fresh weight at $p \leq 0.05$. Maximum germination of 75.25% was observed in cocopeat, which also produced the best overall growth performance, followed by a combination of cocopeat plus vermicompost and cocopeat plus peatmoss, while soil and peatmoss proved to be poor. The study concludes that cocopeat-based media enhance growth and quality in cauliflower seedlings and can be recommended for commercial nursery practices in Nepal.

Keywords: Cocopeat, growth, peatmoss, seedling, vermicompost

INTRODUCTION

Cauliflower (*Brassica oleracea* var. botrytis) ranks among the most important winter vegetables in Nepal, due to its high market demand and broad adaptability from Terai plains to the high hills, and also contributing significantly to household income and national vegetable production (Giri et al., 2018; Dahal et al., 2019). With increasing

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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population and food preference, consumption has continued to rise; accordingly, the need for high-quality seedlings capable of ensuring better field establishment with higher yields is pressing further. The quality of seedlings depends basically on the characteristic features of the growing medium. Traditionally, soil is the majorly used nursery substrate but often causes problems such as the presence of pathogens, poor aeration, compaction, and inconsistent nutrient availability which may inhibit seedling vigor and root growth (Landis et al., 2014). In this regard, the use of soilless media, which give better physical and chemical properties, enhanced aeration, balanced moisture retention, and reduced disease risk, has become more prevalent. Among the numerous soilless media, cocopeat with high water-holding capacity, favorable pH, good aeration, and slow rate of decomposition, generally stands for a strong alternative to soil. Peatmoss contributes good aeration and buffering, while vermicompost enhances nutrient supply, microbial activity, and structural quality (Ismail et al., 2013; Lazcano and Dominguez, 2014). Compost, although nutrient rich, may have limitations such as high bulk density and salinity when used alone (Raviv, 2013). Despite the growing adoption of alternative media in many countries, limited scientific information is available in Nepal regarding their comparative performance for cauliflower seedling production. Hence, this study was initiated to explore the performance of different media combinations on key growth parameters to identify the most suitable nursery substrates for cauliflower.

MATERIALS AND METHODS

Study area

The experiment was conducted inside a plastic house at the Spices Crop Development Center (SCDC), Panchkhal, Kavrepalanchowk district, Nepal. The site lies in the mid-hill region with warm summer temperatures suitable for vegetable seedling production.

Experimental Design

The experiment was conducted from August to September 2020, designed as a Randomized Complete Block Design (RCBD), with seven treatments and three replications. The treatments were:

- T1: Cocopeat
- T2: Peatmoss
- T3: Vermicompost

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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- T4: Soil
- T5: Cocopeat + peatmoss (1:1 by volume)
- T6: Cocopeat + vermicompost (1:1 by volume)
- T7: Soil + compost (1:1 by volume)

A total of 21 plastic trays containing 128 cells each were washed and filled with their respective media. Cocopeat was pre-soaked to improve its physical condition. Cauliflower seeds were sown uniformly in each cell, and the trays were arranged according to the RCBD layout. Irrigation was provided lightly after sowing and subsequently when needed.

Data collection

The following parameters of seedling growth were monitored:

- Germination percentage: Counted at 5, 10, and 15 days after sowing (DAS).
- No. of leaves: Recorded from five randomly selected seedlings per treatment at 15, 22, and 30 DAS.
- Shoot length: Measured (cm) at 15, 22, and 30 DAS using a ruler.
- Shoot diameter: Measured (mm) at 30 DAS using a vernier caliper.
- Shoot fresh weight: Measured at 30 DAS after separating the shoots from the roots.
- Root length: Measured (cm) at 30 DAS from uprooted seedlings.
- Root fresh weight: Weighted (g) at 30 DAS.

Data analysis

Data were entered in Microsoft Excel and analyzed using RStudio. The ANOVA was conducted to test the differences among treatments. Significant means were separated by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

Germination percentage

There were significant differences in media concerning germination percentage in all observation stages. Cocopeat always showed the highest germination percentage. Similarly, (Bhandari & Kharal, 2019) also reported the maximum germination percentage of tomato seed in cocopeat compared to other growing media used. The lowest germination percentage was recorded in soil when calculated 5 DAS. However,

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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10 DAS and 15 DAS, the lowest germination percentage were recorded from peatmoss which were statistically similar with vermicompost and soil. Even though, peat has very favourable water-holding capacity, high CEC, it is low in nutrient contents and pH (Raviv, 2013).

Table 1. Effect of different media on germination % of cauliflower seedling

Treatments	Germination, %		
	5 DAS	**10 DAS**	**15 DAS**
T1	74.99^{a}	74.99^{a}	75.25^{a}
T2	8.58^{de}	10.14^{d}	11.70^{d}
T3	16.66^{d}	16.92^{d}	16.92^{d}
T4	1.06^{e}	18.48^{d}	19.52^{d}
T5	39.31^{c}	39.31^{c}	39.31^{c}
T6	57.81^{b}	63.53^{b}	64.06^{b}
T7	12.49^{de}	13.28^{d}	13.28^{d}
Grand Mean	30.13	33.81	34.29
SEM(±)	0.55	0.47	0.47
CV, %	22.14	16.93	16.93
F-Test	***	***	***

*Means followed by the same letter (s) in a column are not significantly different at 5 % level of significance (P≤0.05);SEM: Standard Error of Mean; CV: Coefficient of Variation;***:Significant at 0.1% level of significance*

Number of leaves

Media composition had no significant effect on the leaf number at any stage. Though there were slight numerical differences, these were statistically similar across treatments. However, (IJARBN, 2019) reported that using cocopeat as media component and organic fertilizer for fertigation showed an increase in number of leaves of lettuce compared to peat as a media component and synthetic fertilizer for fertigation.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Table 2. Effect of different media on no. of leaf of cauliflower seedling

Treatments	Number of leaves		
	15 DAS	**22 DAS**	**30 DAS**
T1	1.33	1.93	2.80
T2	1.26	1.86	2.26
T3	1.60	1.86	2.46
T4	1.53	2.13	3.33
T5	1.26	2.00	3.13
T6	1.60	2.13	3.13
T7	2.00	2.13	2.86
Grand Mean	**1.51**	**2.01**	**2.85**
SEM (±)	**0.03**	**0.02**	**0.33**
CV (%)	**28.29**	—	—
F-Test	**NS**	**12.28 (NS)**	**14.37 (NS)**

Shoot length

There were no significant differences in shoot length among the various media. However, treatment means for soil and soil + compost were numerically higher, while cocopeat-based treatments were uniform but of shorter length. (Lazcano et al., 2009) suggested that addition of compost or vermicompost in peat-based media increased the aerial biomass of tomato plants.

Shoot diameter

Media had a significant effect on shoot diameter. The largest shoot diameter was recorded on both soil and soil + compost and was closely followed by cocopeat. On the other hand, the peatmoss, the vermicompost and the mixed treatments produced smaller diameters. Soil organic matter provides nutrients to plants and improve soil aggregation and water-holding capacity of soil. Soil particles attract positively charged cations and make them available for plants (Balasubramanian, 2017).

Shoot Fresh Weight

Media also had a significant effect on shoot fresh weight. The highest shoot fresh weight was recorded in the soil+ compost treatment, closely followed by the soil only

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

treatment. Treatment with cocopeat and its mixes gave lower shoot weights, despite higher germination rates. And experiment conducted by (Demisie et al., 2019) taking different soil mixtures also showed an increase in shoot fresh weight of tomato seedling in mixtures where organic matter were in higher proportion

Table 3. Effect of different media on shoot length of cauliflower seedling

Treatments	Shoot length (cm)		
	15 DAS	22 DAS	30 DAS
T1	2.71	3.78	4.58
T2	2.26	3.54	4.18
T3	3.15	3.83	4.40
T4	3.00	4.54	5.50
T5	2.94	3.41	3.99
T6	2.61	3.88	4.82
T7	3.45	5.18	5.82
Grand Mean	2.87	4.02	4.76
SEM(±)	0.03	0.05	0.05
CV, %	13.27	14.98	13.31
F-Test	**NS**	**NS**	**NS**

Table 4. Effect of different media on shoot diameter, shoot fresh weight, root length and root fresh weight of cauliflower seedling

Treatments	Shoot diameter, cm	Shoot fresh Weight, g	Root length, cm	Root fresh Weight, g
	30 DAS	30 DAS	30 DAS	30 DAS
T1	1.30[a]	0.04[b]	6.15	0.02
T2	1.18[b]	0.04[b]	7.12	0.02
T3	1.29 [b]	0.04[b]	5.33	0.02
T4	1.46[a]	0.05[a]	7.98	0.03
T5	1.29[b]	0.04[b]	6.18	0.02
T6	1.29[b]	0.04[b]	6.52	0.02
T7	1.42[a]	0.06[a]	7.11	0.04
Grand Mean	1.32	0.05	6.63	0.03
SEM(±)	0.05	0.00	0.09	0.00
CV, %	47.95	11.29	17.58	27.67
F- Test	*	*	**NS**	**NS**

**: Significant at 5% level of significance; NS: Non-significant*

Root Length and Root Fresh Weight

Media had no significant effect on root length and root fresh weight. Greater values for soil + compost and peatmoss, however, were slightly observed. However, a study

conducted by (Abbey et al., 2012) suggested that increasing the proportion of vermicompost in coir leads to the increase in fresh weight of Swiss chard.

CONCLUSION AND RECOMMENDATION

Considering all growth variables together, cocopeat proved to be the best medium for yielding healthy and uniform cauliflower seedlings, particularly for germination and early growth. Cocopeat + vermicompost and cocopeat + peatmoss performed equally well and could provide balanced physical and nutrient properties. Soil and soil + compost resulted in higher stem strength and biomass production but had a low germination rate and lower uniformity. These findings identify the use of well-aerated, pathogen-free, and lightweight media as an important component for cauliflower seedlings in nursery production. Thus, cocopeat-based media can be recommended for commercial nursery operations in Nepal where input quality and uniform seedling production are priorities.

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Molecular Characterization, Biochemical Isolation and Identification of Salmonella species from Poultry Liver and Fecal Samples at Dinajpur, Bangladesh

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ABSTRACT

Poultry products are the main means of transmission for Salmonellosis, a significant foodborne infection in the world. The purpose of this work was to separate, biochemically identify, and molecularly describe Salmonellosis from samples of poultry feces and liver. A total of 150 samples (50 livers, 100 cloacal swabs) were collected from Dinajpur broiler farms and transferred to the Department of Microbiology, HSTU, Dinajpur, in an ice box with PBS by maintaining aseptic conditions. The samples were streaked in Nutrient Agar 37°C following incubation for 24 hour and sub-cultured on selective media MacConkey Agar at 37°C for 24 hours. Then Salmonella was identified in Gm staining technique. Then Colonies were streaked to S.S Agar(Salmonella Shigella Agar) and finally biochemical tests like Motility Indole Urease (MIU), Simmons citrate, Indole, Methyl Red, and Triple Sugar Iron (TSI) utilization were positive. Then Serological test was performed, followed by PCR-based confirmation including genomic DNA isolation and gel electrophoresis. Isolates confirmed as Salmonella were serotyped and further characterized by Polymerase Chain Reaction (PCR) targeting the invA genus-specific gene. The overall prevalence of Salmonella was 13.3 %, with a higher isolation rate from fecal samples (14%) than liver samples (12%).More poultry fecal and liver samples will be studied in future to carry out research.

Keywords: Biochemical identification, invA gene, poultry, PCR, Salmonellosis

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INTRODUCTION

Salmonella is a Gram-negative, facultatively anaerobic bacterium belonging to the family Enterobacteriaceae. It mostly contains two species: *Salmonella Enterica* and *Salmonella Bongori.* Over 2500 serotypes of the genus Salmonella have been identified globally to date, and many of them have the potential to infect both people and animals (Berhanu and Fulasa, 2020). Most human cases of salmonellosis are caused by *Salmonella enterica ser. Enteritidis (S. Enteritidis) and Salmonella enterica ser. Typhimurium (S. Typhimurium)* which are members of the non-typhoidal Salmonella group (NTS). Globally, non-typhoidal Salmonella is responsible for roughly 93 million cases of gastroenteritis and 155,000 fatalities annually (Majowicz *et al.,* 2010). Salmonellosis is a zoonotic food-borne enteric infection that has great economic value in the animal market, notably in the chicken business (Li *et al.,* 2020). Among animals that produce food, poultry is the primary reservoir for several non-typhoidal Salmonella (NTS) serotypes. Epidemiologically relevant NTS serotypes include *S. Typhimurium, S. Enteritidis, S. Heidelberg, and S. Newport.* In North America and Europe, *S. Enteritidis* dominated the egg-borne transmission of infection to humans, whereas *S. Typhimurium* was the predominant serovar linked with external egg contamination in Australia (Howard *et al.,* 2011). Poultry birds commonly operate as asymptomatic carriers of *S. enteritidis* with the bacteria colonizing the gastrointestinal tract and later infecting systemic areas such the liver, spleen, and ovaries (Gantois *et al.,* 2009). *Salmonella enterica* and *serovar Enteritidis (S. enteritidis)*, two of the approximately 2,600 serovars, have become the most common cause of human salmonellosis and are often linked to the consumption of contaminated poultry products, especially eggs and undercooked meat. Edible organs and, in the case of laying hens become contaminated as a result of this systemic invasion. Fecal shedding also adds to environmental contamination and horizontal transmission among flocks (Dunkley *et al.,* 2009). The rise of multi-drug resistant (MDR) Salmonella resistance to clinically important antimicrobial drugs hampers therapy and pro-phylaxis. This raises infection-related morbidity and mortality, while also raising healthcare and economic expenses (Gong *et al.,* 2013). Bio-film generation by bacteria such as Salmonella is a key virulence mechanism that aids evasion of human immunity and resists drug penetration. Consequently, there is a significant risk to both the food sector and public health (Harrell *et al.,* 2021).

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MATERIALS AND METHODS

Collection of samples

A total of 150 samples were collected as part of the study population during the September to December 2025 period in the Dinajpur district, namely in the vicinity of the Hajee Mohammad Danesh Science and Technology University (HSTU) University. Only 50 liver samples and 100 fecal(Cloacal swabs) samples were collected from the vicinity of Hajee Mohammad Danesh Science and Technology University in Dinajpur during the first stage of sample collection. The Phosphate Buffer Saline (PBS) Solution was made to keep the sample safe while it was being transported in a plastic zipper. For microbiological analysis, the samples were sent to the Department of Microbiology at HSTU, Dinajpur, in an ice box with PBS to ensure aseptic conditions.

PBS Preparation

Isolation and biochemical identification of bacteria

Samples were collected from broiler farms in Dinajpur and brought to the Department of Microbiology, HSTU, Dinajpur, in an aseptic ice box containing PBS. The obtained samples were prepared and cultured on nutrient agar at 37°C for 24 hours, after which samples indicating growth were selected for isolation and those without growth were rejected. The isolates were analyzed by morphology and staining to separate Gram-negative and Gram-positive bacteria; Gram-positive isolates were rejected while Gram-negative isolates were put to further culture on MacConkey agar. To isolate Salmonella species, a loopful of enriched solution was streaked in Mac-Conkey agar and incubated at 37°C for 24 hours.

Table 1. PBS Preparation for poultry fecal and liver sample collection

Ingredients	Amount (per 1 L PBS)
NaCl	8.0 g
KCL	0.2 g
Na_2HPO_4	1.44 g
KH_2PO_4	0.24 g
Distilled Water	Up to 1 Liter

. Presumptive Salmonella colonies showed as colorless or pale colonies on MacConkey agar and were subjected to Gram staining, which revealed Gram-negative rods. Before conducting biochemical assays including Motility Indole Urease (MIU), Simmons citrate, Indole, Methyl Red, and Triple Sugar Iron (TSI) utilization, colonies

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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were monitored and sub-cultured on selective media Salmonella Shigella (SS agar) at 37°C for 24 hours. Serological assays were used to establish the presence of bacteria, and then PCR-based confirmation using gel electrophoresis and genomic DNA extraction was carried out. Virulence genes will be identified in the future with more sample collections and antibiotic sensitivity tests will also be carried out using the disc diffusion method, leading to the final discovery of antibiotic resistance genes. Based on the colony morphology of the putative bacteria identified on the different selective agars, additional characterization was attempted utilizing staining techniques. Gram's staining was used to classify the isolates for the first time, confirming that they were Gram-negative bacilli. To detect their motility and flagellar arrangement, which is a major diagnostic feature, both flagellar staining using malachite green and the hanging drop slide technique were conducted. The positive isolates identified as Gram-negative bacilli were then selected for further inspection, ensuring that a pure culture from each was grown on appropriate selective media for future confirmation testing.

Picture 1. (Simmons Citrate-Positive) (Indole -Negative) (MIU) -Positive)

The Gram-negative isolates underwent a thorough battery of biochemical assays for final identification after the isolation and staining processes. Fructose, galactose, glucose, sucrose, and mannose were used to evaluate the isolates' capacity to ferment carbohydrates. Motility Indole Urease (MIU), Simmons citrate, Indole, Methyl Red, and Triple Sugar Iron (TSI) utilization were among the routine enterobacterial tests carried out. The specific combination of observed reactions typically positive for glucose fermentation (with gas), MR, TSI (alkaline slant/acid butt with H2S), citrate utilization, and ornithine decarboxylase, but negative for VP, indole, and urease provided a conclusive biochemical profile consistent with *Salmonella* species. Following biochemical identification, the putative *Salmonella* isolates were verified serologically using a slide agglutination test. One drop of the isolate's overnight broth culture and one drop of Polyvalent O antisera, which contains antibodies against *Salmonella's* common somatic (O) antigens, were combined on a clean glass slide for

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

this process. After that, the slide was gently rocked for up to two minutes, and any apparent agglutination; the clumping of bacterial cells indicated a successful antigen-antibody response. Before moving on to more precise serotyping to identify the *Salmonellosis,* a positive result with the polyvalent antisera offered serological evidence that the isolate belonged to the genus *Salmonella*.

Picture 2. (Methyl Red-Positive) (TSI-Positive) (PCR-DNA Extraction)

Molecular characterization of virulence genes

To enable molecular characterization, bacterial genomic DNA was extracted from the pure cultures after serological confirmation. Two procedures were employed: a standard boiling method and a commercial kit protocol conducted according to the manufacturer's instructions. For the boiling procedure, 1.5 mL of a pure bacterial culture was transferred to a micro-centrifuge tube and pelleted. The pellet was then resuspended in 100 µL of nuclease-free distilled water. The suspension was exposed to boiling in a hot water bath at 100°C for 10 minutes to lyse the bacterial cells and denature proteins. Immediately after boiling, the tube was transported to an ice box for 30 minutes to induce a cold shock, which aids in precipitating cellular debris. The lysate was then centrifuged at 10,000 rpm for 10 minutes to separate the cellular fragments from the soluble DNA. After the genomic DNA was extracted, the supernatant was carefully collected and put into a new microcentrifuge tube to be stored at -20°C until further PCR analysis. A modified boiling cell approach was used to extract the genomic DNA from *Salmonella* isolates (Pui *et al.,* 2011). Cultured Salmonella colonies were injected into 1 mL of Luria-Bertani broth and incubated at 37◦C for 24 h. After centrifuging the bacterial culture for three minutes at 15,000 x g, the supernatant was disposed of. The pellet was resuspended in 500 µL of nuclease-free water, heated at 100◦C for 10 min, and then rapidly cooled to 4◦C for 10 min. Following this, the samples were centrifuged at 15,000 x g for 3 min. After that, the genomic DNA-containing supernatant was moved to a new Eppendorf tube and kept at 20°C until PCR amplification. Using spectrophotometry (Quawell, UV-Vis

Spectrophotometer Q5000) at 260 and 280 nm, the concentration and purity of the DNA extracted from the Salmonella culture were measured; acceptable ratios ranged from 1.6 to 2. One virulence gene *(invA)* was amplified by PCR using a Bio-Rad T100TM Thermal Cycler (Bio-Rad, USA). Five microliters of Master Mix (Invitrogen), one microliter of forward primer, one microliter of reverse primer, one microliter of DNA template, and two microliters of nuclease-free water (Ambion, REF: AM9932) were all included in each 10-microliter reaction mixture. PCR was performed to amplify the virulence genes of *Salmonella*. The Primer *InvA* -F(5'-CGGTGGTTTTAAGCGTACTCTT-3') and *InvA* -R (5' CGAATATGCTCCACAAGGTTA-3'). The cycling conditions included pre-denaturation at 95◦C for 5 min, 95◦C for 3o second, 60◦C for 30 seconds, 72◦C for 60 second with 35 cycles, 72◦C for 7 minutes and 4◦C with infinite. 1.5% agarose gels made in 0.5X TBE (Tris-Borate-EDTA) with 2 µl ethidium bromide (EtBr) were used to separate the amplified PCR products. A 1000 bp DNA ladder was loaded with microliters of PCR product combined with loading dye. DNA bands were visible under

a Ultra Violet (UV) transilluminator (Platinum Q9, Uvitec Cambridge) after the gel electrophoresis was carried out at 90 V for 60 minutes. In order to use agarose gel electrophoresis to analyze PCR products, 0.75 grams of agarose powder were dissolved in 5 milliliters of Tris-Acetate-EDTA Buffer (TAE) buffer and 45 milliliters of distilled water to create a 1.5% gel solution. The mixture was then heated in a microwave until the agarose was completely dissolved. In Micro wave at 30 second interval the solution was mixed by shaking with hands for four times at similar time interval. After a little cooling, a DNA-intercalating dye was added, and the mixture is then poured into a casting tray using a comb to create wells. Once the gel solidified, it was placed into an electrophoresis chamber filled with TAE buffer that submerges the gel, and the PCR products, mixed with a loading dye, were carefully pipetted into the wells alongside a DNA ladder for size comparison. The lid was secured, and an electric current was applied, causing the negatively charged DNA fragments to migrate through the gel matrix towards the positive anode; smaller fragments move faster and travel farther than larger ones. Once the dye front moved far enough, the power was switched off, the gel was examined under a UV lamp, and the band pattern that result was examined to verify the size and existence of the amplified DNA targets from the initial PCR reaction.

Statistical analysis

The collected data were processed and analyzed with Microsoft Excel.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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RESULTS AND DISCUSSION

Identification of bacteria by cultural, morphological and bio-chemical properties

This study analyzed 150 samples (100 fecal, 50 liver) for *Salmonella* using culture on MacConkey and Salmonella Shigella agar followed by biochemical confirmation. While initial growth on MacConkey agar suggested 33 positives, biochemical tests, the definitive method, confirmed only 20 samples (14 fecal and 6 liver) as true positives. The final overall prevalence from this step-by-step confirmation procedure was 13.3%, with a slightly higher confirmed rate in fecal samples (14%) than in liver samples (12%).

Table 2. Table of Fecal and Liver Samples

Category	Total Samples	Positive Samples on Culture in MacConkey Agar	Positive Samples on Culture in Salmonella Shigella Agar	Confirmed by Biochemical Test	Prevalence %
Fecal (Cloacal swabs)	100	22	17	14	14%
Liver	50	11	8	6	12 %
Total	150	33	25	20	13.3%

This table illustrates the variability of culture-based screening by describing a rigorous diagnostic procedure in which 150 samples were cultured on selective media. MacConkey agar initially suggested 33 positives, but the more selective Salmonella Shigella agar only detected 25. Only 20 of these presumed isolates were conclusively identified as true *Salmonella* by biochemical confirmation, which was a crucial step that effectively eliminated over one-third of the initial candidates as false positives and highlighted the need for confirmatory testing. This multi-stage verification ultimately yielded a true, confirmed overall prevalence of 13.3%, with a slightly higher rate in fecal samples (14%) than in liver samples (12%), reflecting the expected biological distribution of the pathogen.

The bar chart (Figure 1) illustrates a multi-stage diagnostic process for detecting *Salmonella* in 150 samples (100 fecal, 50 liver). The most presumptive positives (33

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

total) were found in the initial culture on MacConkey agar. These were further refined by the more selective Salmonella Shigella agar (25 total), and biochemical tests ultimately produced 20 true positives. The overall prevalence was 13.3% as a result of this stepwise confirmation. Fecal samples had a marginally higher confirmed infection rate (14%) than liver samples (12%).

Picture 3. Picture showing *Salmonella* Positive in S.S. Agar

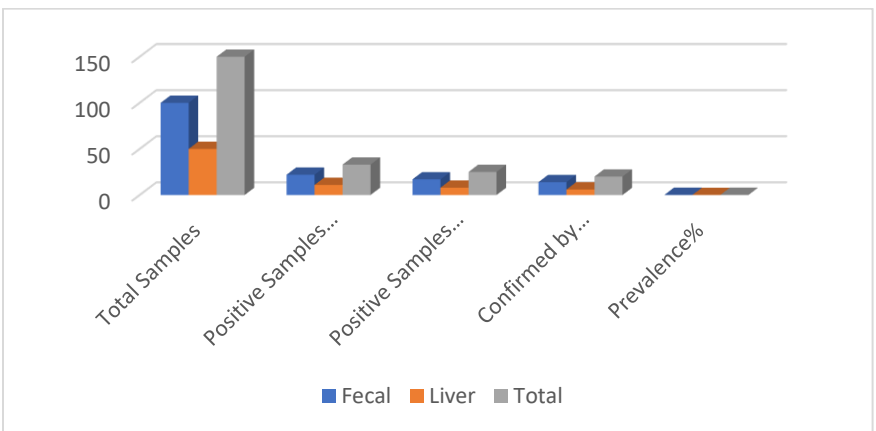

Figure 1. Bar showing Liver and Fecal positive samples

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Molecular Confirmation by PCR

The isolation results from poultry fecal and liver samples were graphically compared in the chart, which indicates that culture on MacConkey Agar produced the greatest number of positive samples for both sample types, followed by Salmonella Shigella Agar and biochemical confirmation produced the most conclusive but lowest count. These confirmed cases used to calculate the final prevalence percentage, which shows the true infection rate lower than the initial culture-positive results.

Only few samples seem to be better for PCR as *Salmonella* appear as transparent or translucent, colorless colonies, often with a black center on Salmonella Shigella Agar. PCR was performed however it gave bands not in convincing way. The PCR enable to find the expected band however it might be due to low sample size for PCR or denaturation and annealing might have significantly affect the outcome of a PCR test for *Salmonella* in poultry samples, and problems with these steps are a common reason for non-clear bands especially when dealing with complex sample matrices. In order to obtain positive *Salmonella* genes in PCR as well as specific *Salmonella species* as specified in the experiment, more broiler samples from different regions will be gathered in the future, and numerous PCRs will be carried out following positive biochemical reactions. For the molecular detection of *Salmonella* in poultry fecal samples via PCR, the *invA* gene primers would be gold-standard tool, targeting a conserved sequence essential for the bacterium's invasion of host cells.

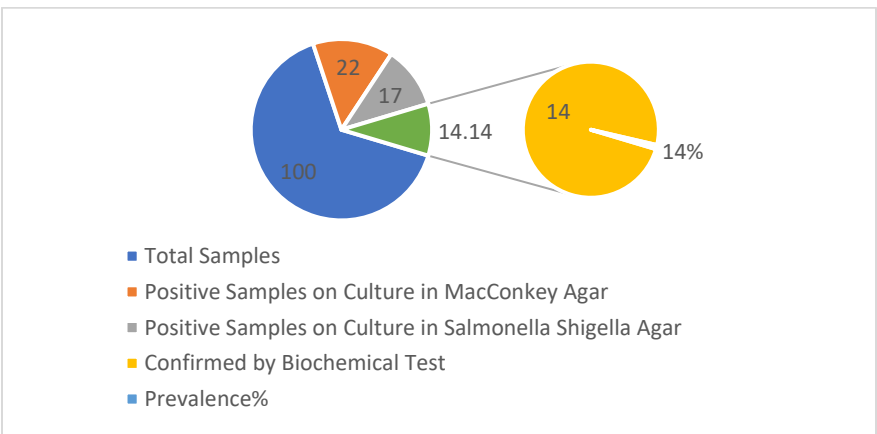
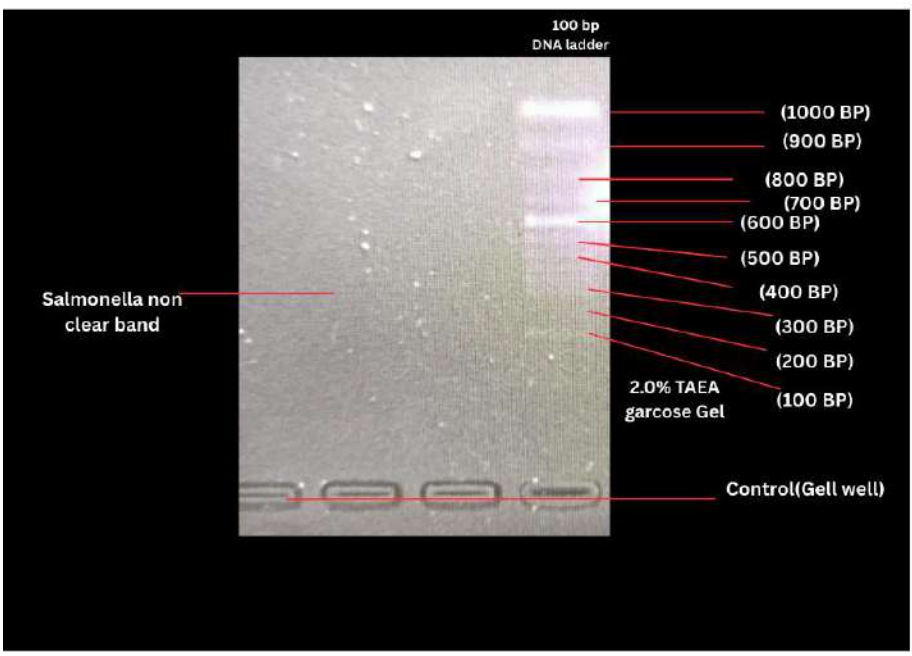


Figure 2. Pie chart showing positive Fecal and liver sample

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

The prevalence of *Salmonella* found in this study is in close agreement with reported rates as reported by (Shehata 2019) in Pakistani hatcheries found to be (12.5%) and Egyptian researcher (Barac *et al.,* 2024) reported in hatcheries to be (10%) prevalence. The 13.3% prevalence of *Salmonella* observed in this study is consistent with international reports placing it within a well-documented global range for poultry. Ferreira (2021) reported 12.8% of *Salmonella* Prevalence in Brazilian broiler flocks. Kuan (2017) reported 14.2% prevalence rate in Malaysian markets. India Kumar *et al.,* (2020) and Wangy *et al.,* (2018) reported nearly identical figures of *Salmonella* Prevalence rate as 13.5% and 13.8%, respectively. This prevalence rate of 11-16% is further supported by research from Odonkor *et al.,* (2018) in Nigeria (15.0%), Padungtod *et al.,* (2006) in Thailand (11.4%), Rahimi *et al.,* (2014) in Iran (14.1%), Islam *et al.,* (2021) in Bangladesh (16.3%), and finally Wasyl (2012) reported in Poland (11.8%) in Prevalence. All this prevalence from this literature supports the result of Prevalence in this Experiment. The challenge of *Salmonella* contamination is a persistent and widespread issue in the poultry industry across diverse geographic and production systems.



Picture 4. PCR for Identification of Salmonellosis

CONCLUSION

In the biochemical and laboratory test it showed positive and even in Salmonella Shigella Agar it showed positive result for the fecal samples. This study successfully isolated *Salmonella* from poultry samples with an overall prevalence of 13.3%, but highlighted a critical methodological discrepancy where biochemically confirmed However; isolates failed to yield more convincing positive PCR results with their band for the *invA* gene. The bands seem to be non-convincing. This might be potentially attributable to the small number of samples processed by PCR or technical issues during the denaturation and annealing steps that can lead to such results and underscores the challenges in molecular characterization from complex matrices like poultry feces and liver. In future more sample sizes with various regions would be collected so, that might give a convincing positive result of PCR .

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Farmers' Perceptions, Knowledge and Practices for Nematode Management in Tomato Farms at Meghang, Nuwakot

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ABSTRACT

This study was carried out in Meghang Rural Municipality, Nuwakot, Nepal, to assess farmers' knowledge, perceptions, and practices regarding nematode management in tomato cultivation. The research was conducted from April 28 to June 20, 2025, covering the tomato cropping cycle to observe nematode symptoms, progression, and management outcomes. The Primary data were collected through field visits and semi-structured interviews using a simple random sampling method. A total of 100 tomato growers were selected across different wards. Findings revealed that 79% of farmers considered nematodes a growing problem, and average yield loss was reported to be 30%. Only 17% of farmers demonstrated high knowledge of nematode management. Traditional practices such as application of animal manure were most common (67%), while integrated pest management (IPM) was rarely practiced. Some farmers adopted crop rotation with onion, garlic, and legumes, common trap crops used by farmers was marigold, velvet been and rapeseed. A few used grafted seedlings as a management strategy. Field monitoring was weak, with less than 27% of farmers conducting regular inspections. Chemical control was widely adopted (88%), yet only 12% of farmers rated it as highly effective. Awareness of IPM was particularly low, with 80% reporting insufficient knowledge. Farmers have limited awareness and low adoption of sustainable nematode management practices. Capacity building, farmer training on IPM, promotion of resistant varieties and grafted seedlings, and improved access to non-chemical alternatives are urgently required. Strengthening institutional support can help minimize nematode related yield losses and improve tomato productivity.

Keywords: IPM, management practices, nematode infestation, yield loss

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INTRODUCTION

In Nepal, vegetables are considered a significant crop in terms of their food and economic value (Gurung *et al.,* 2016). In comparison to cereal crops, vegetables have higher rates of commercialization and a higher cost-benefit ratio (Rai *et al.,* 2019). Among different vegetables cultivated in Nepal, tomato (*Solanum lycopersicum*), are grown largely in a variety of environmental conditions. It is the second most important vegetable crop after potato in the world with the production of 186.12 million tons of fresh fruit in 4.92 million hectares of land and achieving average yield 37.84 tons per hectare (chaudhary,2024). Whereas in Nepal, tomato is ranked the third most commercially grown vegetable after cauliflower and cabbage which cultivated in total 22,911 hectares of land and produces annually 4,22,703 tons with an average productivity 18.45 ton per hectare (MoALD 2023). Tomatoes are susceptible to biotic and abiotic stress throughout their development stage (Adhikari & Shrestha,2020). Tomatoes are highly susceptible to a wide range of pests and diseases such as tomato leaf miner (Tuta absoluta), bacterial wilt (Ralstonia solanacearum), late blight (Phytophthora infestans), and root-knot nematodes (Meloidogyne spp.), which significantly reduce yield and quality (Sharma & Bhattarai,2021). Tomato plants can be susceptible to root-knot nematodes (Meloidogyne spp.), which are microscopic, roundworms that inhabit the soil. In presence of large population, they cause significant yield reduction (Baidya, 2013). Root-knot nematode in tomato is reported to cause yield reduction in a considerable amount world widely including the symptoms ranging from stunted growth, galled roots, chlorosis, wilting and eventually death of the host. Studies reported a 26.5 to 73.3 % reduction in yield in tomato due to root-knot nematode causing about $125 billion in annual losses world widely (Rawal, 2020). A nematode is the major biotic factor causing intolerable and uncontrolled stress which is also a reason for the low yield production in tomato (Ansari and Asif, 2016). In Nepal, nematode is reported from the districts such as Kathmandu, Bhaktapur, Lalitpur, Kavre, Chitwan, Dhankuta, Palpa and Jhapa suggesting 30% yield reduction in tomato cultivation in polyhouse (Rawal,2020).

MATERIALS AND METHODS

Study area

The study was conducted in the tomato growing region in Meghang rural municipality, Nuwakot District, Nepal. The area is characterized by mid-hill agroecology, where tomato cultivation is widespread as both subsistence and commercial farming.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Sampling

A total of 100 tomato farmers were purposively selected using simple random sampling across five wards. Each ward contributed 15–25 respondents depending on the number of tomato growers.

Data collection

Primary data were obtained through structured questionnaires, semi structured interviews, and field observation. Questions focused on farmers' demographic profiles, perceptions of nematodes, knowledge of symptoms, and management practices adopted. The data entry and analysis were conducted using Microsoft excel. The primary data collected from the survey was entered and coded into a Microsoft excel sheet. The final data was analyzed and presented in the form of a bar diagram, pic charts, tables, and graphs using Microsoft excel.

RESULTS AND DISCUSSION

Years of tomato cultivated by respondents

From the survey, 44% of the respondents had been cultivating tomatoes for 5–10 years, making it the largest group.35% had experience ranging from 1–5 years, indicating a considerable proportion of moderately experienced farmers.8% of the respondents had been involved in tomato farming for less than 1 year, representing the least experienced group.13% had more than 10 years of experience in tomato cultivation.

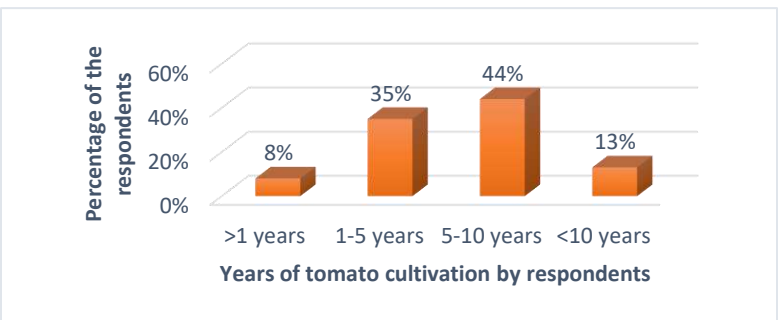

Figure 1. Years of tomato cultivated by respondents

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Seed source of the respondents

The seed source for most respondents, 82 percent, was nearby Agrovets, while 6 percent used self-preserved seeds. The remaining 7 percent obtained seeds from varietal trials, agricultural officers, and neighbors and remaining 5 percent was collected seeds from government offices . Most of the respondents used the sirjana varieties of tomato.

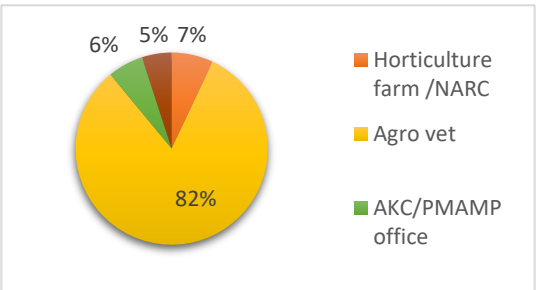

Figure 2. Seed source of the respondents

Methods of irrigation

The method of irrigation was categorized into four group i.e., manual, furrow, drip and rainfed irrigation. According to Figure 8, 25 percent of respondents used manual irrigation, while 48 percent had access to drip irrigation. 10 percent of the respondents relied solely on rainfall, without adopting any irrigation methods, and 17 percent used furrow irrigation. This study suggests that respondents was aware of the advantages of drip irrigation, which minimizes nutrient loss and reduces weed growth in fields.

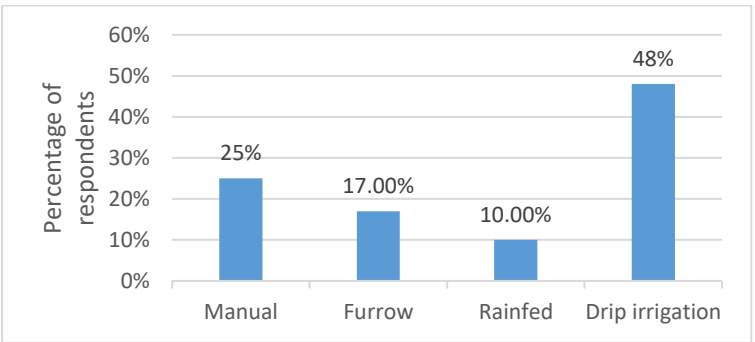

Figure 3. Methods of irrigation used by respondents

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Respondents get information on nematode identification and management

Respondents received information on nematode identification and management from various sources. About 40% of the respondents reported getting information from agrovets, 25% from neighbors and other farmers, 15% from other unspecified sources, 10% from mass media, and another 10% from Agricultural Knowledge Centers (AKC), Prime Minister Agriculture Modernization Project (PMAMP), or Farmer Field School (FFS) facilitators. The findings indicated that agrovets were the primary source of information on nematode identification and management for most respondents 40.

Respondents training on tomato cultivation and nematodes management

Respondents had received training related to tomato cultivation and nematode management from various sources. Among them, 44% were trained by other organizations, 24% through Farmer Field Schools (FFS), and 16% each from Agricultural Knowledge Centers (AKC) and the Prime Minister Agriculture Modernization Project (PMAMP). The findings revealed that 44% of the respondents received training from other organizations, which may have included NGOs, cooperatives, or private sector actors. Farmer Field Schools (FFS) accounted for 24% of the training sources, indicating their important role in hands-on, participatory learning approaches. Meanwhile, only 16% of the respondents were trained by AKC and another 16% by PMAMP, showing relatively limited involvement of government-led institutions in capacity building on tomato and nematode management.

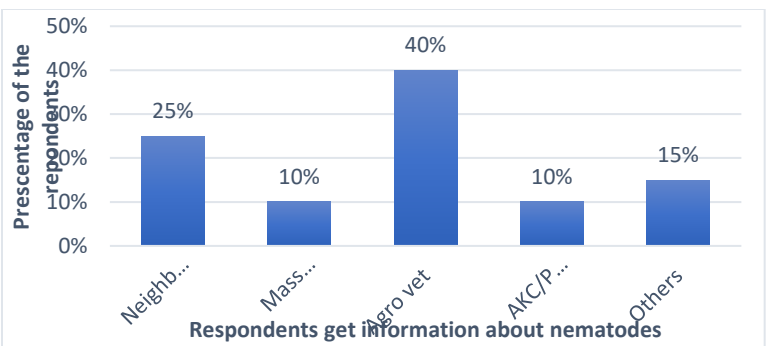

Figure 4. Respondents gets information about nematodes

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

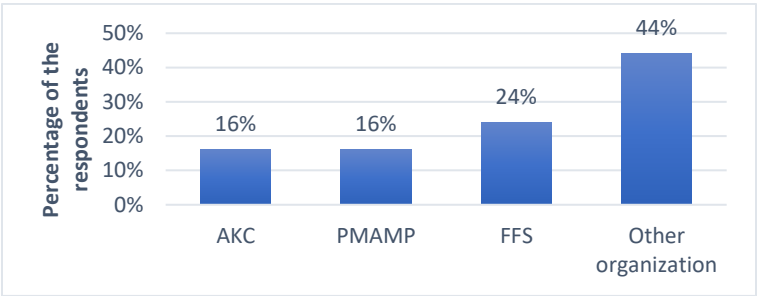

Figure 5. Training on tomato cultivation and nematodes management

Nematode infestation is a serious problem as compared to other pests In comparison to other pests, 27% of the respondents considered nematode infestation to be a very serious problem, 48% viewed it as somewhat serious, and 25% believed it was not a serious issue. The findings showed that nematodes were perceived as a significant pest problem by the respondents. A combined 75% of the farmers considered nematode infestation to be either very serious or somewhat serious, indicating a general awareness of the damage caused by nematodes in tomato cultivation. They found that while many farmers were aware of root-knot nematodes (RKN), knowledge about their biology, damage symptoms, and control was limited. For instance, some farmers misdiagnosed nematode damage as water stress or nutrient deficiency (Khanal et al.,2019).

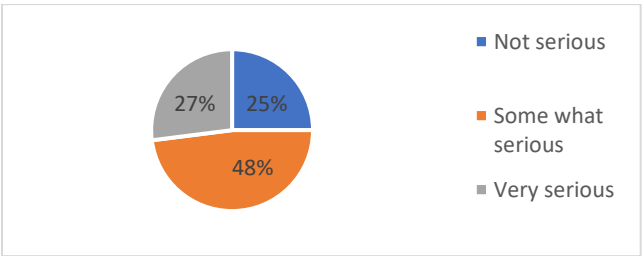

Figure 6. Nematode infestation is a serious problem as compared to other pests

Yield loss due to nematode infestation

Respondents reported varying levels of yield loss due to nematode infestation. About 38% experienced a yield loss between 10%- 30%, while 30% reported a loss of 30%-

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

50% ,23% suffered less than 10% loss, and only 9% faced losses exceeding greater than 50% loss. Studies report ,In Nepal, farmers have reported losses mostly in the range of 10–30%, with some cases exceeding 50% under severe infestation (NARC, 2019). field study in Chitwan, Nepal, showed that root galling led to up to 40% reduction in fruit yield in tomato.

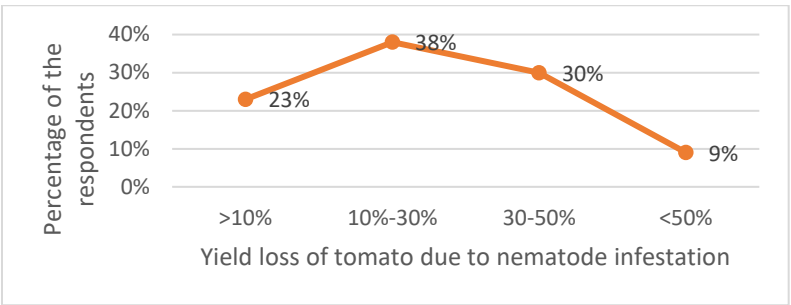

Figure 7. Yield loss due to nematode infestation

Knowledge of respondents about nematodes

Regarding knowledge about nematodes, 46% of the respondents were somewhat knowledgeable, 37% were not knowledgeable, and only 17% were very knowledgeable. The results showed that nearly half of the respondents 46% possessed some knowledge about nematodes, indicating a basic understanding of the pest and its effects. However, a substantial portion 37% lacked knowledge, which could hinder effective identification and management practices. Only 17% of respondents were very knowledgeable, likely due to access to training, experience, or extension services. A comparable study by **Nakarmi et al. (2025)** in central Nepal found that although farmers had heard of root-knot nematodes (Meloidogyne spp.), many confused nematode damages with nutrient deficiencies or drought stress, showing gaps in practical understanding (khanal *et al.,*2019).

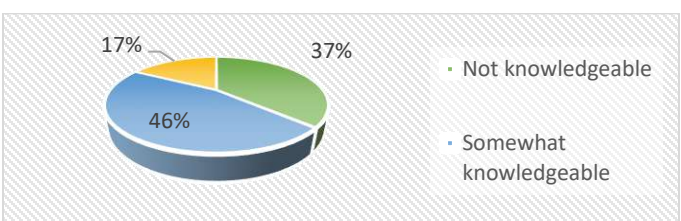

Figure 8. Knowledge of respondents about nematodes

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 1. Practices adoption by farmers for nematode management

Management practices	Adoption by Farmers (%)
Crop rotation	Cowpea/Soybean–Tomato: 40% Onion/Garlic–Tomato: 38% Mustard–Tomato: 22%
Organic amendments	Animal manure: 67% Oil cake: 23% Compost: 12% Neem cake: 5%
Intercropping / Trap cropping	Mustard: 35% Marigold: 34% Cowpea: 17% Onion/Garlic/Radish: 14%
Grafted seedlings	15%

Cultural method adopted by farmers

The survey revealed diverse strategies employed by tomato farmers to manage nematode infestations. **Crop rotation** was common, with 40% practicing cowpea/soybean–tomato rotation, 38% onion/garlic–tomato, and 22% mustard–tomato. Leguminous crops suppress nematode populations, while alliums provide nematocidal compounds, and mustard acts as a biofumigant (Chitwood, 2002). Adoption of **resistant varieties** was negligible, as all farmers cultivated the 'Sirjana' variety despite awareness of resistance benefits. For **organic amendments**, 67% applied animal manure, followed by oil cake (23%), compost (12%), and neem cake (5%). Prior studies report neem and mustard oil cakes significantly reducing *Meloidogyne* spp. infestation (Khan et al., 2020; Bhat et al., 2021). **Intercropping/trap cropping** included mustard (35%), marigold (34%), cowpea (17%), and alliums or radish (14%). Marigold and mustard are recognized for nematode suppression through bioactive compounds (Hooks et al., 2010). Use of **grafted seedlings** was limited (15%), although grafting onto resistant rootstocks is proven to reduce nematode damage and enhance yield.

Biological / Botanical method

From the survey, Among the fungal biocontrol agents used by farmers for nematode management in tomato, the most commonly identified were *Trichoderma spp.* and *Purpureocillium lilacinum*. *Trichoderma spp*. are widely recognized for their antagonistic properties against a variety of soil-borne plant pathogens, including nematodes. *Purpureocillium lilacinum* is a specialized fungal biocontrol agent

effective against the egg and juvenile stages of root-knot nematodes (Khan *et al.,* 2020). The bacterial biological control agents commonly used for nematode management in tomato include *Bacillus subtilis* and *Pseudomonas fluorescens*. The strain *Bacillus subtilis* CRB7, when applied as a drench, reduced gall formation by up to ~ 85.8 % under protected cultivation, while increasing tomato yield by ~ 15–30 % in successive trials (Gowda et al., 2024). *Pseudomonas fluorescens* also acts as a biocontrol agent by producing antibiotics, siderophores, and hydrogen cyanide, which can suppress nematode activity. According to survey the respondents of Meghang used Various botanicals, such as neem (Azadirachta indica), marigold (Tagetes spp.), mustard (Brassica spp.), garlic (Allium sativum), and castor (Ricinus communis), which can inhibit nematode development, reduce egg hatching, and suppress population density.

Physical method

Among the physical control practices adopted by respondents, the most commonly reported method was soil drying 52%, followed by deep ploughing or tillage 44%. Only a small proportion of respondents 4% reported using flooding or waterlogging as a nematode management practice. Farmers practicing soil drying likely expose the infested soil to sunlight during fallow periods, which can help reduce nematode survival due to increased temperature and decreased moisture conditions unfavorable for nematode activity and reproduction. Deep tillage practice helps in exposing nematode eggs and juveniles to desiccation and predators and also disrupts their lifecycle by disturbing their habitat. Two rounds of deep summer ploughing reduced nematode infestation by 40–50% (Barker, 2013).

Chemical method

From the survey, A large majority of respondents 88% reported using chemical nematicides for managing nematodes in tomato fields, while only 12% indicated that they did not use any chemical nematicides. Commonly used nematicides in Nepal include products such as Nemazone, Carbofuran, and Ethoprophos, which target nematodes by disrupting their nervous systems or reducing egg hatch and mobility.

Name of chemical nematicides used by respondents

Respondents reported using several types of chemical nematicides in tomato fields to control nematodes. The use of these nematicides reflects the range of chemical options

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

available to farmers in Nepal for managing nematodes. Ethoprophos (Nemazone) is a broad-spectrum organophosphate nematicide known for its effectiveness against nematodes and other soil pests. It acts as a contact and systemic poison. Fosthiazate (Nemathorin) is a systemic nematicide that offers both protective and curative action. It is effective when applied at transplanting and has shown strong activity against root-knot nematodes. Fluensulfone (Nimitz) is a newer generation, non-fumigant nematicide that has gained attention for its low toxicity profile and specificity to nematodes.

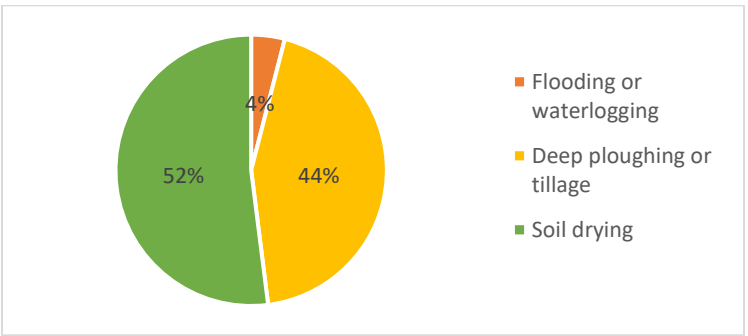

Figure 9. Physical control method used by respondents

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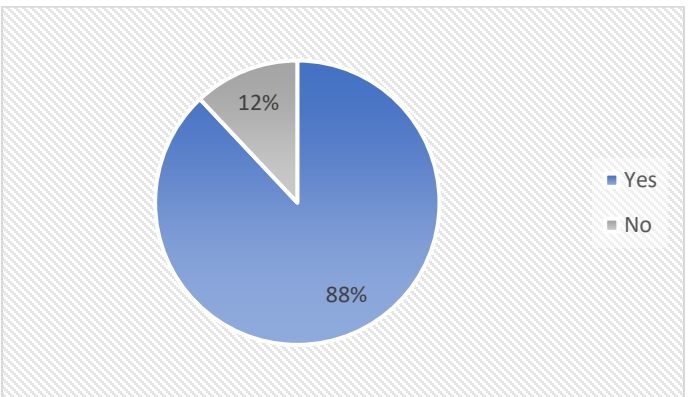

Figure 10. Chemical nematicides used by respondents

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Integrated pest management (IPM)

From the survey, only 20% of respondents reported receiving training or extension support on Integrated Pest Management (IPM) practices for nematode management in tomato cultivation, whereas a majority of 80% had not received any such support. The low percentage of farmers receiving training or extension services on IPM, a significant gap in knowledge transfer and capacity building in the study area.

Table 2. Benefits experienced by respondents when using IPM practices

S.N	Benefits
1	Long-term control
2	Improved soil health
3	Better yields
4	Safe for environment and human health
5	Reduced input cost

This ranking order flows from sustainability → soil foundation → yield outcome → safety → cost saving.

Table 3. Challenges faced by respondents while applying IPM method for nematodes control

S.N	Challenges faced by respondents
1	Limited Knowledge and Awareness about Nematodes and IPM Techniques
2	Lack of Technical Training and Practical Demonstration
3	Misdiagnosis of Nematode Symptoms
4	Inadequate availability of IPM inputs
5	Higher labor, time, and land requirements

This ranking flows from knowledge → skills → diagnosis → access → resource intensity.

CONCLUSION

The study identified root-knot nematodes as the most damaging pest affecting tomato production in Meghang, Nuwakot. Although farmers are aware of their impact, effective management practices remain limited, with heavy reliance on chemical nematicides such as ethoprophos, carbofuran, and nemathorin. The use of cultural, biological, and botanical methods such as crop rotation, neem, banmara, titepati, garlic extracts, and organic amendments is minimal. Limited awareness, inadequate training, and poor access to resources hinder the adoption of sustainable practices. Therefore, an integrated pest management (IPM) approach that combines chemical, cultural,

biological, and botanical strategies is essential. Strengthening farmer capacity, improving input access, and fostering collaboration among contributor can enhance sustainable tomato production and soil health in Meghang.

SUGGESTIONS

- Encourage the application of organic soil amendments like neem cake, mustard cake, animal manure, and compost to suppress nematode populations.
- Conduct targeted training and workshops on nematode identification, life cycle, symptoms, and management strategies, with emphasis on root-knot nematodes.

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Effect of Environmental Change on the Welfare Status of Crop Farmers in Kaduna State and Federal Capital Territory, Nigeria

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ABSTRACT

This study investigated the effect of environmental change on the welfare status of crop farmers in Kaduna State and Federal Capital Territory, Nigeria. A multi-stage sampling technique was used to select 198 crop farmers. Primary data were used based on a well-structured questionnaire. The data were analyzed using descriptive statistics, farmer household income exchange, Foster, Greer, and Thorbecke (FGT), and the Probit model analysis. The results show that the mean age was 49 years with approximately farm experience of 12 years. The on-farm household income (74.41%) is the dominant source. The largest expenditure is on production cost (46.97%) reflecting the significant investment required for agricultural activities. Furthermore, majority of the farm households (61.90%) have an income greater than their expenditures, this suggests that they have their welfare condition enhanced. Approximately, 43 (79.63%) of the farm households without secondary income fell below the poverty line. About 161 (81.31%) of the farm households with both primary and secondary incomes were below the poverty line. The significant socio-economic factor and environmental change that influence the welfare status of crop farmers

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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include age, number of years spent in school education, total crop output, change in temperature, reduction in the size of water bodies, and heat waves. The study recommended that climate-smart agriculture training, subsidies for drought-resistant maturing crop varieties should be provided by Government and non-government organizations and establish localized community-based early warning systems in collaborating with NiMet (Nigerian Meteorological Agency) to provide farmers with real-time planting and harvesting schedules.

Keywords: Effect, environmental change, welfare status, crop farmers, probit regression model

INTRODUCTION

Environmental change has become a defining challenge for sustainable development in Nigeria, with far-reaching implications for agriculture and the welfare of farming households. (FAO, 2023). Nigeria's economy and food system remain heavily dependent on agriculture, which employs a substantial proportion of the rural population and contributes significantly to national food security and livelihoods. (FAO, 2023). However, the agricultural sector is increasingly threatened by environmental changes such as climate variability, rising temperatures, erratic rainfall patterns, flooding, drought, land degradation, and desertification. These environmental stressors have intensified in recent decades, posing serious risks to agricultural productivity and farmers' welfare across the country (FAO, 2023; IPCC, 2022).

Farmers' welfare in Nigeria extends beyond income generation to include food security, nutritional status, health outcomes, asset ownership, resilience to shocks, and overall living standards. Environmental change directly affects these welfare dimensions by altering production conditions, increasing uncertainty and risks, and undermining the stability of farm-based livelihoods. (World Bank, 2021). For instance, climate-induced crop failures, livestock losses, and declining soil fertility often result in reduced household income, food shortages, and increased vulnerability to poverty, particularly among smallholder farmers who dominate Nigeria's agricultural landscape (World Bank, 2021).

Nigeria is especially vulnerable to environmental change due to its diverse agro-ecological zones and heavy reliance on rain-fed agriculture. In the northern parts, increasing temperatures and desertification have reduced arable land and intensified conflicts over scarce natural resources. In contrast, the southern regions frequently experience flooding, soil erosion, and waterlogging, which damage crops and rural

infrastructure. These region-specific environmental challenges interact with socio-economic constraints such as limited access to credit, weak extension services, poor rural infrastructure, and low adoption of climate-resilient technologies, thereby exacerbating the welfare impacts on farmers (Nigerian Meteorological Agency [NiMet], 2022). Although Nigerian farmers employ various coping and adaptation strategies such as crop diversification, changes in planting dates, adoption of improved seed varieties, and livelihood diversification the effectiveness of these strategies varies widely (IPCC, 2022). Many smallholder farmers lack the financial, technical, and institutional capacity to adopt sustainable adaptation measures at scale, limiting their ability to protect and improve their welfare in the face of environmental change (FAO, 2023). Consequently, environmental change has emerged as not only an environmental concern but also a major socio-economic and welfare issue in Nigeria.

Environmental change in Nigeria is driven by a combination of natural processes and human-induced activities, including greenhouse gas emissions, deforestation, unsustainable agricultural practices, rapid population growth, and urban expansion. These factors have accelerated climate variability, land degradation, loss of biodiversity, and depletion of water resources across the country. Nigeria is already experiencing higher average temperatures, unpredictable rainfall patterns, prolonged dry seasons, and more frequent extreme weather events such as floods and droughts (IPCC, 2022; NiMet, 2022). Agriculture in Nigeria is highly sensitive to environmental conditions, as the majority of farmers depend on rain-fed production systems and natural resource availability. Changes in rainfall timing and intensity disrupt planting and harvesting schedules, while increased temperatures affect crop growth, pest and disease prevalence, and livestock productivity. Environmental degradation, particularly soil erosion and declining soil fertility, reduces land productivity and increases the cost of maintaining output levels, thereby threatening the sustainability of farm livelihoods (FAO, 2023).

The welfare of farmers in Nigeria is multidimensional and closely linked to agricultural performance. Reduced productivity resulting from environmental change often leads to lower household income, food insecurity, malnutrition, and reduced access to essential services such as healthcare and education. Furthermore, climate-related shocks frequently force farmers to sell productive assets or resort to unsustainable coping mechanisms, which can have long-term negative consequences for household welfare and resilience (World Bank, 2021).

Regional disparities further shape the welfare impacts of environmental change in Nigeria. In the northern zones, desertification and recurrent droughts have undermined

crop and livestock production, contributing to declining rural incomes and heightened food insecurity. In the central and southern zones, recurrent flooding has destroyed farmlands, displaced farming households, and disrupted rural markets. These environmental challenges are often compounded by weak institutional frameworks, limited social protection, and inadequate access to climate information and agricultural support services (National Bureau of Statistics (NBS, 2022).

Several studies indicated that Nigerian farmers adopt various adaptation strategies to cope with environmental change, including mixed cropping, use of early-maturing and drought-tolerant crop varieties, soil conservation practices, and diversification into non-farm activities. While such strategies can mitigate adverse effects, their adoption is uneven and largely influenced by farmers' socio-economic characteristics, access to extension services, education level, and institutional support. In many cases, resource-poor farmers face barriers that limit the welfare benefits of adaptation efforts (FAO, 2023; World Bank, 2021). Nigeria is not immune to the effects of climate and environmental change affecting the rest of the world (Ani et al., 2021). The effects of climate and environmental change are evident throughout Nigeria's vegetative regions. Nigeria's agricultural productivity is increasingly being threatened by environmental change. Some formerly well-drained agricultural plains have recently become inundated, and the region's agricultural activities are negatively impacted by the Sahel and Sudan savannah belts' growing aridity (Ojo and Adebayo, 2012). Other effects of environmental change, such as excessive precipitation, unusual rainfall initiation and cessation, rising temperatures, and changes in relative humidity, pollution, soil degradation, loss of environmental resources have a severe impact on Nigerian agriculture and food systems (Ani et al., 2021). Due to this change, the seasonal cycle of food production and distribution has been disrupted, leading to a shortage of supplies, which has increased food costs and restricted access to food (Oyinloye et al., 2018). Furthermore, climate change has caused food crises in some regions of the world and security issues in other areas as a result of conflict that results from the competition for scarce agricultural resources (Oyinloye et al., 2018).

Given the increasing intensity of environmental change and its implications for agricultural livelihoods, there is a growing need for empirical research that systematically examines how environmental change affects farmers' welfare in Nigeria. Such research is essential for identifying vulnerable groups, understanding transmission pathways, and informing policies aimed at promoting climate-resilient agriculture and improving rural welfare. Despite increasing policy attention to climate change and environmental sustainability, empirical evidence on how environmental

change affects the welfare of farmers in Nigeria remains limited and fragmented. Understanding the welfare implications of environmental change is critical for designing evidence-based policies that enhance farmers' resilience, reduce vulnerability, and promote inclusive agricultural development.

This study was conducted to evaluate the effect of environmental change on the welfare status of crop farmers in Kaduna State and Federal Capital Territory, Nigeria.

MATERIALS AND METHODS

This investigation was conducted in Kaduna State and Federal Capital Territory (FCT) Nigeria. A simple random sampling technique was utilized to select 198 crop farmers from a population of 600 respondents within Kaduna state and FCT, respectively. The total sample size consists of 99 crop growers selected each from Kaduna state and FCT respectively. The simple random sampling was used because it avoids element of bias in selecting the crop farmers. Secondly, the sampling technique gives the probability for every crop farmer to have equal chance of being selected. Primary data of cross-sectional sources were utilized based on a well-structured questionnaire that was subjected to validity and reliability test.

This sample size was calculated following the formula suggested by Cochran (1963) as follows:

$$n = \left(\frac{Z.\delta}{E}\right)^2 = \left(\frac{1.96 \times 0.35896}{0.05}\right)^2 = 198 \qquad (1)$$

Where,
n = Sample size
Z = The z-score 1.96
E = The desired margin of error, 5%
δ = Standard deviation
The data obtained were analyzed using descriptive statistics, Foster, Greer and Thorbecke (FGT), farmer household income exchange, and Probit model analysis.

Farmer Household Income Exchange
This study follows the approach of Kuswanto et al. (2019) who reported that rice farmers' revenue is derived from crop cultivation as well as other farming and non-farming agricultural enterprises. Mathematically, it is expressed as:

$$Y = Y_{sf} + Y_{of} + Y_{nfa} \qquad (2)$$

Where;

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Y = Farmers Income,
Y_{sf}= Income from Crop Farming Businesses,
Y_{of}= Income from Other Farming Enterprises, and
Y_{nfa} = Income from Non-Farming Agricultural Businesses.

Farmers' spending accounts for the majority of their households spending. According to Kuswanto et al. (2019), a farmers' household spending comprises of production expenditures (such as seed, fertilizers, land rent, and agrochemicals) as well as extra capital and household consumption (food, processed food, housing, clothing, health, education, recreation, sports, among others). Agricultural expenditure, non-agricultural expenditure, and home consumption expenditure are the three types of spending that farmers incur.

$$E = E_{sf} + E_{of} + E_{nfa} \qquad (3)$$

Where;
E= Farmers Expenditure,
E_{sf}= Expenditure on Crop Farming Businesses,
E_{of}= Expenditure from Other Farming Businesses, and
E_{nfa}= Expenditure from Non-Farming Agricultural Businesses.

By comparing the total income received by the farmers with the total household expenditure, FHIE was generated as a measure of the level of welfare of farmers as in the equation (4)

$$FHIE = \frac{Y}{E} \qquad (4)$$

Where;
FHIE = Farmer Household Income Exchange,
Y = Total Income, and
E = Total Expenditure.

If FHIE >1 shows that the farmers household incomes have increased. However, if FHIE < 1 shows that the farm household incomes have not increased. Thus, farmers FHIE >1 is more likely to meet their consumption and business needs.

1.1.1 FGT (Foster, Greer and Thorbecke)

This follows Oladele et al. (2024) and it is expressed as:

$$P = \frac{1}{N}\sum_{i=1}^{q}\left[\frac{(Z - Y_i)}{Z}\right]^{\alpha} \qquad (5)$$

Where,
P = Foster, Greer, and Thorbecke Index ($0 \leq P \leq 1$)
N = Total Number of Crop Farmers (Number)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

q = Number of Crop Farmers below the Poverty Line
Z = Poverty Line (Naira)
Y_i = Per Capital Household Expenditure of the Crop based Farmers
α = Non-Negativity Aversion Parameter (0, 1, or 2)
The estimation of poverty status can be decomposed to Prevalence of Poverty(P_0), Poverty Depth(P_1), and Severity of Poverty(P_2). The model is expressed as:

$$P_0 = \frac{q}{N} \ (if\ \alpha = 0) \qquad (6)$$

$$P_1 = \frac{1}{N}\sum_{i=1}^{q}\left[\frac{(Z - Y_i)}{Z}\right](if\ \alpha = 1) \qquad (7)$$

$$P_2 = \frac{1}{N}\sum_{i=1}^{q}\left[\frac{(Z - Y_i)}{Z}\right]^2 (if\ \alpha = 2) \qquad (8)$$

The Construction of Poverty Line
The poverty line is defined as:

$$MPCHE = \frac{THPHE}{TNR} \qquad (9)$$

$$PL = \frac{2}{3} \times MPCHE \qquad (10)$$

Where,
$MPCHE$ = Mean Per Capital Household Expenditure (Naira)
TNR = Total Number of Respondents
$THPHE$ = Total Household Per Capital Expenditure (Naira)
PL = Poverty Line

Probit Model Analysis
The Probit model follows Alabi et al. (2013) and is stated explicitly as:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \cdots \beta nXn + \mu_i \qquad (11)$$

Where;
Y_i= Welfare Index (1, Crop Famers have Increase Income; 0, Otherwise),
i = Crop Farmers,
β_0 = Constant Term,
$\beta_1 - \beta_{12}$ = Regression Coefficients,
X_1 = Age of the Farmer (Number),
X_2 = Number of Years spent in Schooling (Years),
X_3 = Household Size (Total Number of Persons),

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

X_4 = Access to Credit (1, Yes; 0, Otherwise),
X_5 = Total crop Output (Kg),
X_6= Change in Temperature (1 = Yes, 0 Otherwise)
X_7 =Loss of Farmland as a result Urbanization (Number)
X_8 = Reduction in the Size of Water Bodies (Number)
X_9= Migration (Rural-Urban) (Number)
X_{10}= Conflicts (Farmers-Herders Clashes) (Number)
X_{11}= Heat Waves/Stress (Number)
X_{12} = Loss of Forest Resources as a result of Urbanization (Number)
U_i= Error Term

RESULTS AND DISCUSSION

Socio-economic characteristics of crop farmers

Table 1 shows the descriptive statistics of variables of crop farmers. Approximately, 85% of crop farmers were male, while 15% were female. The mean age of crop farmers was evaluated at 49 years. This implies that the crop farmers are middle-aged, and they can easily adopt new technologies. This study is in line with the results of Alabi et al. (2022). The household sizes were large with an average of 10 persons per household. The number of years spent in school education was 7. This low educational attainment agrees with the findings of Aminu et al. (2022), who noted that limited education among Nigerian farmers restrict them access to information and innovation, perpetuating poverty. They had considerable experience of 12 years in crop farming. The average farming experience of 12 years show considerable expertise, which could enhance productivity but may not translate to poverty reduction without access to complementary resources like credit (Ojo & Baiyegunhi, 2020).

Table 1. Descriptive statistics of variables of crop variables

Variables	Mean Values
Gender (% Male)	85
Age (Years)	49
Household Size	10
Number of Years Spent in School Education	7
Farm Experience (Years)	12

Source: Field Survey Data (2025)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Welfare Status of Farm Household based on Farm Household Income Exchange (FHIE)

Types of farm household income

Table 2 shows that on-farm household income is the dominant source, contributing approximately 74.41% of the total household income. This indicates that most households in the study area rely heavily on agricultural activities for their livelihood. While, off-farm income makes up 25.59% of the total income, suggesting that a significant portion of households also engaged in secondary activities to supplement their earnings.

Table 2. Types of Farm Household Income

Sources of Income	Value (₦ Per Month)	Percentage
On-Farm	331,102.733	74.41
Off-Farm	113,863.343	25.59
Total	444,966.076	100.00

Source: Field Survey Data (2025), Exchange Rate = 1 USD = ₦ 1400

Types of household expenditure

The largest expenditure is on production costs (46.97%), reflecting the significant investment required for agricultural activities (Table 3). The non-food expenses and food purchases together accounted for a substantial portion of the expenditure, indicating that households also prioritize essential needs beyond agriculture.

Table 3. Types of household expenditure

Type of Household Expenditure	Value (₦ Per Month)	% Expenditure
Food		
(i) Non-Purchased Food	29,141.04	11.10
(ii) Purchased Food	29,595.08	11.27
Non-Food	80,495.65	30.66
Production Cost	123,314.13	46.97
Total Expenditure	262,545.90	100
Residual	47,454.10	
Total	310,000	

Source: Field Survey Data (2025), Exchange Rate = 1 USD = ₦ 1400

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Income and expenditure of the farm households

Table 4 reveals that majority of the farm households (61.90%) have an income greater than their expenditure, this suggests that they have their welfare condition enhanced. However, 38.10% of farm households experience higher expenditures than income, this indicates that they are in financial stress or their welfare status are not enhanced.

Table 5 shows that the national poverty line 2024 per month is 1300. Approximately, 43 (79.63%) of the farm households without secondary income fell below the poverty line, with incomes ranging from 45.11-720.00 Naira per month, while 11 households (20.37%) exceed the poverty line, with incomes per month ranges between 1 1,200.00-1,501.41. In contrast, households with both primary and secondary income have a range of 9.59-547.95 Naira per month with 161 households (81.31%) are below the poverty line and 37 farm households (18.69%) were above the poverty line. Thus, secondary income contributes to increasing per capita monthly income for farm households and has enhanced welfare status of seventeen additional households, this shows that a minority of the farm households enjoys relatively better economic conditions. A significant portion of farm households (79.63% and 81.31%) are below the national poverty line, indicating widespread poverty in the study area.

Table 4. The income and expenditure of the farm households

Description	Income (₦ Per Month)	Expenditure (₦ Per Month)	Number of Households
Income < Expenditure	23781.01	32201.25	72(38.10)
Income > Expenditure	29491.76	27072.32	117(61.90)

Source: Field Survey Data (2025), Exchange Rate = 1 USD = ₦ 1400

Table 5. The household welfare based on poverty line

Description	Household Income without Secondary Income (₦ Per Month)	Number of Households	Total Household Income in ₦ Per Month	Number of Households	The National Poverty Line 2024 (Per Month)
Household Income below the Poverty Line	45.11 - 720.00	43(79.63)	9.59-547.95	161(81.31)	1300
Household Income above the Poverty Line	1,200.00 - 1,501.41	11(20.37)	1,015.93-1,643.86	37(18.69)	

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

The household welfare based on ratio of the farmer household income to farmer household expenditure

Table 6 shows that the majority of households (67.92% and 79.29%) have the ratio of farmer household income to expenditure (ERFHI) less than 1, meaning their income does not sufficiently cover their expenditure. Also, a smaller portion (32.08% and 20.71%) of the farm households have an ERFHI greater than 1, indicating they are better able to manage their financial situation even when considering exchange rate fluctuations. This demonstrates that secondary income contributes to an increase in the income of each household and reduces the number of households that have lower welfare status. If the ERFHI value is calculated based on the income of each household without the secondary income, then 157 farm households (79.29%) would not have their welfare status enhanced. However, if the ERFHI value was determined from the total household income including the secondary income, the number of farm households that do not have welfare status enhanced decreases to 36 households (67.92%). This result is in line with the findings of Mustapha et al. (2018).

Table 6. The Household Welfare based on Exchange Rate of the Farmer Households (Income and Farmer Household Expenditure)

Description	Household Income without Secondary Income (₦ Per Month)	Number of Households	Total Household Income in ₦ Per Month	Number of Households
ERFHI < 1	45.11-1120.00	36(67.92)	9.59-1300.29	157(79.29)
ERFHI > 1	1,400.00-1,501.41	17(32.08)	1,409.41-1,643.86	41(20.71)

Source: Field Survey Data (2025), ₦1, 400 per USD

The effect of socio-economic factors and environmental change on the welfare status of crop-based farmers

The Table 7 presents the results of a Probit regression analysis examining the effects of socio-economic factors and environmental changes on the output of crop farmers. Below is an interpretation of each variable and its implications:

Model Fit and overall implications

The Log pseudo likelihood value of -103.82101 with an associated Wald chi-square value of 29.59 and a Prob > chi square of 0.0032. This suggests that the overall model is statistically significant at 1% probability level, meaning that the variables collectively have significant impact on the welfare of the crop-based farmers.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Age of the farmers: The negative coefficient (β_1= -0.0167, z = -1.73) suggests that as farmers' age increases, crop output tends to decrease slightly. This is significant at the 10% probability level, this implies that older farmers might have lower productivity, possibly due to less physical ability or reluctance to adopt new techniques.

Number of years spent schooling: This shows that number of years in schooling is positive (β_2 -0.0379, z = 1.63) and significant at 10% probability level. This suggests that for each additional year of schooling, welfare status is expected to improve by 0.0379 units. This study is in line with the findings of Alabi and Anekwe (2023), who reported that education helps farmers to make better informed decision and increase welfare and productivity. This results also agrees with the research conducted by Aminu et al. (2022), who reported that education enhances farmers' ability to adopt productivity-enhancing technologies and access information, thereby reducing poverty.

Table 7. The influence of socio-economic factors and environmental change on the welfare status of rice farmers

Variables	Parameters	Coefficient	Standard Error	Z-Value
Age of the crop farmers	β_1	-0.0167*	0.0097	-1.73
Number of years spent schooling	β_2	0.0379*	0.0230	1.65
Household size	β_3	-0.0232	0.0174	-1.33
Access to credit	β_4	0.3117	0.2582	1.21
Total crop output	β_5	0.1147***	0.0400	2.87
Change in temperature	β_6	-0.3596***	0.0960	-3.75
Loss of farmland as a result of urbanization	β_7	-0.1145	0.2070	-0.55
Reduction in the size of water bodies	β_8	-0.2356*	0.1336	-1.76
Migration	β_9	0.3737	0.2639	1.42
Conflict	β_{10}	-0.2891	0.2193	-1.32
Heatwave	β_{11}	-0.0650**	0.0286	-2.27
Loss of foresry resources as a result urbanization	β_{12}	0.0995	1.1131	0.88
Constant	β_0	-0.9558	1.1294	-0.85
Log Pseudo Likelihood	-103.82101			
Wald Chi^2	29.59			
Prob > Chi^2	0.0032			
Number of Observation	198			

Source: Field Survey Data (2025)

*** = significant. @ 1%, ** = significant @ 5% and * = significant @ 10%

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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Total crop output: This finding shows that an increase in total crop output is associated with an increase in welfare by 0.1147 units. This relationship is highly statistically significant at the 1% probability level. This suggests that the farmer enjoys increased income, improved food security and poverty alleviation in the study area.

Change in Temperature: This shows that an increase in temperature negatively affects welfare, with a coefficient of (-0.3596). This factor was statistically significant at the 1% probability level; this implies that temperature changes may not favour certain crops or farming conditions.

Heat Waves: The negative and highly significant coefficient (β_{11} = -0.0650, z = 2.27) indicates that heat waves drastically reduce crop output. This highlights the severe impact of extreme heat on agricultural productivity.

Reduction in the Size of Water Bodies: The result indicate that the coefficient is negative and statistically significant (β_8= -0.2356, z = 1.76) at 10% probability level. This implies that as a unit increase in reduction in the size of water bodies, while keeping all other variables constant will lead to 0.2356 unit reduction in the welfare status of crop farmers.

CONCLUSION

The socio-economic factors and environmental change do not have a significant effect on the welfare status of crop-based farmers in the study area.

The socio-economic factors that had significant effect on welfare status of crop farmers included age of crop farmers, year of school education, and total crop output. The environmental change that significantly affected the welfare status of crop farmers. That included heat waves, change in temperature, and reduction in the size of water bodies.

RECOMMENDTIONS

- Extension agents should prioritize teaching crop farmers about zero-tillage, crop rotation, and contour farming to preserve soil moisture and prevent erosion.

- Government and NGOs should provide subsidies for drought-resistant and early-maturing crop varieties to bypass shortened rainy season.

- Establishing localized, community-based early warning systems in collaborating with NiMet (Nigeria Meteorological Agency) to provide farmers with real-time planting and harvesting schedules.

- Policies and programmes should be there to promote small-scale irrigation particularly for Fadama (Wetland) farming.

- "Climate-Resilience Loans" with low interest rates should be provisioned to the smallholder farmers to purchase necessary inputs.

- Implementing the climate action plan by encouraging the composting of agricultural waste into organic manure should be provisioned.

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Study on Seroprevalence of Contagious Caprine Pleuropneumonia in Goats Marketed in Kathmandu Valley

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ABSTRACT

Contagious caprine pleuropneumonia (CCPP) is a highly contagious respiratory disease of small ruminants that is caused by gram-negative, pleomorphic, facultative anaerobic bacterium *Mycoplasma capricolum,* sub-sp. *Capripneumoniae*. It is a severe respiratory disease of goats characterized by high morbidity and mortality, as well as the potential to spread across borders. A study was conducted to determine the seroprevalence of CCPP in the marketed goats of Kathmandu Valley of Nepal from June to August, 2024. The study was conducted in goats entering the Kathmandu valley through a Quarantine check post of Nagdhunga, Kathmandu to assess the prevalence of CCPP. A total of 168 goat serum samples were tested using a competitive enzyme-linked immunosorbent assay (c-ELISA) (IDEXX CCPP Ab test kit, United States) for antibodies against *Mycoplasma capricolum capripneumoniae*. Out of the total serum samples tested, 15 (8.9%) samples were seropositive for CCPP. Significantly higher seroprevalence was observed among goats of Rukum-Paschim 3 (50%), and Kailali 2 (22.2%) followed by Baitadi 1 (14.3%), Bardiya 3 (14.3%), Parasi 1 (14.3%), Kanchanpur 2 (12.5%), Rolpa 1 (7.7%), Dang 1 (2.4%) and Kathmandu 1 (2.8%). The result was negative in Salyan and Makwanpur districts. This study revealed the presence of CCPP in the goat population of Nepal and the potential circulation of the pathogen inside the country. Therefore, appropriate preventive measures such as maintaining effective biosecurity, minimizing stress in goats, and conducting regular research and investigations should be implemented to prevent potential disease outbreaks.

Keywords: Caprine, CCPP, ELISA, mycoplasma, pathogen

INTRODUCTION

Nepal is primarily an agricultural country, with around 66% of its population engaged in this sector and the livestock sector contributes about 24.01% of AGDP in Nepal

(DLS, 2020). Goats are very important to the rural economy, especially in hilly and mountainous areas. Goats, which are frequently called "poor man's cows," are an important source of food and revenue in rural Nepal since they are tough and can provide meat, milk, and manure (Bhattarai *et al*., 2019).Goat meat, or "chevon," is important to both culture and the economy. This is especially true in cities like Kathmandu, where demand for it rises during festivals and other special events (Das *et al.,* 2019). With a population of 14.54 million, goats rank third in national meat production after chicken and buffalo (Krishi Diary, 2079/80). However, goat farming encounters a lot of challenges, especially with contagious caprine pleuropneumonia (CCPP), a highly contagious respiratory disease caused by the gram-negative, anaerobic bacterium *Mycoplasma capricolum* subsp. *capripneumoniae* (Ahaduzzaman, 2020). CCPP has been widely recorded in Asia, Africa, and the Middle East. It is a serious respiratory disease in goats that can spread across borders and can cause high morbidity and mortality (Iqbal *et al.,* 2019; Parray *et al*., 2019).

CCPP is transmitted primarily through direct contact via aerosols from infected goats, making it especially difficult to contain during animal movement. Clinical signs include high fever (41–44 °C), coughing, nasal discharge, dyspnea, chest pain, depression, weight loss, and death, with mortality rates reaching up to 100% in acute cases (MacOwan & Minette, 1976; Radostits *et al*., 2000; Ahaduzzaman, 2020). Common risk variables connected to increased CCPP seroprevalence are age, sedentary farming methods, species, location, season, the introduction of new animals from markets, and the lack of therapeutic intervention (Parray *et al.,* 2019). Diagnosing CCPP involves a combination of clinical observation and laboratory techniques such as ELISA, PCR, and serological tests. For the epidemiological research of CCPP, the competitive ELISA kit, based on a Mccp-specific monoclonal antibody, is a suitable instrument due to its high specificity (99.8–100%) and suitability for mass-scale testing (Asmare *et al*., 2016).

The disease thrives in environments with high goat density and poor biosecurity practices (Kyotos et al., 2022). Twenty-six (26) animal diseases are regarded as notifiable in Nepal per Animal Health and Livestock Service Act 2055 and regulation 2056. CCPP has been included in the list of notifiable diseases of the World Organization for Animal Health (WOAH) and Nepal (Bascunana *et al*., 1994; Manso-Silvan *et al.,* 2011).

Kathmandu, is a major hub where goats are consumed, goats from all over the country are brought here, which raises the chance of CCPP spreading. Poor veterinary services

and lack of organized vaccination strategies further increases the problem, particularly in urban and peri-urban areas (Uprety *et al.,* 2012). Seasonal weather changes and varied topography make disease dynamics even more complicated and hard to control (Kyotos *et al*., 2022). Though Nepal has a rising goat population and is self-sufficient in goat output, the prevalence of diseases such as CCPP makes it difficult for Nepal to reach regional and worldwide markets (Neupane *et al.,* 2018). Despite being a notifiable disease, no national immunization program against CCPP has yet been implemented. This study contributes updated seroprevalence data from goats entering Kathmandu Valley, which is important for tracking the spread of disease and making better disease management measures, especially at transit points and market hubs.

MATERIALS AND METHODS

Site and duration of study

Kathmandu is a major market for the goat population throughout the country. Each day around 1300-1500 goats are slaughtered in Kathmandu. The majority of goats are brought from all districts to Kathmandu (DLS 2020). The major entry point of the goat is Nagdhunga. So, the study was carried out to collect samples from the checkpoint. The trader brought a veterinary certificate which included the contact number of the owner, and address, and the study was then a proxy indicator of disease in that area. The cross-sectional study was carried out from June to August of 2024.

Sample size

According to the literature review, the prevalence of CCPP in Chitwan was found to be 4.71 % (Regmi *et al*., 2023). As Chitwan is very close to our study area, its prevalence was used as a reference, and the desired sample size was calculated with an expected precision of 5% at a 95% confidence level (Thrusfield *et al.,* 2017). The calculated minimum sample size required for the study was 145.

In the study, a total of 168 samples were collected randomly from the vehicles entering through the Nagdhunga checkpoint.

$$n = \frac{1.96^2 \times P_{exp}(1-P_{exp})}{d^2}$$

n = required sample size

d = Desired absolute precision (0.05)
P exp = Expected prevalence (0.05)

Sample collection

The study was carried out by sampling goats brought to Kathmandu Valley through animal quarantine check post-Nagdhunga. Goats are either brought in big trucks or in small vehicles. Simple random sampling was undertaken selecting every alternate vehicle bringing the animals. At most 10% of the animals were sampled from each vehicle. Selected animals was restrained by two people and the site was prepared around the mid-jugular vein by using 70% ethanol. Using a sterile disposable syringe and needle, blood was taken from the jugular vein aseptically. The collected blood samples was labelled. An icebox containing ice packs was used to transfer the sample to the Central Veterinary Laboratory (CVL) in Tripureswor, Kathmandu. The serum was separated and separated serum samples were transferred into sterile cryovial tubes and stored in a deep freezer at 5°C in the Central Veterinary Laboratory (CVL) in Tripureswor, Kathmandu, until serological analysis.

Laboratory examination

The serum samples was examined for the detection of specific antibodies against Mccp by using the C-ELISA test kit (IDEXX CCPP Ab test kit, US). The entire test was performed according to the manufacturer's guidelines. The result was interpreted by a percentage of inhibition (PI) = ((OD Mab - test serum)/ (OD Mab – OD conjugate)) ×100 and Serum with a PI≥ 55% was judged positive for Mccp infection, whereas a PI < 55 % were considered negative.

Data analysis: Data were analyzed using Microsoft Excel, SPSS, and R Studio. The chi-square test was utilized as a statistical test in which the confidence level was set at 95%, and the significance was fixed at $p<0.05$. The value less than or equal to 0.05 were considered to be statistically significant.

Ethical statement

Ethical approval of the study was obtained from the internship advisory committee, Himalayan College of Agricultural Sciences and Technology (HICAST) and CVL, Tripureswor during the proposal seminar. Verbal consent was obtained from the

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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respondents by explaining the objectives of the study. Blood samples were collected with minimal pain to the animals.

RESULTS AND DISCUSSION

In this study, out of 168 samples collected,15 (8.9%) samples were found to be seropositive.

District wise prevalence of disease

Among the district covered in this study, Bardiya and Rukum-paschim revealed highest number of positive cases as showin in figure no 2. below.

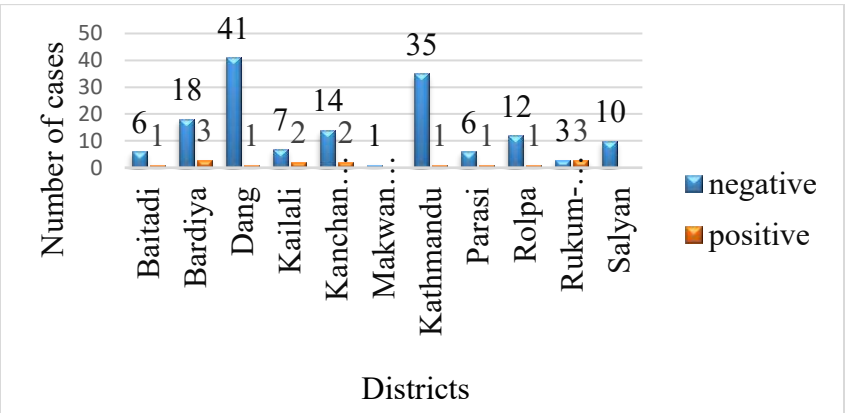

Figure 2. District wise results of CCPP according to the number of samples

The chi-square statistic of 20.88, coupled with a p-value of 0.0219, indicated that the differences observed in the distribution of seropositive and seronegative cases were statistically significant, with a less than 2.2% probability that these differences occurred by chance. This finding suggested that the prevalence of CCPP was not uniformly distributed across the country, with certain districts exhibiting either significantly higher (Rukum-Paschim) or lower rates of infection (Makwanpur, Salyan).

This study found that the total seroprevalence of CCPP among marketed goats in Kathmandu was 8.9% (15 out of 168 goats), which was higher than the findings of a study in Chitwan district at 4.71% (Regmi et al., 2023) and in Rupendehi and Palpa districts of Nepal at 3.90% (Adhikari et al., 2022). It is also higher than the study

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

conducted by CVL, Tripureswor in Dolakha, Rukum-West, and Chitwan which is 3.4 %(14 out of 402 goats) (Annual Technical Report of CVL, 2021/2022).

Table 1. Association of seropositivity within districts

Districts	Total no. of sample	Positive cases (%)
Bardiya	21	3 (14.3%)
Baitadi	7	1 (14.3%)
Dang	42	1 (2.4%)
Kailali	9	2 (22.2%)
Kanchanpur	16	2 (12.5%)
Makwanpur	1	0%
Parasi	7	1 (14.3%)
Rolpa	13	1 (7.7%)
Rukum-Paschim	6	3 (50%)
Salyan	10	0%
Kathmandu	36	1 (2.8%)
Total	168	15 (8.9%)

There is significant association at 5% significance level between districts and disease (CCPP) prevalence (chi square=20.882, df=10, p=0.022).In this study, a relatively high seroprevalence was seen in Rukum-Paschim(50%) followed by Kailali(22.2%) and Bardiya(14.3%), Baitadi(14.3%), Parasi(14.3%), Kanchanpur (12.5%), Rolpa (7.7%), Dang (2.4%) and Kathmandu (2.8%). The result was negative in Salyan and Makwanpur. This study showed that the goat populations in the districts of Kailali, Baitadi, Bardiya, Parasi (which borders India), and Rukum-Paschim are at high risk of acquiring CCPP infection. The higher prevalence observed in marketed goats of Kathmandu could be due to concentration of goats from various regions of the country, potentially creating ideal conditions for the transmission of CCPP.

In this study, the overall seroprevalence of CCPP in marketed goats in Kathmandu was found less than serological studies carried out in various regions of South Asia, where prevalence rates ranged from 32.5 to 45.7% in Pakistan (Awan *et al*., 2010), in a different state of India like 33.67 % in Nagpur (Sivakumar *et al*., 2008), 10.65 % in Jabalpur, Madhya Pradesh (Gupta *et al*., 2016), 9.93% in Ladakh (Parray *et al*., 2019), 16.05 %, and 20.24 % in sheep and goats respectively in Maharashtra (Suryawanshi *et al*., 2015). There are many possible reasons for the differences in seroprevalence, such as the small sample size, goat management and production systems, geographic area,

the research locations, the population density, the risk of exposure, the availability of veterinary care, and the methods used to measure seropositivity.

India has had a lot of cases of CCPP, especially in the states of Kerala and Kashmir. Using molecular typing, the disease was confirmed, and *Mycoplasma capricolum* subsp. *capripneumoniae* was found to be the cause. There is also a vaccination program for CCPP in India (Farooq *et al.*, 2018). In 2020/2021, Nepal imported 13,827 live goats from India in 2020/2021(Euro-meat news.com, 2024). The Krishnanagar border crossing in western Nepal has been identified as the largest entry point for these animals. The high CCPP seroprevalence in Rukum-Paschim and Indian bordering districts like Bardiya and Kailali may be a sign of cross-border disease transmission.

Similar findings in Ethiopia's Guji and Borana zones demonstrated that the primary source of CCPP transmission was cross-regional movement of animals, highlighting the importance of restricting livestock movement to reduce the disease's spread (Bekele *et al.,* 2011). This study found no seropositive cases in goats from Salyan and Makwanpur, possibly due to smaller sample sizes or effective local control measures. Another factor contributing to the greater transmission rates may be the movement of goats across the nation without appropriate quarantine protocols. The increased risk of disease transmission may arise from traveling goats frequently interacting with animals from different regions.

Long-term travel stress may also impair the animals' immune systems, making them more susceptible to disease-like CCPP. These results align with research conducted in Ethiopia, where the movement of livestock was identified as a significant factor in the spread of CCPP (Hadush *et al*., 2009). A study analyzing outbreaks of CCPP found that poor housing and stressful transportation conditions greatly enhanced the probability of disease transmission among goats. Stress-related suppression of immune functions facilitates the rapid colonization of respiratory tissues by *M. capricolum*, leading to severe symptoms such as pleuropneumonia and higher morbidity and mortality rates in goat populations (Abraham *et al.,* 2015).

CONCLUSION

In this study, the overall seroprevalence of CCPP among marketed goats in Kathmandu was found to be 8.9 %(15 out of 168 goats).As there is no CCPP vaccination program in Nepal, seropositivity results could be the result of the causative agent's spontaneous infection. This will serve as a foundation for future surveillance

and monitoring. In order to comprehend the epidemiology of CCPP in Nepal, our study offers basic data on the disease among goats in that country. An understanding of the disease's prevalence in Nepal can be greatly enhanced by doing additional epidemiological research using suitable sample sizes across the nation.

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Biochemical and Molecular Characterization of *Escherichia coli* from Poultry Intestine and Feces in Dinajpur, Bangladesh

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ABSTRACT

Escherichia coli (E. coli) in poultry presents a significant zoonotic concern, as certain pathogenic strains particularly ETEC (Enterotoxigenic Escherichia coli) can be transmitted from poultry to humans through direct contact, environmental contamination, or the food chain, especially via undercooked poultry meat or contaminated produce. The objective of this study was to separate, biochemically identify, and molecularly characterize E. coli from samples of poultry feces and intestine. A total of 150 samples (50 intestinal, 100 feces) were collected from Dinajpur broiler farms and transported to the Department of Microbiology, HSTU, Dinajpur, in an ice box with PBS while maintaining aseptic conditions. In Nutrient Agar Colonies were observed and further sub cultured on MacConkey agar and then on selective media Eosin Methylene Blue Agar (EMB agar) at 37°C for 24 hours before undergoing biochemical tests such as Motility indole Urease (MIU), Simmons citrate, Indole, Methyl Red and Triple sugar Iron (TSI) utilization. Bacterial confirmation was performed followed by PCR-based confirmation including genomic DNA isolation and gel electrophoresis. Isolates confirmed as E. coli were serotyped and further characterized by Polymerase Chain Reaction (PCR) targeting the E. coli primer gene. The overall prevalence of E. coli was 69.33 %, with a higher isolation rate from fecal samples (73%) than intestine samples (62%). There weren't many samples used for PCR. PCR produced bands that were positive during the analysis. In the future, more intestinal and fecal samples from different areas will be examined for research purposes.

Keywords: Biochemical, Identification*, E. coli,* ETEC, PCR, Poultry

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INTRODUCTION

The Enterobacteriaceae family includes the ubiquitous gram-negative bacterium *Escherichia coli,* which is frequently found in the environment and in poultry's normal intestinal flora. Although the majority of strains are not harmful, certain virulent strains, referred to as Avian Pathogenic *E. coli* (APEC), can result in colibacillosis, a serious economic illness. When the host's defenses are weakened by co-infections, immunosuppression, or environmental stressors, APEC usually functions as an opportunistic pathogen, causing localized or systemic infections (such as cellulitis, septicemia, or omphalitis). Because of resistance issues and possible zoonotic connections between some APEC and human extra-intestinal pathogenic *E. coli* (Ex PEC), control depends on biosecurity, good management, and vaccination. Antimicrobial use is also cautious (Percival and Williams, 2014; Islam *et al*., 2023). While many strains are harmless, some particularly Avian Pathogenic *E. coli* (APEC) can cause severe disease in birds, leading to disorders such as colibacillosis, which affects the respiratory and systemic systems and leads in economic losses owing to mortality and reduced production. Additionally, zoonotic *E. Coli* strains, especially those resistant to antibiotics, are found in poultry and can spread to people through direct contact or the food chain. Consequently, monitoring and managing *E. coli* in poultry is critical for both animal health and public health, notably in preventing infections and minimizing the spread of antibiotic resistance. Only a small number of *E. coli* serotypes are thought to be nonmotile due to the arrangement of peritrichous flagella (Percival and Williams, 2014). It is prevalent in domesticated cattle species and is regarded as one of the most prevalent bacterial infections worldwide (Nolan *et al.,* 2020). In terms of toxicity and virulence, *E. coli* is a very diverse bacterial species. It is extensively dispersed across the ecosystem, indicating a significant risk to human health (Ghanem and Haddadin 2018). According to Jang *et al.,* (2017), *E. coli* can grow and survive outside of various hosts because it can reproduce in water and soil in tropical and subtropical regions. Hatcheries are a common source of spreading infections (Papouskova *et al.,* 2023).

MATERIALS AND METHODS

Sample collection

A total of 150 samples were gathered as part of the study population during the September–December 2025 period in the Dinajpur district, namely in the vicinity of the Hajee Mohammad Danesh Science and Technology University (HSTU). Now the initial round of sample collection only 100 fecal and 50 intestinal samples were collected from the surrounding areas of Hajee Mohammad Danesh Science and

Technology University, Dinajpur. The Phosphate buffer Solution (PBS) Solution was made to keep the sample safe while it was being transported in a plastic zipper. For microbiological analysis, the samples were sent to the Department of Microbiology at HSTU, Dinajpur, in an ice box with PBS to ensure aseptic conditions.

PBS preparation

Table 1. PBS preparation for poultry fecal and liver sample collection

Ingredients	Amount (per 1 L PBS)
Nacl	8.0 g
KCL	0.2 g
Na_2HPO_4	1.44 g
KH_2PO_4	0.24 g
Distilled Water	Up to 1 Liter

Isolation and biochemical identification

Samples were taken from broiler farms in Dinajpur and brought to the Department of Microbiology at HSTU, Dinajpur, in an aseptic ice box filled with PBS. The obtained samples were prepared and cultured on Nutrient Agar at 37°C for 24 hours, after which samples indicating growth were selected for isolation and those without growth were rejected. The isolates were analyzed by morphology and staining to separate Gram-negative and Gram-positive bacteria; Gram-positive isolates were rejected while Gram-negative isolates were put to further culture on MacConkey agar. A loopful of enriched suspension was streaked in MacConkey agar and incubated at 37◦C for 24 h for isolation of *E. coli*; because *E. coli* is a lactose-fermenting bacterium, colonies on MacConkey agar appear pink to rose-red. The fermentation of lactose produces acidic by products that lower the pH of the medium, leading the pH indicator (neutral red) to turn pink. *E. coli* on MacConkey agar were submitted to Gram staining, which exhibited Gram-negative rods. Before conducting biochemical assays including Motility Indole Urease (MIU), Simmons citrate, Indole, Methyl Red, and Triple Sugar Iron (TSI) utilization, colonies were detected and then sub-cultured on selective media Eosin-Methylene Blue (EMB agar) at 37°C for 24 hours.

Picture 1. (Simmons Citrate-Negative) (Indole -Positive) (MIU -Positive)

PCR-based confirmation using gel electrophoresis and genomic DNA isolation was carried out. Based on the colony morphology of the putative bacteria identified on the different selective agars, additional characterization was attempted utilizing staining techniques. Gram's staining was used to classify the isolates for the first time, confirming that they were Gram-negative bacilli. The positive isolates identified as Gram-negative bacilli were then selected for further inspection, ensuring that a pure culture from each was grown on appropriate selective media for future confirmation testing.

Picture 2. (MR Test-Positive) (TSI-Positive) (DNA Extraction)

Molecular characterization of virulence genes

To aid in molecular characterization, bacterial genomic DNA was extracted from the pure cultures after serological confirmation. Two procedures were employed: a standard boiling method and a commercial kit protocol conducted according to the manufacturer's instructions. For the boiling procedure, 1.5 mL of a pure bacterial culture was transferred to a microcentrifuge tube and pelleted. The pellet was then resuspended in 100 µL of nuclease-free distilled water. The suspension was exposed to boiling in a hot water bath at 100°C for 10 minutes to lyse the bacterial cells and denature proteins. Immediately after boiling, the tube was transported to an ice box for

30 minutes to induce a cold shock, which aids in precipitating cellular debris. The lysate was then centrifuged at 10,000 rpm for 10 minutes to separate the cellular fragments from the soluble DNA. The extracted genomic DNA-containing supernatant was carefully collected and put into a new microcentrifuge tube to be stored at -20°C until further PCR analysis. The genomic DNA was isolated from *E. coli* isolates using a modified boiling cell approach (Pui *et al.*, 2011). Cultured *E. coli* colonies were injected into 1 mL of Luria-Bertani broth and incubated at 37◦C for 24 h. After centrifuging the bacterial culture for three minutes at 15,000 x g, the supernatant was discarded. The pellet was resuspended in 500 µL of nuclease-free water, heated at 100◦C for 10 min, and then rapidly cooled to 4◦C for 10 min. Following this, the samples were centrifuged at 15,000 x g for 3 min. After that, the genomic DNA-containing supernatant was moved to a brand-new Eppendorf tube and kept at 20°C until PCR amplification.

The concentration and purity of the DNA recovered from the *E. coli* culture were quantified spectrophotometrically (Quawell, UV-Vis Spectrophotometer Q5000) at 260 and 280 nm, with acceptable ratios ranging from1.6-2. One virulence gene (invA) was amplified by PCR using a Bio-Rad T100TM Thermal Cycler (Bio-Rad, USA). Five microliters of Invitrogen Master Mix, one microliter each of forward and reverse primers, one microliter of DNA template, and two microliters of nuclease-free water (Ambion, REF: AM9932) were all included in each 10-microliter reaction mixture. PCR was per-formed to amplify the virulence genes of *E. coli.* Detailed information on the primers (Macrogen, Inc., Seoul, South Korea), including their melting temperatures (Tm) and amplicon sizes, was performed as protocol. Pre-denaturation at 95°C for 3.5 minutes, 95°C for 3 seconds, 56°C for 30 seconds, 72°C for 60 seconds with 35 cycles, 72°C for 10 minutes, and 4°C with infinite were the cycling conditions. 1.5% agarose gels made in 0.5X TBE (Tris-Borate-EDTA) with 2 µl ethidium bromide (EtBr) were used to separate the amplified PCR products. A 100 bp DNA ladder was loaded with five microliters of PCR product combined with loading dye. The gel electrophoresis was done at 90 V for 60 min, and DNA bands were observed under a UV transilluminator (Platinum Q9, U Vitec Cambridge).

The primer used in PCR for E. coli was Ee116Srna F(5'GACCTCGGTTTAGTTCAC)AGA-3' and Ee116Srna R(5'CACACGCTGACGCTGACCA)3'. To examine PCR results using agarose gel electrophoresis, gel was generated by dissolving 0.75 grams of agarose powder in a mixture of 5 mL of TAE buffer and 45 mL of distilled water, which generates a 1.5% gel solution; this solution is heated in a microwave until the agarose was completely

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dissolved. In Micro wave at 30 second interval the solution was mixed by shaking with hands for four times at comparable time interval. Then let to cool somewhat before adding a DNA-intercalating dye, and is lastly poured into a casting tray with a comb to make wells. Once the gel has set, it is placed into an electrophoresis chamber filled with TAE buffer that submerges the gel, and the PCR products, combined with a loading dye, are carefully pipetted into the wells alongside a DNA ladder for size comparison. The negatively charged DNA fragments moved through the gel matrix in the direction of the positive anode when the lid was fastened and an electric current was applied; smaller fragments traveled farther and quicker than bigger ones. Once the dye front has moved far enough, the power is switched off, the gel is examined under a UV lamp, and the band pattern that results is examined to verify the size and existence of the amplified DNA targets from the first PCR reaction.

Statistical analysis

The collected data were processed and evaluated utilizing Microsoft Excel software.

RESULTS AND DISCUSSION

Identification of bacteria by cultural, morphological and bio-chemical properties

The findings of a microbiological study on enteric bacterial pathogens (*E. coli*) from two sample sources intestinal tissue and feces are shown in this table. First, 150 samples were cultured on MacConkey Agar, a generic medium for Gram-negative bacteria, and subsequently on Eosin Methylene Blue (EMB) Agar, a selective medium. Through biochemical testing, all samples that developed on EMB Agar were conclusively identified as target pathogens.

Table 2. Table of Fecal and Intestinal Samples

Category	Total Samples	Positive Samples on Culture in MacConkey Agar	Positive Samples on Culture in Eosin Methylene Agar	Confirmed by Biochemical Test	Prevalence, %
Fecal	100	73	73	73	73
Intestine	50	31	31	31	62
Total	150	104	104	104	69.33

The final Prevalence% is derived from these verified positives, demonstrating a very high infection rate: 73% in fecal samples (73 out of 100) and 62% in intestinal samples (31 out of 50), with an overall prevalence of 69.33% (104 out of 150). The exact numbers across the last three columns imply perfect agreement between selective

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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culture and biochemical confirmation in this dataset, pointing to a substantial burden of enteric bacterial illness in the examined population.

Picture 3. *E. coli* Positive in EMB Agar

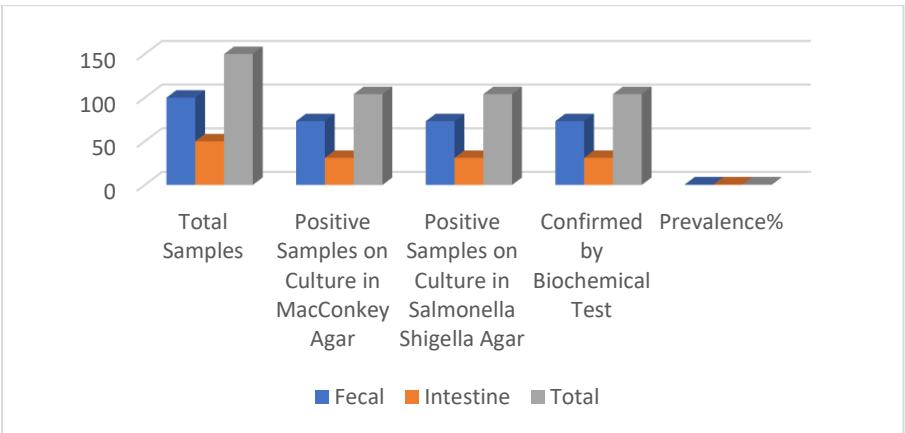

Figure 1. Bar showing Fecal and intestinal positive samples

This clustered bar chart visually compares the results for fecal and intestinal poultry samples across four major criteria. Each measure (e.g., Positive on MacConkey Agar) is represented by a pair of bars blue for fecal and orange for intestinal. The chart clearly demonstrates that for every parameter, the count for fecal samples (Total=100) is higher than for intestinal samples (Total=50), which is predicted due to the bigger sample size. The most important comparison, however, is found in the Prevalence% bars on the far right, where the orange bar (intestinal, 20%) is taller than the blue bar

(fecal, 15%). This suggests that, despite the lower total number of tests, *E. coli* was confirmed at a greater proportional rate in intestine samples.

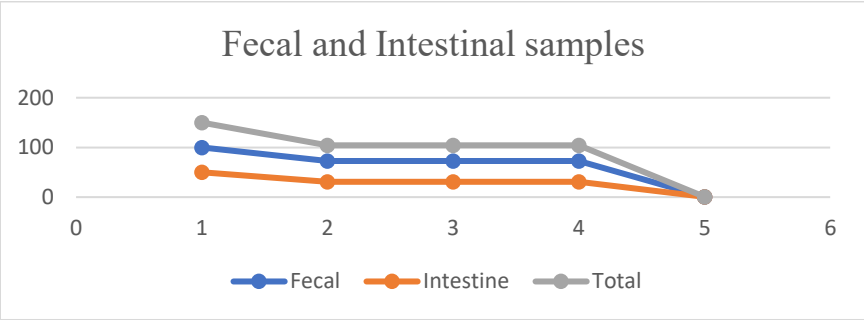

Figure 2. Chart showing positive Fecal and Intestinal sample

Fecal, Intestine, and Total are the three sample categories listed. This is a simple label structure, likely used to organize or present data from a microbiological or epidemiological study comparing two types of biological specimens' fecal samples (such as stool) and intestinal tissue samples (possibly collected post-mortem or surgically) with a Total row that sums or summarizes results from both categories. Three sample categories are listed in it: total, fecal and intestinal. This is a simple label structure, likely used to organize or present data from a microbiological or epidemiological study comparing two types of biological specimens' fecal samples (such as stool) and intestinal tissue samples (possibly collected post-mortem or surgically) with a Total row that sums or summarizes results from both categories.

Molecular confirmation by PCR

Few Sample seems to be better for PCR as *E. coli* as on EMB Agar. A crucial distinguishing feature of *E. Coli* colonies is their dark-centered appearance and green metallic sheen. This is owing to its capacity to ferment lactose, which causes the colors in the medium to precipitate and form dark, almost black colonies with an iridescent shine. The incidence of *Escherichia coli (E. coli*) in poultry fecal matter is constantly high, often ranging from roughly 50% to over 80%, depending on factors like farm management, geographic region, and specific testing procedures.

Conversely, Blaak *et al.,* (2015) found extended-spectrum beta-lactamase (ESBL)-producing *E. coli* in 81, 60, and 57% of samples taken from surface water, dust, and rinse water near chicken flocks, respectively. The overall prevalence of *E. coli*

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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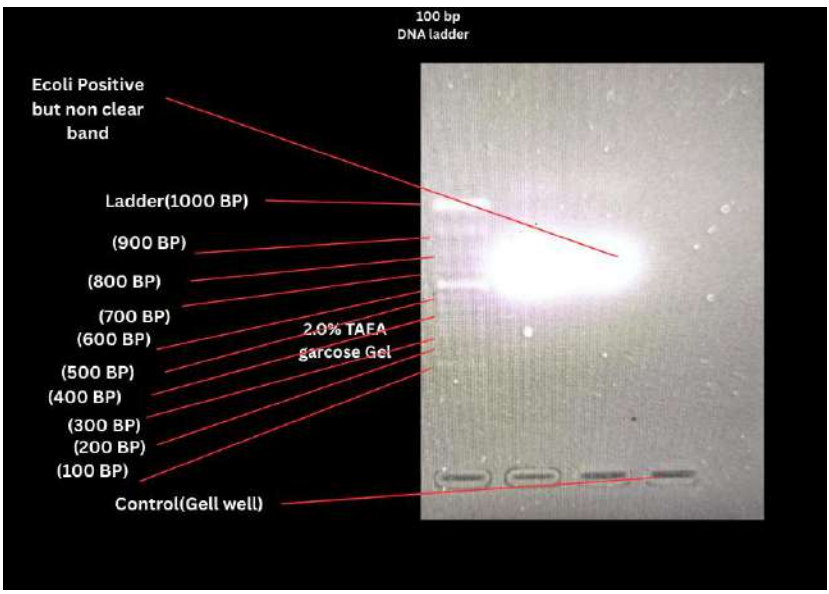
reported in this study was 77.7%, which coincides with other recent studies conducted in Bangladesh (Davies *et al.,* 2024; Al-Salauddin *et al*., 2015) and Turkey (Telli *et al*., 2022). In contrast, our results surpass the lower prevalence rates reported in countries like Sri Lanka, the United States, the United Kingdom and even Bangladesh at 66.8%, 67.9%, 36.4%, 63.5% and 56.5%, respectively (Ranasinghe *et al.,* 2022). These findings unmistakably support one another.



Picture 4. PCR for identification of *E. coli*

CONCLUSION

This study found a notable discrepancy between biochemical and molecular confirmation, even though *E. coli* was successfully isolated from 69.33% of chicken samples. Biochemically confirmed isolates frequently failed to produce strong, unambiguous positive results in PCR assays, often showing only faint bands. To resolve this discrepancy and achieve more reliable PCR confirmation, future work will require larger sample sets drawn from varied regions.

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Study on the Effect of Breeds on Physiochemical Parameters of Goat Milk at National Goat Research Program, Bandipur Tanahun Nepal

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ABSTRACT

This study analyzed breed-specific variations in milk composition among pure Saanen, pure Boer, and pure Khari goats at National Goat Research Program in Bandipur, Tanahun between March and May, 2018. Using a milk analyzer, we evaluated 96 Saanen, 12 Boer, and 12 Khari milk samples for protein, fat, SNF, lactose, and freezing point. Statistical analysis was performed using SPSS software with mean comparisons at a 0.01 significance level. The results revealed no significant differences ($p>0.01$) among the breeds for protein, lactose, SNF, and freezing point values. However, pure Boer goats showed significantly higher fat content (7.96±0.48%) compared to both Saanen and Khari breeds ($p<0.01$), while no significant difference was observed in fat level between Saanen and Khari goat milk. Despite Boer goats having the highest fat percentage, their low milk yield makes them less suitable for dairy product manufacturing, particularly for cheese production. The comparative analysis demonstrated that Saanen goats possess superior milk production characteristics compared to both Khari and Boer breeds. Saanen is recommended as the most appropriate breed for commercial dairy processing in Nepal due to its balanced milk composition and better production performance.

Key words: Genetic group, goats, milk, production parameter

INTRODUCTION

Asia is often regarded as the global hub of goat farming, holding 60% of the world's one billion goats. Most of these goats including dairy breeds are raised by small-scale farmers, many of whom have poor resource and landless. Goat milk plays a vital role in underdeveloped nations, serving as a key source of nutrition and livelihood for rural

populations (Park, 2007). In terms of total production, Asia and Africa outpace the Mediterranean region in goat milk output. Globally, non-bovine milk accounts for over 17% of total milk production, yielding approximately 133 million tons annually. Within this, goat milk contributes around 12.2 million metric tons about 2% of the world's milk supply (Yadav, 2016). Although Asia lacks the structured marketing and distribution systems found in Europe, it leads in both production (52%) and consumption of goat milk. The top Asian producers are India, Bangladesh, and Pakistan, while Sudan, South Sudan, and Somalia dominate in Africa. In Europe, the leading producers are France, Spain, and Greece (FAO,1997). Dairy goat farming is becoming increasingly popular in Nepal due to the country's favorable geographical and economic conditions. Goat milk plays a crucial role in combating malnutrition, particularly in rural communities. Recently, it has also been recognized for its potential in dengue disease prevention and management. In many Nepalese villages, goat milk is primarily fed to children rather than sold commercially. Beyond its nutritional benefits, goat milk is valued for its medicinal properties, aiding in the management of diabetes, dengue fever, ulcers, and skin allergies. Nutritionally, goat milk is comparable to cow milk, offering similar levels of protein, fat, and other key nutrients. However, it has distinct advantage, smaller fat globules make it easier to digest, and it is less likely to cause allergic reactions compared to milk from other livestock. Despite these benefits, goat milk accounts for only about 2% of the world's total milk production (FAO, 1997). In terms of mineral content, goat milk contains slightly higher levels of calcium, phosphorus, and chlorine than cow milk. However, it has a lower iron content (Banerjee, G.C., 2008, Eighth Edition). These nutritional characteristics make goat milk a valuable dietary component, particularly for individuals with digestive sensitivities or specific health needs.

In Nepal, only a small number of farmers commercially produce goat milk, while most raise goats primarily to feed their kids. Indigenous breeds yield very little milk and their lactation periods are short, barely meeting the nutritional needs of their offspring. Saanen and crossbred goats produce significantly higher milk volumes. While a few Nepalese farmers keep pure Saanen goats, the majority raise local or crossbreds. Only government institutions maintain pure Saanen breeds for breeding or research purposes. National Goat Research Program Bandipur and Goat Development Farm Chitlang, Makwanpur Nepal raising goats for research and making cheese. Indigenous goats showed very high levels of milk fat and protein, whereas Saanen goats showed much lower levels. In National Goat research program, Bandipur now a days started to produce goat cheese. It is organic, which is attractive to consumers. Many consumers around Gandaki province they buy goat cheese regularly and others too. They also make soap from the Saanen goat milk including other ingredients. A human infant fed solely on goat milk is oversupplied with protein, Ca, P, vitamin A, B1, B2, niacin, pantothenic acid, while

deficient in iron, vitamin B6, B12, C, D, and folic acid (Jenness, 1980). Goats are important for both commercial and subsistence types of farming systems in Nepal. Commercial farmer's rears goats primarily for meat production and subsistence farmers use them as a source of meat and milk, as well as cash for other expenses (Casey and Van Niekerk, 1988).

Breed description

A. Boer Goat

The Boer goat (*Capra hircus*), found in South Africa, consists of a mixture of blood from various goats. The fact that the Boer goat is generally farmed with under extension conditions in South Africa, this breed is capable of producing offspring with exceptional growth rates. The average 100-day weights of performance Boer goat kids were 25.3 kg for male, and 22.3 kg for female kids. During 1996, these goats were 26.9 and 23.4 kg, respectively (Campbell, 1998). Having established the fact that high fecundity is one of the Boer goat's strongest attributes, the conclusion may be drawn that milk production of the doe during the preweaning stage is of most importance to enable high growth rates of kids, especially in having multiple births. It has been reported that the extent of mammary development in milch goats depends on, amongst others, the number of fetal placental units and placental weight (Hayden et al., 1979).

In Nepal, a more recent initiative, the Agriculture and Food Security Project (ASFP) imported purebred Boer bucks and does from Australia in the fiscal year 2014/015. Prior to this, some private farmers had already introduced Boer bucks independently. Subsequently, the *Kisanko Lagi Unnat Biubijan Karyakram (KUBK)* program facilitated the large-scale importation of purebred Boer bucks and does. After their arrival, these goats were distributed to establish community managed Boer breeding nucleus herds in Gwadi (Gulmi) and Dibarna (Arghakhanchi). Some bucks were provided to the National Goat Research Program (NGRP) in Bandipur to form a government managed Boer nucleus herd. These nucleus herds produce purebred Boer goats, which are then supplied to multiplier herds across various project districts. The NGRP also distributes breeding bucks to commercial farmers to enhance meat goat production. Today, Boer goat meat is increasingly available in markets, and Boer bucks have gained popularity among farmers for breeding purposes at the farmers field level.

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B. Saanen Goat

The Saanen breed originates from Switzerland, from the Saanen Valley, where the annual average temperatures are 9.5° C (Silva et al. 2017). Saanen does are heavy milk producers and usually yield between 3% and 4% fat. The Saanen is a typical dairy type goat; it has a dished or straight facial line and a wedge-shaped body. Saanens are of medium height when compared with the other Alpine breeds in Australia. Does weigh at least 64 kg. Saanen goats are large in size with straight nose and erect ears pointed forward and upward. The body has good dairy conformation and the udder is well developed. It is known as the milk queen of the goat world. Goat have straight and curved sharp horn. Average height of male is 75 cm and female 90 cm. The breed is sensitive to excessive sunlight and performs best in cooler conditions. Saanen goat which is the most commonly used breed in goat breeding studies possesses 800-1000 kg milk yield with 3-4% fat content, 250-300 days of lactation period 1.80- 1.90 kidding rate and 55-60 kg live weight. Saanen is probably the most developed dairy breed. The milk production performance of the Saanen goat breed was superior to that of crossbred and local goat.

In Nepal, according to Mr. Dala Ram Pradhan, former manager of Goat Development Farm in Chitlang, Makwanpur, first purebred Saanen goats were introduced in 1971 through Israeli government. About 20 Saanens were initially brought to the Livestock Development Unit in Khumaltar, Lalitpur, and then transferred in 1972 to Goat Development Farm in Chitlang for research and breeding purposes. In a more recent initiative, the Agriculture and Food Security Project (ASFP) imported purebred males and does from the United States of America in the fiscal year 2014. These goats formed a nucleus herd at the National Goat Research Program in Bandipur, NARC. Under this project, 15 males and 20 does were allocated for research activities. Also, seven breeding goats were distributed to various locations in Dadeldhura district, while three were maintained at the National Animal Breeding office (NLBO) in Pokhara for semen collection and breeding programs. The purebred Saanen goats developed at the NGRP, Bandipur have been distributed to multiple districts, including Makwanpur, Tanahun, Kaski, Lamjung, and Syangja. These goats are being crossbred with local breeds to produce different blood level crossbreds, enhancing goat productivity in Nepal (Saanen Booklet, GRS, 2018).

C. Khari Goat

Khari is the principal goat breed of Nepal found across the country. They represent 56% of the total goat population in the country (Kharel & Neopane 1998). Having twinning kids are common on Khari as compared to other Nepali breed. The litter size of Khari

goat at birth is 1.6 and the kidding interval is substantially shorter than one year. They attain sexually maturity at an age of 7 to 10 month and produce the first progeny at an age of 12 to 17 years (Gorkhali et al, 2022). The weight is 16-20 kg in a year. Breeds are variations in weight and coat color. They are Seti (Pure white), kali (Pure black), Khairi (brown), Ghorli (brown to white and other color patches), Shingari (black with white stripes on face) and Dhobini (ash colour) (Kharel & Neopane 1998). Body length 63.1±0.39 cm, heart girth 65.5 ±0.37cm and weither height is 55.9±0.28 cm respectively. There population is normal in size. They have been characterized at phenotypic and chromosomal level (Annual Report, ABD 2003). Age at first service is in 311±5.6, weight at first service 15.4 ± 0.22 kg, Age at first kidding 453±6.2, kidding intervals 302±3.7, litter size at birth 3.38±0.06 kg and gestation length 144.8±0.15 days (Gorkhali et al, 2021).

MATERIALS AND METHODS

A total of 120 milk samples were collected over a three-month study period, including 96 samples from Saanen goats, 12 from pure Boer goats, and 12 from pure Khari goats. All goat milk samples were collected once daily during the morning milking time. Goats' udders were washed with clean water and allowed to dry before collection. Milk samples were obtained from two different farms of National Goat Research Program (NGRP) at the Chhap site. Each sample, consisting of 15 ml of milk, was collected daily in clean, sterile plastic bottles. After collection, samples were stored in the NGRP laboratory at a temperature of 2-8°C and analyzed within 1-2 hours. Before analysis, each sample was stirred gently for more than 5 minutes using vertical and circular slow movements to ensure uniformity. Physiochemical analysis was conducted using a milk analyzer. Statistical analysis of the data was performed using the Kruskal-Wallis test in SPSS software.

RESULTS AND SIACUSSION

A. Fat content

The analysis revealed significant variations in fat content among different goat breeds. Pure Saanen milk showed an average fat content of 3.13±0.22%, while Pure Khari milk contained 4.53±0.49% fat. Pure Boer milk showed substantially higher fat levels at 7.96±0.48%, significantly exceeding the values observed in the other two breeds.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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Table 1. Fat value of milk samples collected from different pure goat breeds.

S.N.	Breed	Mean ±SEM	p-value
1	Pure Saanen	3.13±0.22	**0**
2	Pure Khari	4.53±0.49	
3	Pure Boer	7.96±0.48	

B. Protein

Protein content was found in the range 2.71±0.024 % in Pure Saanen milk, 2.79±0.06% in pure Khari and 2.72±0.06 % in Pure Boer (Table 2). There was non-significant difference between the amount of protein content and milk of different goat breed. The amount of protein content in Pure Saanen, Pure Khari and Pure Boer milk was nearly similar.

Table 2. Protein value of milk samples collected from different pure goat breeds.

SN	Breed	Mean ±SEM	p-value
1	Pure Saanen	2.71±0.024	0.544
2	Pure Khari	2.79±0.06	
3	Pure Boer	2.72±0.06	

C. Lactose

Lactose content was found in the range of 3.84±0.035 % in Pure Saanen, 3.86±0.12 % in Pure Khari and Pure Boer milk 3.85±0.09 %. There was non -significant ($p>0.05$) difference between the amount of lactose content of different goat breeds. The amount of lactose content in Pure Saanen, Pure Khari and Pure Boer milk was nearly similar.

Table 3. Lactose value of milk samples collected from different pure breeds.

SN	Breed	Mean± SEM	P-Value
1.	Pure Saanen	3.84 ± 0.035	0.978
2.	Pure Khari	3.86 ±0.12	
3.	Pure Boer	3.85 ± 0.09	

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D. SNF (Solid not Fat)

SNF content was found in the range of 7.28±0.065 % in Pure Saanen milk, Pure Khari 7.48±0.17 and Pure Boer 7.27±0.20. There was non-significant ($p>0.05$) difference between the amount SNF is higher in Pure Khari and similar of Pure Saanen and Pure Boer.

Table 4. SNF value of milk samples collected from different pure goat breeds.

S.N.	Breed	Mean ±SEM	p
1	Pure Saanen	7.28±0.065	0.58
2	Pure Khari	7.48±0.17	
3	Pure Boer	7.27±0.20	

E. Freezing Point

Freezing Point values was found in the range 0.56±0.09 where as Pure Khari was 0.48±0.013 and Pure Boer was 0.49±0.010, shown in Table 5.

Table 5. The freezing point values of milk samples collected from different breeds of goats.

SN	Breed	Mean ±SEM	p-value
1	Pure Saanen	0.56±0.09	0.93
2	Pure Khari	0.48±0.013	
3	Pure Boer	0.49±0.010	

The significant variations in milk fat content among the studied goat breeds (Saanen: 3.13±0.22%; Khari: 4.53±0.49%; Boer: 7.96±0.48%) align with existing research on breed-specific milk composition. Our findings support the work of Park et al, 2007, who reported that fat content in goat milk varies substantially by breed, ranging from 2.5% to 7.0% across different genetic lines. The exceptionally high fat content in Pure Boer milk (7.96%) corresponds with findings by Mestawet et al, 2012, who noted that Boer goats, being a meat-purpose breed, typically produce milk with higher fat percentages compared to dairy breeds like Saanen. Protein content in goat milk was higher than that reported by Kholif et al,1994.

The fat content was highest in the third parity followed by the second parity and least in the first parity, wet season had higher fat content than dry season. Park et al, 2007 reported that lactose typically ranges between 3.8- 4.1% in goat milk, serving as the

primary osmotic regulator in mammary secretions, which explains its consistent levels across breeds. Pandya & Ghodke 2007, who reported that SNF content in goat milk typically ranges between 7.0 - 9.5%, varying slightly depending on breed and management factors. Similarly, Park et al, 2007 noted that genetic differences among goat breeds could lead to minor variations in SNF, though environmental and nutritional factors often play a more dominant role. In contrast, Kholif et al, 2016 observed lower SNF values (6.8- 7.2%) in some goat breeds, possibly due to differences in feeding regimes or regional conditions. The relatively higher SNF content in pure Khari milk in the present study could be attributed to its adaptation to local climatic conditions, which may influence milk composition. Further research is needed to assess the impact of diet, lactation stage, and agroecological factors on SNF variability in these breeds.

CONCLUSION

This study showed there were variations in the physio-chemical composition of milk depending on the goat breed, which ultimately affects the quality of different milk products. The composition among Saanen, Khari, and Boer goat milks, with Boer milk showing significantly higher fat content compared to Khari and Saanen. Protein content remained relatively consistent across breeds suggesting minimal genetic influence on this component. Lactose levels showed remarkable constancy confirming its role as a physiologically regulated constituent in caprine milk. The SNF content followed a pattern similar to fat, with Khari milk containing slightly higher amounts than Saanen and Boer. These findings highlight how breed-specific genetic selection has differentially affected milk composition, with dairy breeds (Saanen). Further research with larger sample sizes for each group and expanded breed comparisons is recommended to validate these findings, better assess breed-specific performance traits and also aware the Nepalese farmers to consume goat milk and milk products.

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Socio-Economic and Environmental Factors Influencing the Output of Rice Farmers in Kaduna State and Federal Capital Territory, Nigeria

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ABSTRACT

This study investigated the socio-economic and environmental factors influencing the output of rice farmers in Kaduna State and Federal Capital Territory, Nigeria. A multi-stage sampling technique was employed to select 185 respondents. Primary data were used based on a well-structured questionnaire. The data was analyzed using descriptive and inferential statistics. The findings reveal that the majority of the farmers are female (76.22%) with an average age of 48 years. Most are married (88.11%) with an average household size of 9 persons and have spent an average of 6 years in school education. The farmers have significant farming experience (18 years) but limited access to credit (8.65%) and the average monthly income was ₦36, 189.8. The socio-economic factors such as age, household size and cooperative membership, along with environmental factors such as rainfall variation and heat waves significantly influence the output of rice farmers. Environmental changes significantly impact output of rice farmers, with change in temperature, heat waves, migration, loss of crop due to soil degradation and reduction in size of water bodies being the most reported issues. These changes could

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January, 2026, volume 30
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lead to reduced output, poor harvests, and increased health hazards. The study recommended adaptation strategies such as multiple crop types and planting dates and mitigation efforts such as minimizing agrochemical use and reduce food and water wastage.

Keywords: Adaptation strategies, environmental change, propensity score matching, socio- economic factors

INTRODUCTION

Environment is defined as the physical, biological, socio-cultural, and political elements that affect a person's ability to survive and meet their needs for development. Furthermore, the environment is everything around us, and without it, survival is not conceivable (Adesiyan, 2005). All living things are influenced by their surroundings in terms of their health, life cycles, and mortality. According to Akinbode (2012), the environment encompasses all the locations and circumstances in which we live, work, and interact with others in pursuit of cultural, religious, political, and socio-economic goals that lead to personal fulfilment and advancement in the community. As sustainable development encompasses three essential dimensions; social, economic, and environmental. it is imperative that we make sure our actions today enable us to meet both our current needs and the requirements of future generations without compromising (Agbola, 2008). Due to human activity, the natural environment is changing to the point where it is becoming more challenging to characterize or understand. However, man's surroundings also have an impact on him and his actions, therefore there is a reciprocal interaction between man and his surroundings. Both natural and human processes can cause environmental change. By converting and moving huge amounts of energy and materials, environmental systems and human activities both contribute to environmental changes. Through the cycling of materials through geological, biological, oceanic, and atmospheric processes, natural systems convert the sun's energy into living matter and bring about changes. Contrarily, human activities transform raw resources and energy into goods and services to satisfy human needs and aspirations.

The environment is affected greatly by changes in land use, both locally and globally. These major changes result in the loss of biodiversity on a local, regional, and global scale, increased soil erosion, increased sediment loads, and erratic water cycle patterns (Lambin and Geist, 2006). Local changes in land use and cover have an impact on micro-climatic resources, which directly affect local inhabitants' means of subsistence (Sultan, 2016). About 15% of all anthropogenic greenhouse gas emissions are

attributed to the cattle industry, while the other 10% are attributable to land use change, which includes deforestation, cropping, and the conversion of vegetation to built-up areas (FAO, 2016). One of the main causes of low and declining agricultural production, which subsequently worsens poverty is land degradation. (Okeleye et al., 2016; Kirui, 2016).

The majority of the poor in developing nations live in rural areas, despite the fact that the development rate of urban slums has increased over the past ten years which exposes them to harsh effect of environmental change (Oni-Jimoh et al., 2018). Climate, food security, and human security are all significantly impacted by soil protection and sustainable land use (Amundson et al., 2015). Global migration is viewed as a complicated and rising phenomenon. As a result of hazards and disasters brought on by nature (the environment) and climate, there were no fewer than 26.4 million people displaced per year between 2008 and 2015, and this tendency has continued to rise (Froese and Schilling, 2019).

Sub-Saharan Africa has diverse patterns of rural-urban migration, environmental, political, cultural, demographic, or socio-economic issues may push people to migrate. Most of the time, a combination of the aforementioned criteria affects the decision to relocate (Sedoo et al., 2019). Because there is a shortage of housing due to migration to metropolitan areas, many urban inhabitants live in unofficial housing (Amrevurayire and Ojeh, 2016).

One strategy for coping with climate change is migration (IOM, 2016). According to the International Organization for Migration (IOM) (IOM, 2017), migration that is well-managed, safe, and regular can support the expansion and improvement of agriculture, economy, rural residents' means of subsistence, and food security. Climate change-related agricultural asset degradation is causing a production reduction and sharply diminishing rural communities' chances for employment (Okeleye and Olurunfemi, 2016). Rural-urban migration is influenced by both poverty and food insecurity (IOM,2017). Potential paths from climate change to migration include increases in the frequency and severity of weather- and climate-induced risks, including rapid and slow-onset events (FAO,2016). Extreme weather events, which have a quick onset and often have an immediate effect, are directly related to migration and climate change (FAO,2016). Rural people sometimes experience displacement as a result of natural catastrophes linked to these sudden-onset events damaging their assets and/or output (IPCC,2014, Okeleye and Olurunfemi,2016).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Nigeria, and specifically Northern Nigeria, which had previously been noted for its agricultural production, is now severely impacted by climate change and soil degradation in the form of frequent drought and flood (IPCC,2007). Due to the over-reliance on rainfed agricultural practices and the extreme poverty of the population, the majority of the crops are less productive (IPCC, 2007). The majority of farming households in North Central and North West, Nigeria have between one and four individuals who relocate each year as a result of disasters caused by climate change and changes in land use, which makes it harder for them to be food secure (Ngutsav et al., 2021). Poor access to excellent education, an inadequate health care system, low agricultural yields, and poverty are a few of the main variables that influence rural-urban migration (IOM, 2016). Although many academics have discussed migration as a technique for adapting to climate change (Davis et al., 2018), it is also referred to as the inability to adapt or mitigate (Mayer,2011).

This study investigated the socio-economic and environmental factors influencing the output of rice farmers in Kaduna State and Federal Capital Territory, Nigeria.

MATERIALS AND METHODS

The study was carried out in the Federal Capital Territory and Kaduna State, Nigeria. The study adopted a multi-stage random sampling technique. In the first stage, four (4) Area Councils were randomly selected in Federal Capital Territory. Also, four (4) Local Government Areas (LGAs) were randomly selected in Kaduna State. In the second stage two (2) wards were randomly selected in the four (4) LGAs selected in Kaduna State and in the 4 Area Councils selected in Federal Capital Territory making a total of sixteen (16) wards. In the final stage, equation (1) was used to select a proportionate and random sample of one hundred and eighty-five (185) small-scale rice farmers from the total sample frame of three hundred and forty-four (344) small-scale rice farmers in the study area. The study used Yamane (1967) for estimating sample size:

$$\mathrm{n} = \frac{N}{1 + N(e^2)} = 185 \qquad (1)$$

Where,

n = Sample Size (Units)
N= Sample Frame/Population size (Units)
e = Level of Precision (5%)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

1.1.2 The Multiple Regression Model

This study follows the model used by Justice et al. (2016); the multiple regression model is explicitly stated as follows:

$$Q_{ij} = \emptyset_0 + \sum_{n=1}^{11} \emptyset_i X_i + \mu_i \qquad (2)$$

Where;

Q_{ij} = Quantity of Output (Kg)

X_1 = Age of the Farmer (number),

X_2 = Number of years spent in schooling (Years),

X_3 = Marital Status of the Farmer (1, Married; 0, Otherwise),

X_4 = Households Size (Total Number of Persons),

X_5 = Access to Credit (1 = Access, 0 Otherwise),

X_6 = Member of Cooperative Society (1 = Member, 0 Otherwise),

X_7 = Change in Temperature (1 = Yes, 0 Otherwise)

X_8 =Loss of farmland as a result urbanization (Number)

X_9 = Rainfall variation (Number)

X_{10} = Conflicts (farmers-herders clashes) (Number)

X_{11} =Heat waves (Number)

$\emptyset_0$= Constant Term

$\emptyset_i$= Coefficients of the Explanatory Variables

μ_i = Random Error Term

I = Rice Farmers

1.1.3 Propensity Scoring Matching

This formula follows the study of Ali et al. (2018), the most common evaluation parameter of interest is the Average Treatment Effect on the treated (ATT) which is defined as: -

$$ATT_{ij} = E\left(\frac{\vartheta_1 - \vartheta_0}{\rho = 1}\right) - \left(\frac{\vartheta_1}{\rho = 1}\right) \qquad (3)$$

.

$$\rho(X) = \rho_r\left(\frac{\rho = 1}{\theta = \theta_{ij}}\right) \qquad (4)$$

$$ATT_{ij} = \frac{1}{N_1}[Y_1 - Y_0] \qquad (5)$$

Where;

ATT = Average Impact of Treatment on the Treated,

N_1= Number of Matches (From Regression Model),

Y_1= Output Index by Participants, and

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Y_0= Output Index by Non-Participants.
i = Rice Farmers,
A positive (Negative) value of ATT will usually suggest that participants in a programme have higher (lower) outcome variable than non-beneficiaries.

RESULTS AND DISCUSSION

The socio-economic characteristics of rice farmers in the study area

Sex distribution

Table 1 reveals that majority (76.22%) of the rice farmers are female, while (23.78%) of the farmers are male. This implies that women play a significant role in agricultural activities. Gender-targeted interventions might be necessary to support female farmers, ensuring they have access to resources, training, and support systems.

Age distribution

The result reveals that the mean age was 48.10 years, approximately 37.30% of the rice farmers were within 43-53 years, 25.41% were within 32-42 years, 22.16% were within 54-64 years, and 9.19% were greater than 65 years (65-75). The suggests that farming is predominantly undertaken by middle-aged farmers. This might indicate a lack of youth involvement in agriculture, which could impact the future sustainability of farming practices. Efforts may be needed to encourage younger generations to engage in farming through incentives, education, and modern agricultural technologies. This study agrees with the results of Alabi et al. (2022).

Marital status

Marital status of the farmers has direct relationship on the size of the household which will invariably influence the quantity of household labour that will be available for production activity. Marital status of the farmers also means commitment to the business because of the family needs that must be met. This result shows that the majority (88.11%) of the rice farmers are married, (7.03%) are single and 4.86% are divorced. A high percentage of married farmers could mean that farming is often a family-based activity. Policies and programs that support family farming could be beneficial, and social safety nets for family farmers might be important.

Household size

Household size and its composition are important factors to consider in describing households' pursuit for economic activities and welfare of the households most

especially as it affects the availability of family labour for economic activities such as farming. Household labour helps to mitigate/ cope with the issue of scarce and costly hired labour and help reduce the cost incurred in labour purchase. The result shows that majority (43.24%) of the rice farmers had 8-14 persons in their household and (42.16%) had 1-7 persons in their households. The mean household size of the rice farmers is 9. Large household sizes indicate a reliance on family labour for farming activities. This could also mean higher dependency ratios, with more non-working members in the household. Programs that focus on family labour management and productivity improvements could be beneficial. Household size significantly influences food demand and dietary patterns, as larger households consume greater quantities of staple foods, while also facing higher food insecurity risks (Omonona & Agoi, 2007).

Number of years spent schooling

The adoption capacity of a farmer about an innovation, practice or technology requires that he/she is well educated. The result shows the majority (69.77%) of the rice farmers spent 1-7 years in school, (18.02%) had 8-14 years in school, while (9.3%) spent 15-21 years in school education. The mean years of schooling is 6 years. The low average years of schooling suggest limited formal education among the rice farmers. This could affect their ability to adopt new technologies and practices such as adaptive and mitigation strategies which can influence their productivity, efficiency and income. Educational programs and training sessions tailored to this demographic could help improve their farming skills and productivity.

Farm experience

The number of years a farmer spent in farming gives an indication of the practical knowledge he\she has gained on how to cope in production, since experience farmers are better risk managers than inexperienced ones. When experience is channeled it can lead to higher productivity, efficiency and higher income this can translate to higher economic well-being of the farmer and the farm family. The result shows that majority of the rice farmers (38.92%) had 22-32 years of experience, (35.14%) had between 11- 21 years of experience, (24.86%) had 1-10 years of experience, while (1.08%) had 33 years or more years of experience. The mean years of farm experience is 18 years. This implies that most of the farmers are well experienced about rice production and it may have positive influence in their productivity, efficiency and income and invariably in their welfare. Furthermore, with considerable farming experience, these farmers likely have a wealth of traditional knowledge and skills. However, integrating this experience with modern agricultural practices could enhance productivity and

sustainability. Extension services and training programs can play a critical role in this integration.

Access to credit

Access to credit facilities may enable farmers adopt new adaptation and mitigation strategies to enhance their production. The result showed that the majority (91.35%) could not access credit, while (8.65%) were able to access credit. The mean volume to access to credit is (₦22,515.96), this is an indication that access to credit is a problem which is likely to affect productivity. More so, limited access to credit is evident, with a significant portion of farmers not accessing credit facilities. This could hinder their ability to invest in better farming inputs and technologies. Enhancing credit facilities and financial literacy programs for farmers could improve their productivity and economic stability.

Monthly income

The amount of income coming into the household is dependent on the output and ability of the farmer to diversify into off-farm and non-farm activities. This will probably influence the welfare of the farmer, adaptation and mitigation strategies adopted by the farmers. The result shows that the majority (68.26%) of the farmers realized less than ₦25,000 from their secondary occupation, while (8.98%) of the farmers realized above ₦52000 as monthly income from secondary occupation. The mean monthly income (₦36,189.87) suggests that most of the rice farmers are smallholder farmers. The results show that there should be more efforts to improve market access, value addition, and diversification of income sources could help improve their livelihoods.

Extension contact

Majority of the farmers (61.08%) have extension contact, while (38.92%) had no extension contacts. This indicates that while a majority have contact with extension services, a significant portion does not. Improving the reach and effectiveness of agricultural extension services can help disseminate best practices and new technologies to more farmers.

Membership in farm-based organizations

Cooperative association may enable farmers mobilize resources to enjoy economies of scale; it provides information to enhance effective production and acquisition of better and more innovative skills to boost production. The result shows that 51.89% of the farmers are members of farm-based organizations, while 48.11% are not members

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

of farm-based organization. These organizations can play a crucial role in providing support, collective bargaining, and knowledge sharing. Encouraging more farmers to join such organizations could strengthen community-based agricultural development.

Table 1. The socio-economic characteristics of rice farmers

Variable	Frequency	Percentage	Mean Value
Sex			
Female	141	76.22	
Male	44	23.78	48.10
Age (Years)			
21 – 31	11	5.95	
32 – 42	47	25.41	
43 – 53	69	37.30	
54 – 64	41	22.16	
65 – 75	17	9.19	
Marital Status			
Single	13	7.03	
Married	163	88.11	
Divorced	9	4.86	
Household Size (Number)			
1 – 7	78	42.16	
8 – 14	80	43.24	9
15 – 21	23	12.43	
22 – 28	4	2.16	
Number of Years Spent Schooling			
1 – 7	120	69.77	
8 – 14	31	18.02	6
15 – 21	16	9.30	
22 – 28	5	2.91	
Farm Expérience (Years)			
1 – 10	46	24.86	
11 – 21	65	35.14	18
22 – 32	72	38.92	
33 – 43	2	1.08	
Access to Credit			
Yes	16	8.65	
No	169	91.35	₦22, 515.96
Monthly Income (Naira)			
≤ 25, 000	114	68.26	
26, 000 – 51, 000	38	22.75	36, 189.87
≥ 52, 000	15	8.98	
Extension Contact			
Yes	113	61.08	
No	72	38.92	
Membership of Farm-Based Organizations			
Yes	96	51.89	
No	89	48.11	
Total	185	100.00	

Source: Field Survey Data (2025)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

The effects of socio-economic and environmental factors on the output of rice farmers

Table 2 presents the effects of socio-economics and environmental factors on the output of rice farmers. Below is a discussion of each socio-economic and environmental factors and its implications:

Socio-economic factors

Age of the Farmers: The negative coefficient ($\emptyset_1$ = -0.0311, p = 0.060) suggests that as farmers' age increases, rice output tends to decrease slightly. This coefficient is significant at the 10% probability level. This implies that older farmers might have lower productivity, possibly due to less physical ability or reluctance to adopt new techniques.

Household size: The negative coefficient ($\emptyset_4$ = -0.7655, p = 0.021) was significant at the 5% probability level. This indicates that larger household sizes are associated with lower rice output. This might be due to increased consumption demands that reduce the resources available for farming.

Cooperative membership: The positive coefficient ($\emptyset_6$ = 3.1057, p = 0.000) was significant at 1% probability level. This indicates that being a member of a cooperative organizations significantly increases rice output. Farm-based organizations may likely provide resources, information, and support that enhance productivity.

Environmental factors

Rainfall variation: The positive coefficient ($\emptyset_9$ = 0.2695, p = 0.098) was significant at 10% probability level. This suggests that rainfall variations might have a positive effect on rice output. This could indicate that variability in rainfall, perhaps increased or more evenly distributed rain, benefits crop growth.

Heat waves: The negative coefficient ($\emptyset_{11}$ = -2.4752, p = 0.000) was significant at 1% probability level. This indicates that heat waves drastically reduce rice output. This highlights the severe impact of extreme heat on agricultural productivity.

The R-squared value was 0.587,i.e. the model explains approximately 58.7% of the variance in rice output, suggesting a moderately good fit.

Akaike Criterion (AIC = 858.796)- a measure used for model comparison, with lower values indicating a better fit.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 2. The effects of socio-economic and environmental factors on the output of rice farmers

Variable	Parameters	Coefficient	Standard Error	t-Value	*p-Value*
Constant	$\emptyset_0$	11.2104	1.99985	5.61	0.000
Age	$\emptyset_1$	- 0.0311*	0.0164	-1.89	0.060
Number of Years Spent Schooling	$\emptyset_2$	-0.0199	0.0329	-0.60	0.546
Marital Status	$\emptyset_3$	-0.4900	0.5297	-0.93	0.356
Household Size	$\emptyset_4$	-0.7655	0.3278	-2.34	0.021
Access to Credit	$\emptyset_5$	0.2821	0.4442	0.64	0.526
Cooperative Membership	$\emptyset_6$	3.1057***	0.6152	5.05	0.000
Change in Temperature	$\emptyset_7$	-0.1129	0.1775	-0.64	0.526
Loss of Farmland due to Urbanization	$\emptyset_8$	0.4224	0.3681	1.15	0.253
Rainfall Variation	$\emptyset_9$	0.2695*	0.1620	1.66	0.098
Conflict	$\emptyset_{10}$	0.1295	0.3709	0.35	0.727
Heat Waves	$\emptyset_{11}$	-2.4752***	0.5958	-4.15	0.000
R-Square		0.587			
Akaike Crit (AIC)		858.796			
F-Statistics		3.613			
Prob(F-Statistics)		0.000			

Source: Field Survey Data, 2025

*** = significant. @ 1%, ** = significant @ 5% and * = significant @ 10%

Model fit and overall implications

The economic impact of environmental change on the output of rice farmers: The Table 3 presents the results of a propensity-score matching (PSM) estimation that examines the impact of various environmental changes on the output of rice farmers. Below is an interpretation of the results for each of the treatment variables (environmental factors) on crop output, focusing on the average treatment effect on the treated (ATT), the corresponding z-values, and the significance levels:

The economic impact of environmental change on the output of rice farmers in Kaduna state

Heat wave

The negative ATT of -0.2680 implies that heat waves are associated with a decrease in rice output. This effect was also significant at the 10% probability level, suggesting that heat waves negatively impact rice productivity. Heat waves can damage crop

directly by inducing heat stress and disrupting water availability (Lesk et al., 2016). Additionally, heat wave also one of the most detrimental forms of environmental stress on agriculture especially heat sensitive crops.

Migration

Migration has a positive coefficient and was significant at 5% probability level with ATT of 0.3007 on rice output. This means that there is strong evidence that migration affects rice output in this context. Migration affects productivity and also leads to labour shortages (Gray & Mueller, 2012).

Change in temperature

A significant positive coefficient at 1 % probability level with ATT of 0.2300. This indicates that changes in temperature are strongly associated with an increase in rice output. This suggests an impact of temperature change on rice productivity. This shows that adaptation strategies such changing in planting dates, multiple planting dates or use improved varieties to cope with recent increase or changes in temperature (Lobell & Burke, 2010). Furthermore, according to Rosenweig et al. (2014) who reported that rising temperature benefits crop production especially in cool regions where hotter conditions increases the growing season.

Reduction in size of water bodies

The ATT for the reduction in the size of water bodies is 0.2941, which is positive and statistically significant at 10% probability level. This suggests a strong evidence of its impact on rice output. Furthermore, Molden et al. (2007) reported that reduction in water bodies especially in the long run may have detrimental effect on agriculture especially for water intensive crops.

The economic impact of environmental change on the output of rice farmers in FCT

Heat wave

The negative ATT of -1.3811 implies that heat waves are associated with a decrease in rice output. This effect is also significant at the 5% probability level; this suggests that heat waves negatively impact rice productivity. Heat waves can damage crop directly by inducing heat stress and disrupting water availability (Lesk et al., 2016). Additionally, heat wave also one of the most detrimental forms of environmental stress on agriculture.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Change in temperature

A significant positive ATT of 1.4681 indicates that changes in temperature are strongly associated with an increase in rice output, with high statistical significance ($p < 0.05$). This suggests a robust impact of temperature change on rice productivity. This shows that adaptation strategies such changing in planting dates, multiple planting dates or use improved varieties to cope with recent increase or changes in temperature (Lobell & Burke, 2010). Furthermore, according to Rosenweig et al. (2014) who reported that rising temperature benefits crop production especially in cool regions where hotter conditions increases the growing season.

The economic impact of environmental change on the output of rice farmers for pooled

Loss of crop due to soil degradation

The positive ATT of 1.2880 suggests that the loss of crops is associated with an increase in rice output among farmers who experienced this environmental change, compared to those who did not. This result is significant at the 10% probability level. This outcome is in agreement with assertions of Di Falco et al. (2011) who posited that farmers after facing crop loss intensify effort or adopt new coping strategies to increase output.

Heat wave

The negative ATT of -0.7338 implies that heat waves are associated with a decrease in rice output. This effect is also significant at the 10% probability level; this suggests that heat waves negatively impact crop productivity. Heat waves can damage crop directly by inducing heat stress and disrupting water availability (Lesk et al., 2016).

Change in temperature

A significant positive ATT of 1.4301 indicates that changes in temperature are strongly associated with an increase in rice output, with high statistical significance ($p < 0.01$). This suggests a robust impact of temperature change on crop productivity. This shows that adaptation strategies such changing in planting dates, multiple planting dates or use improved varieties to cope with recent increase or changes in temperature (Lobell & Burke, 2010). Furthermore, according to Rosenweig et al. (2014) who reported that rising temperature benefits crop production especially in cool regions where hotter conditions increases the growing season.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 3. Propensity-score matching estimation for the impact of environmental change on the output of rice farmers

Treatment	Variables	Kaduna		FCT		Pooled Data	
		ATT	Z-Value	ATT	Z-Value	ATT	Z-Value
Crop Output	Loss of Crop due to Soil Degradation	-0.1001 (0.2012)	-0.71	-1.3231 (0.3221)	-1.06	1.2880 (0.6859)	1.88*
	Heat Wave	-0.2680 (0.1611)	-1.66*	-1.3811 (0.6856)	2.01**	-0.7338 (0.4124)	-1.78*
	Migration	0.3007 (0.1426)	2.11*	0.3011 (0.4200)	0.41	0.2917 (0.4775)	0.61
	Conflict	-0.2066 (0.1775)	-1.16	0.9316 (0.7377)	0.207	0.4071 (0.3768)	1.08
	Change in Temperature	0.2300 (0.0716)	3.21***	1.4681 (0.6612)	2.22**	1.4301 (0.3925)	3.64***
	Urbanization	0.2339 (0.1665)	-1.40	0.6667 (0.6549)	1.02	0.2999 (0.3815)	0.79
	Soil Infetility	0.5102 (0.3382)	1.03	0.7147 (0.6722)	1.06	-0.0024 (0.4077)	-0.01
	Reduction in Size of Water Bodies	0.2941 (0.1608)	1.83*	0.4334 (0.7846)	0.55	0.3352 (0.4487)	0.75

*** = significant. @ 1%, ** = significant @ 5% and * = significant @ 10%. Standard errors are reported in parenthesis; **Source**: Computed from Field Survey Data (2025)

CONCLUSION

The socio-economic factors that significantly influenced the output of rice included age, household size, and cooperative membership. The environmental factors that influence the output of rice include rainfall variations and heat waves. The environmental changes had significant impact on the output of rice farmers in the study area. In the pooled data for example the environmental change that had significant impact with their corresponding average treatment effect (ATT) included heat waves (0.4124), change in temperature (1.4301), and loss of crop due to soil degradation (1.2880).

An increase in temperature negatively affects welfare, with a coefficient of (-0.3596). This factor was statistically significant at the 1% probability level; this implies that temperature changes may not favor certain crops or farming conditions.

The negative and highly significant coefficient (β_{11} = -0.0650, z = 2.27) indicates that heat waves drastically reduce crop output. This highlights the severe impact of extreme heat on agricultural productivity.

The result indicated that the coefficient is negative and statistically significant (β_8= -0.2356, z = 1.76) at 10% probability level. This implies that as a unit increase in reduction in the size of water bodies, while keeping all other variables constant will lead to 0.2356 unit reduction in the welfare status of crop farmers.

RECOMMENDATIONS

- Farmers should be encouraged to use drought-resistant and early-maturing rice varieties (like the NERICA series) to mitigate the effects of shorter rainy seasons.
- The government should facilitate the construction of tube wells and wash-bores, particularly for lowland rice cultivation.
- Regular soil testing to determine specific fertilizer needs and the use of IPM to reduce the high cost of chemical pesticides.
- Government and financial institutions should provide low-interest loans specifically for smallholder rice farmers.
- There is a need for more extension officers to visit rural areas.
- Policies should specifically target female-headed households with land tenure security and tailored inputs.

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January, 2026, volume 30
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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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REVIEW ARTICLE

Animal Genetic Resources for Sustainable Livestock Development in Nepal

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ABSTRACT

Nepal is rich in animal genetic resources (AnGR) both in terms of diversity and numbers. Animal genetic resources play a key role in livestock development in the country mainly through their contribution to income generation and livelihood enhancement. They have also non-economic values (socio and cultural values) or bequest value, which doesn't seem to be valued. The diversity both species and breeds levels are enormous in the country. A total of 25 indigenous breeds from seven livestock species have been characterized so far. There are several transboundary breeds (regional and international) in the country. Despite of these several breeds, particularly indigenous breeds are declining making system non-sustainable. The major threats for animal genetic resources are genetic erosion, indiscriminate crossbreeding, low productivity, small holding size, lack of specific policies, changing production systems, lack of valuation of local breeds, increasing competition for natural resources and environmental degradation. These factors are contributing to genetic erosion of indigenous breeds in the country. Several breeds have population declined and few are about to be extinct if careful measures are not taken. Strategic actions should be undertaken in order to check genetic erosion and improve their contribution. Effective management of AnGR will address these constraints precisely. Management for AnGR includes its understanding (characterization), using (utilization), maintaining (conservation), accessing and benefit sharing.

Key Words: Animal genetic resources, Conservation and improvement, Economic and non-economic contribution, Food security and livelihood, Sustainable development

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
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BACKGROUND

The total estimated population of large (cattle and buffaloes) and small ruminants (sheep and goats) in the country were 7.8 million and 15.0 million heads, respectively in the year 2022/23. Similarly the estimated population of pigs and poultry (non ruminants) were 1.4 million and 66.5 million heads, respectively. In 30 high hill / mountain districts, the population of Yak and Chauries (cross between Yak and hill cattle) was 53,195 heads. The estimated population of horse/asses and mules was 17,332 and rabbits (wool and meat type) was 43,192 heads (Statistical Information on Agriculture, 2024). The overall growth ranges from <1.0 to 6 % in livestock with average 4.7% (<1% in sheep and 6% in chicken) The annual growth in livetsock products ranges from 5.3% in milk to 8.0% in meat. Similarly growth ranges from 0.05 % in wool to 8.6% in eggs.

There are several others species that are being domesticated and being utilized. They are ducks, pigeons, quails, turkey, rabbits, horse and ostrich. There are several wild relatives of domestic animals such as *Arna* (wild buffaloes), *Gauri Gain* (wild cattle), Blue sheep (wild sheep), *Kalij* (wild chicken), and wild rabbits. The percentage of exotic breeds ranges from 5 to 50 (5 to 10% in sheep and goats and 50% in chicken) (AnGR, 2004) indicating chunk of contribution to the country in the form of food and agriculture comes from indigenous animal genetic resources (AnGR). Though the information has come from old data and this needs updating. It is expected that the proportion of exotic breeds (particularly in chicken and cattle) might have increased.
Animal genetic resources play a key role in livestock development in the country greatly to nutritional food security in terms milk, meat and eggs. They contribute 11 % to total gross domestic product (GDP) and the contribution of livestock to total AGDP of the country is estimated to be about 24 % to agriculture GDP (MoF, 2023). AnGR are kept in the country for multipurpose uses such as food (milk, meat and eggs), transportation (draft and pack), and manure for maintaining/improving soil fertility. Apart from these they have non-economic values (socio and cultural values) or bequest value, which unfortunately don't receive appreciation in terms of value. Increased production and supply of animal source food (ASF) is important to meeting Zero Hunger (Goal #1) of UN Sustainable Development Goal by 2030.

The paper highlights on the status of the animal genetic resources in terms of conservation and utilization in the country. There will be description on their contribution to livelihood and food security. The potential and challenges for better

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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use of AnGR will be highlighted. The suggestive measures and strategies for better AnGR management in the country will be presented.

DIVERSITY

The diversity both species and breeds levels are enormous in the country. A total of 25 indigenous breeds from seven livestock species (7 in cattle, 3 in buffaloes, 4 in sheep, 4 in goats, 3 in pigs, 3 in chicken and 1 in horse) have been characterized so far, though the characterization at molecular level has been made for some breeds (Neopane, 2006; Gorkhali *et al.*, 2021). A wide diversity of livestock exists encompassing cattle, buffalo, sheep, goats, pigs, equines, chicken, ducks, turkey, quails, ostrich, rabbits, and pigeon (AnGR, 2004).

Table 1. Breeds of livestock in the country

Species	Local Breeds	Transboundary: International	Transboundary: Regional
Cattle	Lulu, Achhami, Siri, Terai, Pahadi, Khaila, Yak	Jersey, Holstein-Friesian, Brown Swiss, Ayrshire	Hariana, Sahiwal, Red Sindhi
Buffalo	Lime, Parkote, Gaddi	Murrah	Nili Rabi, Jaffrabadi
Goat	Terai, Khari,Chyangra and Sinhal	Saanen, Boer	Jamnapari, Barbari, Beetal, Ajmeri
Sheep	Lampuchhre, Kage, Baruwal and Bhyanglung	Polwarth, Merino, Rambouillet, Border Leicester, Romney Marsh, Corriedale	-
Pigs	Hurrah,Chwanche, Bampudke, Pakhribas	Large White Yorkshire, Landrace, Hampshire, Saddle back, Tamworth, Duroc	-
Poultry	Sakini, Pwankh Ulte, Ghanti Khuile	New Hampshire, Black Australorp, Several synthetic layers and broilers	Giriraja, Several synthetic layers and broilers
Rabbits	Wild breeds	German Angora, Russian Angora, British Angora	Chinese Angora
Horse	Jumli and several un-identified breeds	-	-

Sources: Neopane and Shrestha (2009); Gorkhali et al. (2021); Neopane et al (2023)
Note: Transboundary breeds are those available in more than one region while regional transboundary are confined to one region.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

There exist a diversity at breed levels within species (Table 1). This diversity is contributing to the economy through several attributes; food production of animal source origin; livelihood enhancement; inputs for agriculture operation and transport, and several others (Neopane *et al*., 2023). There are several transboundary breeds (regional and international) in the country. Despite of these several breeds, particularly indigenous breeds are declining making system non-sustainable.

STATUS OF ANIMAL GENETIC RESOURCES (AnGR)

A total of 25 indigenous breeds has been characterized (Table 2). The characterization at molecular level has been made in some breeds. Others species available: ducks, pigeons, quails, turkey, rabbits are being domesticated and being utilized. Nepal is fortunate to having several wild relatives of domestic animals such as *Arna* (wild buffaloes), *Gauri Gain* (wild cattle), Blue sheep (wild sheep), *Kalij* (wild chicken), wild rabbits, which can be used for improvement of the livestock population.

Table 2. Characterization status of local breeds

Species/Breeds	Characterization Status	Species/Breeds	Characterization Status
Cattle		**Goats**	
Terai	Phenotypic +DNA	Terai	Phenotypic+Chromosomal+DNA
Pahadi	Phenotypic	Khari	Phenotypic+Chromosomal+DNA
Khaila	Phenotypic	Sinhal	Phenotypic+Chromosomal+DNA
Lulu	Phenotypic+Chromosomal+DNA	Chyangra	Phenotypic+Chromosomal+DNA
Achhami	Phenotypic+Chromosomal+DNA	**Sheep**	
Siri	Phenotypic +DNA	Lampuchhre	Phenotypic+Chromosomal+DNA
Yak/Nak	Phenotypic +DNA	Kage	Phenotypic+Chromosomal+DNA
Buffalo		Baruwal	Phenotypic+Chromosomal+DNA
Lime	Phenotypic+Chromosomal	Bhyanglung	Phenotypic+Chromosomal+DNA
Parkote	Phenotypic+Chromosomal		
Gaddi	Phenotypic+Chromosomal		
Pigs		**Chicken**	
Chwanche	Phenotypic+Chromosomal+DNA	Sakini	Phenotypic+Chromosomal+DNA
Hurra	Phenotypic+Chromosomal+DNA	Ghanti Khuile	Phenotypic
Bampudke	Phenotypic+Chromosomal+DNA	Pwankh Ulte	Phenotypic
Horse			
Jumli	Phenotypic		

Sources: Neopane (2006); Pokhrel *et al.* (2012); Gorkhali *et al.* ((2021)

These local breeds have wide variation in the production traits and these variations can be captured through some effective breeding methods for making improvement. Some of the local breeds that have variation are Khari goats, Chwanche and Hurrah pigs, Sakini chicken, Lime and Parkote buffaloes, Baruwal sheep, Lulu and Achhami cattle.

Positive attributes

Indigenous breeds are low producing than the exotics in terms of milk, meat, eggs and wool production. However, they have several other positive attributes such as hardiness, adaptability to local harsh conditions and can produce in low input system. It is observed that these positive attributes are not duly recognized rather exotics breeds are unnecessarily given preference over them.

Availability of livestock products for food security

The per capita availability of milk, meat and egg in the year 2023/24 for Nepal were 88.0 5 kg, 14.7 kg and 55 number respectively. The trend appears to be increasing (Table 3). The ministry of agriculture and livestock development has (in March 2021) declared the country self-reliant on poultry meat and eggs, goat, milk powder and ghee (condensed butter) (The Kathmandu Post 2021). The population of each of the livestock species is lower than human population except in fowl (chicken) where there are 2.6 fowl (chicken) for one person. The ratio for cattle, buffalo, sheep, goat and pigs for human population are 4:1, 5:1, 25:1, 2.5:1 and 20:1 respectively (MoALD, 2024).

Table 3. The per capita availability of livestock products

Products	2018/2019	2023/2024
Milk (Liters)	74.5	88.0
Meat (Kg)	12.3	14.7
Eggs (No)	53	55

Source: MoALD (2020); MoALD (2024)

ANIMAL GENETIC RESOURCES AND SUSTAINABLE LIVESTOCK DEVELOPMENT

Food, livelihood and economic outputs

The contribution of agriculture including forestry and fisheries to the national gross domestic product (GDP) is 24.1% in the country (MoF, 2023). Livestock sector being an important entity within agriculture contributes significantly to the AGDP (24.0%)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

in the country through milk, meat, eggs, wool, manure/fuels. (MoALD, 2023). Livestock products are a vital source for food security and nutrition for growing population in the country. The sector contributes greatly to addressing nutritional food security and enhancing livelihoods. As can be seen from table 4, buffalo is the key livestock component contributing highest of the total livestock GDP followed by cattle, goat, poultry, sheep and duck. Amongst the products, the largest contribution comes from milk followed by meat, manure and eggs.

Table 4. Contribution of livestock to AGDP by components

SN	Species	Milk	Meat	Eggs	Wool	Manure	Total
1	Buffalo	7.282	4.233	-	-	0.8532	12.37
2	Cattle	3.950	-	-	-	0.8532	4.803
3	Goat	0.0052	3.198	-	-	0.0153	3.219
4	Sheep	0.0052	0.0815	-	0.0098	0.0001	0.097
5	Pig	-	0.4172	-	-	-	0.417
6	Poultry	-	1.4475	0.6917	-	0.0004	2.139
7	Duck	-	0.0120	0.0243	-	-	0.036
8	Others	0.0417	0.722	-	-	-	0.764
Total		11.284	10.111	0.716	0.0098	1.722	23.8

Source: Selected Indicators of Nepalese Agriculture (2023).

More than 60% workforce is employed by the sector in the country. More than 50% of the households (HHs) is being engaged with livestock (goats: 72%; buffalo: 42%; cattle: 50% and poultry: 53%) farming throughout the country (National Sample of Census of Agriculture, 2023). Substantial proportion of livelihood of the people is being addressed by the livestock sector.

Both for consumption of animal source food (ASF) and export the sector (through food production, fibres/wool) is contributing greatly. Similarly the livestock sector is contributing to the national economy through transportation and manure though the contribution of transportation (draft power, transportation) and other by-products (e.g., fuel) from livestock has not been included (Selected Indicators of Nepalese Agriculture, 2023). Animal genetic resources have been greatly contributing to food security through supply of animal source food (ASF). They provide stuff that are needed making livelihood sustained. They provide draught power and fertilizer to support agriculture production system. They support product and product related industries and contribute to enhance the economy. Livestock has been contributing to the national Agriculture GDP significantly. This can be seen from table 5 as among top 10 agricultural commodities (contributing to AGDP), there are four livestock commodities; buffalo, cattle, goat and poultry.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

Table 5. Contribution of selected agricultural commodities on Agriculture GDP (2023/24)

SN	Commodities	Percent contribution
1	Vegetables	14.5
2	Rice	12.8
3	Buffalo	12.7
4	Maize	6.64
5	Potato	6.56
6	Wheat	5.87
7	Cattle	4.80
8	Goat	3.27
9	Lentil dry	1.58
10	Poultry	1.52

Sources: Statistical Information on Agriculture (2024).

Production of primary livestock products

In the year 2022/23, a total of 2.6 million MT milk was produced from about 1.77 million milking cattle and buffaloes. Around 19% of total cattle and 28 % of the total buffalo population have been estimated to be in milking stage. Of the total milk produced, 53.6 % was from buffaloes and remaining 46.4 % from the cattle (*Statistical Information on Agriculture (2024)*. The contribution of buffaloes in terms of total milk production has been gradually declining and that from cattle is increasing mainly due to initiation of dairy cattle farming at commercial scale and increase in the number of crossbred dairy animals mainly cattle with increase in artificial insemination (AI) coverage. The contribution of buffalo for total milk was 67% and that of cattle was 33% in the year 2020 (MoALD, 2020). Similarly, a total of 0.43 million MT meat was produced from buffalo, goats, pigs, fowls, ducks and sheep. The highest contribution came from chicken (46.6%), followed by buffalo (27%), goats (18%), pig (7.6%), sheep (0.43%) and duck (0.31%) (*Statistical Information on Agriculture (2024)*.

Sociocultural and ecological roles

Animal genetic resources have important role in cultural and social activities at different levels in the country. They are very important entities at households and community level. For several ceremonial activities livestock and poultry become important entity. In addition of economic importance, AnGR contribution for sociocultural values is enormous (AnGR, 2004). There are preferences over species and breeds for ceremonies and functions. For examples, black colour pigs are preferred for ethnic communities in the eastern hills of the country for their religious ceremony.

White colour pigs are preferred in the western parts of the country. Red colour cockerel (*Rato Bhale Kukhura*), Dark colour goats over light colour are preferred and have more value.

The livestock has cultural values in the country. For instances, slaughter of goats, sheep, male buffaloes, poultry, ducks and pigeon is a common feature that takes place at several religious ceremonies. Sacrificing animals to the Goddess is common features in the society. Livestock provides raw materials to the people for making clothes (*radi/pakhi*), and shoes. The number of animals reflects the status of the family. Horses are still the main means of transportation in hills and mountains. Keeping horses indicates the family status.

Grazing animals have been contributing for the maintenance and regeneration of pasture in the range and communal lands in the hills and mountains (Banstola, 2001). Animals (if kept at good size) will clear the areas which would have grown over. Migratory flocks of the animals while moving keep manuring the land and contribute to the soil fertility. AnGR contributes greatly to the transportation through pack and tracking services. Yak/chauri and horse/mules have been contributing greatly to the hills and mountains economy through transportation. Similarly Chyangra and Sinhal goats as pack animals contributes to hills and mountains economy (Neopane, 2002).

Indigenous livestock in sustainable farming system

Native livestock breeds being well adapted and environmentally effective are reared throughout the country in all ecological zones ranging from tropical/subtropical to alpine. Indigenous breeds have demonstrated their capacity to produce in low input system where the exotics can't cope with (Gorkhali *et al*., 2021; Neopane *et al*., 2023). For example Yak, Nak and Chauri utilize alpine pasture and play an important role for rural livelihood in the mountains of Nepal. Chyangra (mountain goat), Sinhal goat and Bhyanglung and Baruwal sheep are doing very good job for hilly and mountain people for their survival.

The role of native livestock breeds to the draught power has been significant. Draft animals are the major source of power for agricultural operations (Neopane, 2005). Cattle and buffaloes are the major draft animals that are used extensively for agricultural operations. Yak, sheep, goats, mules and horses are used as pack animals but these are also used for draft in high hills and mountains. Yak, nak and chauri are important sources of transportation at high altitudes. Yak and nak can survive at high

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
January, 2026, volume 30
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279

altitudes and remain important sources of transportation. Chauri (cross between yak and native cattle or nak and native cattle bull) can go down to mid hills and play important role for transportation. Similarly mules and horses as pack animals are important sources of transportation for hills. They are mostly used for transportation of food grains from lower hills to higher hills and mountains. Sheep and goats are used as pack animals in hills. They are used for transporting goods from lower place to higher hills (Neopane, 2002).

These animals are providing a substantial amount of manure that is being used for increasing/maintaining soil fertility (Neopane, 2005). Use of chemical fertilizers is not very common in hills and mountains. Animals' manure has an important contribution to this aspect. Apart from these, the livestock is important source of providing animal protein in the diet of hilly people in the form of milk, meat, and eggs.

KEY ISSUES OF THREATS TO ANIMAL GENETIC RESOURCES

The major threats for animal genetic resources are genetic erosion, indiscriminate crossbreeding, low productivity, small holding size, lack of specific policies, changing production systems, lack of valuation of local breeds, increasing competition for natural resources and environmental degradation. These factors are contributing to genetic erosion of indigenous breeds in the country. Few breeds have been extinct and some are about to be extinct if careful measures are not taken.

STRATEGY FOR ADDRESSING THESE THREATS

- Promotion of indigenous breeds
- No importation of exotic breeds at least for hills and mountains
- Strategic crossbreeding
- Value addition to indigenous breeds (both breeding and non-breeding approach)
- Reorientation of research and development programs towards optimum utilization of indigenous breeds
- Promotion of indigenous forage species (tree fodders, perennial fodder)
- Optimum utilization of natural pastureland.
- Use of suitable and combination of conservation methods
- Strategic use of crossbreeding for improvement

- Awareness about the importance of indigenous breeds at the community level

In totality effective management of AnGR will address these constraints precisely. AnGR management encompasses all technical, policy, and logistical operations involved in understanding (Characterization), using and developing (utilization), maintaining (conservation), accessing, and sharing the benefits of animal genetic resources (FAO, 2007, 2015).

OBSERVATION AND WAY FORWARD

Based on the available information and the contribution of AnGR, the following observations are made**;**

- The country is rich in biodiversity
- Great contribution from AnGR (Indigenous)
- Contribution can be enhanced if used properly
- Indigenous breeds have several positive attributes (Multipurpose uses, hardy and well suited to local conditions, can produce in low input system)
- Although low production but variation exists
- These variations could be used for improving the productivity
- Genetic erosion (More with local)
- Attention is needed for indigenous breeds
- Enabling policy for indigenous breeds and their uses
- Effective and appropriate conservation and improvement programs
- Conservation and improvement can/should go together for several cases

CONCLUSION

Animal genetic resources (AnGR) in the country have not been fully utilized. They are far from their full utilization but once it is made, there would be more prosperity through their contribution to income generation, sustainable livelihood, quality food nutrition and many more. For their effective utilization, management of AnGR is paramount and this has to be made precisely. Management for AnGR includes its understanding (characterization), using (utilization), maintaining (conservation), accessing and benefit sharing.

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