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ECONOMICS AND TECHNOLOGICAL GAP RATIOS OF AGROFORESTRY PRODUCTION IN RURAL AREAS OF KADUNA STATE, NIGERIA: IMPLICATION FOR ENVIRONMENTAL RESOURCE MANAGEMENT

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ABSTRACT

This study evaluated the economics and technological gap ratios (TGRs) of agroforestry production in rural areas of Kaduna State, Nigeria: Implication for environmental resource management. A multi-stage sampling technique was used. A total sample size of 120 respondents comprising of 62 (51.67%) male agroforestry farmers and 58 (48.33%) female agroforestry farmers were selected. Primary data were collected with the aid of a well-structured and a well-designed questionnaire. Data were analyzed using the following tools: descriptive statistics, stochastic production efficiency frontier model, stochastic meta-efficiency frontier model, and principal component model. The farm size, labour input, chemical input, fertilizer input, and agroforestry tree density contributes positively to output of male, female agroforestry farmers as well as pooled data respectively. The average agroforestry farmers achieve 83.1% (male), 64.7% (female) and 72.8% (pooled) of their frontier output given their present technologies. In other words, agroforestry farms are losing 16.9%, 35.3% and 27.2% of their maximum potentials output to inefficiencies. The mean technical efficiency relative to meta-frontier was estimated to be 74%, 47% and 59% for the male, female agroforestry farmers and the pooled data respectively. Based on the estimated technological gap ratios (TGRs) of 90%, 73% and 82% for the male, female agroforestry farmers and the pooled data respectively, the average male and female agroforestry farmers and the pooled data could be more technically efficient by increasing their output and closing the gaps of 10%, 27% and 18% respectively. The study recommended that farmers should be educated on the benefits of agroforestry production technologies.

Key words: Economics, technology gap ratios, agroforestry production, stochastic meta – efficiency frontier model, gender

INTRODUCTION

The Food and Agriculture Organization, FAO (2015) defined agroforestry as a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms bamboos, etc.) are deliberately used on the same land management units as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. Agroforestry is a combination of forestry and agriculture; it is an intensive land management system that optimize the benefit from the biological interactions created when trees and or shrubs are combined deliberately with crop and/ or animals. Agroforestry is a proven model of integrated sustainable land use system which can enhance agricultural productivity and production in a low input and in an ecological and economically feasible way in the effort of enhancing food security sustainably (Mbow, 2015). Agroforestry has multiple economic and environmental benefit as it helps farmers adapt to rapidly changing weather patterns and combat climate change (IPCC, 2019a). Agroforestry reduces soil and water erosion, improves water management, and reduces crop yield variability, all of which contribute to adaptation (Ajayi et al., 2019). The growing of trees on the border of the crop land is a good source of income for smallholder farmers on one hand and on the other hand plays an important role in increasing soil fertility, enhances biodiversity and cleans water that ultimately reduces global warming by carbon sequestrations (Ingwe et al., 2009). Agroforestry systems are both stable and sustainable, it has greater diversity than do monoculture practices and can distribute production over a long period, thus provide income that is more regular with increased cash flow stability. Integrating of trees into agricultural systems may result in more efficient use of sunlight, moisture and plant nutrients than is generally possible by monocropping of either agricultural or forestry crops (Amonum et al., 2009). Agroforestry production technology also have economic dimension since it helps maximize agricultural production by reducing soil erosion, water, and organic matter losses. The practice can increase microbial activities which can help nutrient recycling, thus increase the fertility of soil under agricultural production (Jose, 2009). Forests contribute to the resilience of agricultural systems in many ways. At landscape level, they contribute to water and temperature regulation and provide habitats for important species such as pollinators. Agroforestry production technologies have contributed a lot in the protection of watershed services and maximize the production systems. The role of agroforestry is important on current Sustainable Development Goals of the United Nations through climate change adaptation and mitigation. The trees also have a significant contribution in fixing nitrogen that can increase agricultural productivity. Agroforestry is an efficient adaptation strategy known for its capacity to increase resilience and reduce vulnerability of agricultural production systems to climate change effects (Palsaniya and Ghosh, 2016). Agroforestry practices are essential resources to combat climate because of their role in sequestering carbon and other greenhouse gases (AAC, 2014). The choice of tree species is the most important factors to be considered in agroforestry systems. The choice of tree species be made after careful consideration of their benefit for rural populace and adaptability for growth. Restoring degraded forests to healthy states, thereby re-establishing ecosystem functions, is a major strategy for increasing resilience., inundation and flood damage, saltwater intrusion and sea- level rise, and damage from coastal storms. The importance of forests as safety nets in times of natural disasters (e.g. floods and droughts) or civil unrest is well documented (Angelsen and Wunder, 2003). During these times, forests are often relied upon to provide food for the household or products to sell for survival. They also fill gaps in other times of difficulty. While heightened dependence on forest foods and products generally drops off when times return to normal, it is important to keep the safety net option open (i.e. not restricting access of vulnerable people to forests when needed for survival), particularly where relief services and social services are not adequately developed to meet emergency needs. Agroforestry is a combination of forestry and agriculture; it is an intensive land management system that optimize the benefit from the biological interactions created when trees and or shrubs are combined deliberately with crop and/ or animals. The system is intentional, intensive, interactive, and integrated. Agroforestry, the integration of trees in agricultural activities has the capacity to increase soil fertility, reduce evaporation, increase nutrient recycling, reduce land degradation from erosion, and improvement of water quality. Agroforestry system contribute to the rural economy through poverty alleviation, employment generation, and environmental protection at a local, regional and national level (Alavalapati et al., 2004). Agroforestry production technology also have economic dimension since it helps maximize agricultural production by reducing soil erosion, water, and organic matter losses.

A technical efficient firm is the one that produces the maximum output for a given amount of inputs given the level of production technology available. Efficiency implies that firms produce the largest possible quantity of output from a given set of inputs. Efficiency of a firm comprises of two components, technical and allocative efficiency, but that a combination of the two components give a measure of total economic efficiency (overall efficiency). The firm's technical efficiency is the ability to produce maximum output from a minimum quantity of inputs (Obianefo et al.,2021). Stochastic meta-technical efficiency frontier model can be defined as an envelope of all individual production functions. The approach allows the estimation of technology gap ratios, the technological differences between male and female agroforestry farmers, the approach shows how far or how close the individual production technologies are to the best possible production technology (the stochastic meta-technical efficiency frontier model) (Missiame et al., 2021). The stochastic meta technical efficiency frontier relaxes the assumption that firms in an industry face one or the same production technology. It allows a likelihood ratio test (statistical test) to confirm whether there are any differences in technology (Missiame et al., 2021). Estimation procedure when technologies are not the same (technologies are dissimilar) which are prevalent in the situations where comparison of industries/farms from different groups or regions are involved, the stochastic meta-technical efficiency frontier (SMTEF) is more appropriate for such comparative analysis (Onumah et al. 2013). Nan and Basil (2015) reported that stochastic meta technical efficiency frontier is a procedure developed to determine whether there is any difference between technologies adopted among firms. The SMTEF model can be used to evaluate the production efficiency frontier from a non-parametric approach (may or may not rely on normal distribution, mean, variances or rely on assumptions about the populations). The SMTEF model provides the economists with effective and efficient way to evaluate and compare firms' relative production performance (Huang et al., 2014).

Women account for more than half of the work force by participating in different farm activities, either directly or indirectly. In sub-Saharan Africa women are the backbone of the agricultural sector. Women accounted for 60% of agricultural production, 70% of agricultural labor, and 80% of food production (Alabi et al., 2021). The roles of women, the main actor in sub-Saharan African agriculture have not been recognized. Rural women run most of their farm activities themselves, provide most of the agricultural labour, constitutes majority of small-scale, smallholder farmers, are mostly the head of the households and manage their farms on a daily basis (Alabi et al., 2021).

MATERIALS AND METHODS

This study was conducted in Kaduna States, Nigeria. Kaduna State lies between Longitudes 06° $15^{|}$ and 08° $50^{|}$ East and Latitudes 09° $02^{|}$ and 10° $36^{|}$North of the equator. The State has a total land area of 4.5 million hectares. The mean rainfall is about 1,482mm, the temperature of the State ranges from 35°C - 36°C, which can be as low as 10°C to 23°C during the harmattan period. The population of the State in 2021 stood at 8.9 million people. They are involved in agroforestry production. One hundred and twenty (120) respondents comprising of 62 (51.67%) male agroforestry farmers and 58 (48.33%) female agroforestry farmers were selected. Multi-stage sampling technique was employed. The sample frame of male and female agroforestry farmers was 73 and 67 respectively. Primary sources of data were used. Data were obtained through a well-designed and a well-structured questionnaire. This study employed the formula advanced by Yamane (1967) in the determination or estimation of the sample size. The formula is stated thus:

$$n = \frac{N}{1+N(e^2)} \quad \text{...(1)}$$

Where,
n = Desired Sample Size
N = Sample Frame (Number)
e =Maximum Acceptable Margin of Error as Determined by the Researcher
Data were analyzed using the following tools:

Descriptive Statistics

This involves the use of frequency distributions, mean, percentages, and standard deviation to summarize the socio-economic characteristics of male and female agroforestry farmers and pooled data as specified in objective one (I).

This was used specifically to achieve objective one (I)

Stochastic Production Efficiency Frontier Model

According to Alabi et al. (2022) and Alulu et al. (2021), the stochastic production frontier model for male and female agroforestry farmers is stated thus:

$$Ln\, Y_{ik}^{z} = \beta_{ok}^{z} + \sum_{j=1}^{5} \beta_{ik}^{z}\, LnX_{ijk}^{z} + v_{ik}^{z} - u_{ik}^{z} \ldots\ldots\ldots\ldots\ldots(7)$$

$$l_nY_{ik} = \beta_0 + \beta_1 l_nX_1 + \beta_2 l_nX_2 + \beta_3 l_nX_3 + \beta_4 l_nX_4 + \beta_5 l_nX_5 + v_{ik} - u_{ik} \ldots\ldots\ldots\ldots(8)$$

Where,
Y_{ik} = Output of Agroforestry (Kg)
k = Male and Female Agroforestry Farmers
X_{ijk} = Vectors of Factor Inputs
β_{ik} = Vectors of Parameters
v_{ik} = Statistical Noise
u_{ik}= Error Term due to Technical Inefficiency
X_1 = Farm Size (Ha)
X_2 = Labour Input in Mandays
X_3 = Chemical Input in Litres
X_4 = Fertilizer Input in Kg
X_5 = Agroforestry Trees Density (Number of Trees on the Farm Land)

$$u_{ik} = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where,
Z_1 = Age in year
Z_2 = Experience in Agroforestry (Years)
Z_3 = Years of Formal Education
α_0 = Constant Term
$\alpha_1 - \alpha_6$ = Parameters to be Estimated
u_{ik}= Error Term due to Technical Inefficiency
This was used specifically to achieve objectives two (ii) and four (iv)

Stochastic Meta-Technical Efficiency Frontier Model

Stochastic meta-technical efficiency frontier model according to Alulu et al. (2021) for pooled data for agroforestry farmers is given by:

$$Ln\, Y_{i}^{z*} = \beta_{o}^{z*} + \sum_{j=1}^{5} \beta_{j}^{z*}\, LnX_{ij}^{z*} + \varepsilon_{ij}^{z}, j = 1,2,3 \ldots\ldots\ldots j \ldots\ldots\ldots\ldots\ldots(10)$$

Y_{i}^{z*} = The Metafrontier Output
X_{ij}^{z*} = The Vector of Variable Inputs used in the agroforestry farms such as farm size (ha), labour input (mandays), chemical input (litres), fertilizer input(kg), agroforestry tree density (number of trees on the farm land)

β_o^{z*} = The Constant
β_j^{z*} = The Parameters to be Estimated
ε_{ij}^{z} = The Error Term
Asterisk (*) =The Meta-Frontier

The environmental-specific characteristics and economic-specific variables for the meta-technical analysis include climate change, and market access in kilometer. This was used specifically to achieve objectives three (iii) and four (iv)

Technological Gap Ratios (TGR_{ik}^{z})
The ratio between the technology of the itch farm in the jet group and the best technology available for all group is called technological gap ratio (TGR_{ik}^{z}) and is defined as:

$$TE_{ik}^{z*} = TE_{ik}^{z} \times TGR_{ik}^{z} \ldots\ldots\ldots\ldots\ldots\ldots.(11)$$

Where,
TE_{ik}^{z*} = Meta-Technical Efficiency
TE_{ik}^{z} =Technical Efficiency of Individual Group
TGR_{ik}^{z} = Technological Gap Ratio
Technological Gap Ratio (TGR) defined according to Missiame et al. (2021) and Obianefo et al. (2023) as the ratio of *jth* firm's production frontier (Y_i^j)to the meta-frontier[$f^M(x_i^j\beta^j)$] as stated below:

$$TE_{ik}^{z*} = \frac{Y_i^j}{f^M(x_i^j\beta^j)} = TE_{ik}^{z} \times TGR_{ik}^{z} \ldots\ldots\ldots\ldots\ldots\ldots.(12)$$

Principal Component Analysis: The constraints facing agroforestry farmers and militating against agroforestry production practices were subjected to principal component analysis. This was used specifically to achieve objective five (v).

Log-Likelihood Ratio Test
The generalized likelihood-ratio (LR) test was used to validate the stated hypotheses. The model is specified as:

$$LR_c = -2[Ln(L(H_0) - Ln(L(H_a)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(13)$$

$$\text{If } LR_c > LR \text{ Tabulated, The Null Hpotheses } (H_0) \text{ is Rejected}$$

Where,
LR_c= The Calculated Likelihood Ratio
$L(H_0)$ = Likelihood Function for Stochastic Frontier Estimated by Pooling the Data
$L(H_a)$= The Sum of the Likelihood Function for the Two Groups (Male and Female) Stochastic Frontier Estimation

RESULTS AND DISCUSSION

Test of hypotheses for the analysis

The results of the hypotheses test of stochastic frontier assumptions are presented in Table 1. In the first hypothesis, the specification of the Cobb-Douglas production function for the data set of the group levels and also for the pooled data is rejected in favour of the alternative hypothesis which state that the stochastic frontier model is better than the ordinary least squares regression model or the Cobb-Douglas production function model. The Likelihood ratio (LR) statistics for male (27.14), female (21.85), and pooled data (36.75) were greater than LR critical value (20.15) each at 0.001 and 5 degrees of freedom respectively. This result is in line with similar findings of Kadua et al. (2022) who reported that the estimates stochastic frontier model is more consistent and accurate compared to the results in the Cobb-Douglas production function model. In the second null hypothesis or assumption that male agroforestry farms and female agroforestry production technologies are the same was also rejected. The LR statistics (42.65) was greater than the LR critical value (32.909) at 0.001 and 12 degrees of freedom, this confirmed the alternative hypothesis that the meta-technical efficiency frontier model is the appropriate estimation technique to use for this work. The specification of the meta-technical frontier model would not have been necessary if the agroforestry production technologies in the two farms (male and female) were the same. This result is in consonance with similar observations made by Asravor et al. (2015) and Onumah et al. (2013). The third hypothesis test confirmed that the inefficiency effects are present in all the models (i.e male, female frontiers, and the pooled data frontier). The LR statistics for male (28.51), female (23.17), and pooled data (34.42) were greater than LR critical value (20.515) at 0.001 and 5 degrees of freedom, this null-hypothesis is hereby rejected, this confirmed the existence of the inefficiency effects are existed in the models at every levels. This result is in line with findings of Ayinde et al. (2009). The fourth null hypothesis which state that the exogenous factors or variables included in the inefficiency model have no effects on agroforestry farmers' level of efficiency was rejected. This implies that the combined effects of the exogenous factors or variables hypothesized in the inefficiency model are statistically significant in explaining agroforestry farm efficiency. The LR statistics for male (31.26), for female agroforestry farmers (33.19), and pooled data (37.79) were greater than the LR critical (26.125) at 0.001and 8 degree of freedom. This implies that the null hypothesis was rejected and the alternative hypothesis was accepted. This confirmed the influence of the exogenous factors on the variations of the agroforestry farmers' efficiency level.

Table 1. Results of the hypotheses test of stochastic frontier assumptions

S/N	Hypotheses	LR Statistics(λ)	LR Critical Value @ 0.001	DF	Decision
1	$H_0: \beta_{ik} = 0$				
	Male	27.14	20.515	5	Reject H_0
	Female	21.85	20.515	5	Reject H_0
	Pooled	36.75	20.515	5	Reject H_0
2	$H_0: f(X_i;\ \beta_M^z) = f(X_i;\ \beta_F^z)$ Pooled	42.65	32.909	12	Reject H_0
3	$H_0: \gamma = \delta_0 = \delta_1 = \delta_2 \ldots. = \delta_6 = 0$	28.51	20.515	5	Reject H_0
	Male	23.17	20.515	5	Reject H_0
	Female	34.42	20.515	5	Reject H_0
	Pooled				
4	$H_0: \delta_1 = \delta_2 \ldots. = \delta_6 = 0$				
	Male	31.26	26.125	8	Reject H_0
	Female	33.19	26.125	8	Reject H_0
	Pooled	37.79	26.125	8	Reject H_0

Source: Field Survey (2023)

Socio-economics and farm specific characteristics of agroforestry farmers

Table 2 presented the summary statistics of socio-economic and farm specific characteristics of agroforestry farmers. The mean age of 46 years (Male), and 44 years(Female) were indicated by the group specific variables and 45 years for pooled data. The mean experiences in agroforestry production technologies for male farmers were 12.7 years, for female farmers were 7.1 years and for pooled date were 6.4 years. These statistics demonstrate that the agroforestry farmers were young, agile, in their productive age, they are better experienced to handle farming challenges with strength and vigor, this will help them in adopting new agroforestry production technologies. In addition, age has an impact on the managerial capability of the respondents. This result is similar to the findings of Umar et al. (2020), and Obianefo et al. (2020). The household sizes were large with 9 people for male, 6 people for female agroforestry farmers, and 7 people for pooled data respectively. The large household sizes provide or is a good source of family labour for farm activities. On the average, the results indicated that male, female agroforestry farmers and pooled date spent 13, 10, and 11 years in formal learning institutions. This means that the agroforestry farmers had formal education and were literate but do not finish their secondary education. This result is similar with the findings of Bime et al. (2014) who reported that 58% of respondents had primary education. The mean yield and farm sizes were calculated as follows for male (1,951.31Kg/ha, 2.07ha), for female (1,631.7Kg/ha, 1.38ha) and for pooled data (1,852.4Kg/ha, 1.73ha) respectively. This shows that the agroforestry farmers were smallholder farmers because they all had less than 5 hectares of farm land.

Table 2. summary statistics of socio-economic and farm specific characteristics of Agroforestry farmers

Variable	SI Unit	Male		Female		Pooled	
		Mean	SD	Mean	SD	Mean	SD
Age	Years	46	11.18	44	11.49	45	1.29
Household Size	Number	9	2.7	6	3.4	7	2.91
Experience in Agroforestry	Years	12.7	7.1	9.6	2.8	10.8	6.4
Formal Education	Years	13.84	5.18	10.91	6.0	11.41	4.56
Yield	Kg/ha	1,951.31	112.31	1631.7	146.31	1852.4	90.51
Farm Size	ha	2.07	0.97	1.38	0.74	1.73	0.98

Source: Field Survey (2023)

Parameter estimates for gender specific stochastic production frontier model

Table 3 presented the parameter estimates of the stochastic production frontier model for the male and female agroforestry farmers. The gamma values were 0.748 and 0.364 for the male and female agroforestry farmers. These statistics show that the male and female agroforestry farmers were 74.8% and 36.4% deviation from frontier output was coming out from the gender specific variables. The remaining 25.2% and 63.6% emanating from the random noise or disturbances. According to Obianefo et al. (2023), the gamma parameter in the stochastic production frontier model (SPFM) measures the inefficiency of production. Huang et al. (2014) reported that gamma value is used to measure how far output falls short of the achievable maximum. The male and female agroforestry farmers with higher gamma values are more efficient in delivering a quantity of output using the production technologies. Also, the cause of the inefficiency is attributed to their managerial characteristics, and not the obsolete production technologies. The sigma and Log –likelihood ratios were for male (0.069, - 24.816) and for female agroforestry farmers (0.038, -8.648) respectively. In the technical efficiency (TE) component, the results show that, farm size, chemical input, fertilizer input, and agroforestry tree densities are the significant factors that influence agroforestry production for male farmers at ($P < 0.01$). The fertilizer input, and agroforestry tree densities are the significant factors that influence agroforestry production for female farmers at ($P < 0.05$). The coefficients of fertilizers were positive and statistically significant for male (0.421) and female (0.291) agroforestry farmers respectively. This finding suggests that a 1% increase in the use of fertilizer input with other factors held constant will lead to 42.1% and 29.1% increase in output of male and female agroforestry farmers respectively. Therefore, there is need for agroforestry farmers to be encouraged to apply fertilizer input to agroforestry farms to increase output in a way that is environmentally sustainable.

The estimates of gender-specific variables are presented at the bottom of Table 3. A gender-specific variable with a positive coefficient signifies that the variable has a negative effect on technical efficiency. In contrast, those variables with negative coefficients signifies that the respective variables have a positive effect on technical efficiency. The results show that experience in agroforestry at ($P < 0.01$) and years of formal education at ($P < 0.05$) were the significant factors influencing output of male agroforestry farmers. Also, experience in agroforestry and years of formal education are the factors significantly influencing output of female agroforestry farmers at ($P < 0.05$).

Table 3. Parameter estimates for gender specific stochastic frontier models

Variables	Male			Female		
	Estimate	**Std. Error**	**Z**	**Estimate**	**Std. Error**	**Z**
Farm Size	0.671***	0.1859	3.61	0.087	0.1474	0.59
Labour Input	0.189	0.372	0.51	0.142	0.1183	1.20
Chemical Input	0.116***	0.025	4.64	0.451	0.4214	1.07
Fertilizer Input	0.421***	0.136	3.09	0.291**	0.098	2.95
Agroforestry Tree Density	0.461***	0.130	3.55	0.492**	0.2102	2.34
Constant	8.205***	1.412	5.81	7.271**	2.587	2.81
Gender-Specific Variables						
Age	-0.030	0.05	-0.60	-0.030	0.1298	-0.231
Experience in Agroforestry	-0.202***	0.055	-3.68	-0.021**	0.0091	2.31
Years of Formal Education	-0.126**	0.052	-2.44	-0.316**	0.1183	2.67
Constant	-5.326	4.76	-1.12	-4.417	3.371	-1.31
Model Statistics						
Log-Likelihood	-24.816			-8.648		
Sigma	0.069			0.038		
Gamma	0.748			0.364		

Source: Field Survey (2023), ***-Significant at 1% probability level, **-Significant at 5% probability level, *-Significant at 10% probability level.

The coefficients of years of formal education are negative for male (-0.126) and female (-0.316) agroforestry farmers. A 1% increase in years of formal education and keeping other factors constant will lead to 12.6% decrease in technical inefficiency among male agroforestry farmers. Also, a 1% increase in years of formal education and keeping other factors constant will lead to 31.6% decrease in technical inefficiency among female agroforestry farmers.

Parameter estimates of the stochastic meta-frontier model (smfm)

The results of the stochastic meta-frontier analysis of pooled data for agroforestry production are presented in Table 4. In the diagnostic statistics, the study revealed that the gamma value was 0.648, this implies that the meta-frontier model experienced a 64.8% deviation from the maximum or expected optimal. This deviation from optimum output is associated with environmental and economic specific variables. The gamma value is a measure of variation in total output of agroforestry due to inefficiencies in the usage and combination of input variables. Therefore, to have a gamma value of 0.648 means that 64.8% of the variations in output of agroforestry farmers are due to inefficiency in farm level practices and input usage. This implies that the stochastic factors beyond the control of the agroforestry farmers contributes 35.2% of the variations in output.

Table 4. Parameter estimates of the stochastic meta-frontier model

Variable	Estimates	Std. Error	Z
Farm Size	0.245***	0.028	8.75
Labour Input	0.162***	0.0531	3.05
Chemical Input	0.004	0.009	0.44
Fertilizer Input	0.163***	0.059	3.78
Agroforestry Tree Density	0.481***	0.153	3.15
Constant	7.428***	2.141	3.47
Environmental/Economic Specific Variables			
Climate Change	0.721**	0.263	2.74
Market Access	-0.631	0.198	- 3.19
Constant	-18.064	7.002	- 2.58
Model Statistics (Diagnostic Statistics)			
Log-Likelihood	-158.340		
Sigma	0.027		
Gamma	0.648		

Source: Field Survey (2023), ***-Significant at 1% probability level
**- Significant at 5% probability level, *-Significant at 10% probability level

According to Binam et al. (2008) the stochastic factors include unfavorable weather conditions, policy constraints, diseases and pest infestations, measurement errors, endowment constraints. The Log-likelihood function and the sigma values were -158.340 and 0.027 respectively. The results of the stochastic meta-frontier model (SMFM) show that the significant factors influencing output of agroforestry farmers were farm size ($P < 0.01$), labour input ($P <0.01$), fertilizer input ($P <0.01$), and agroforestry tree density ($P < 0.01$). All the variables included in the model had positive coefficients. A 1% increase in fertilizer input will lead to 16.3% increase in output of agroforestry farmers. Also, a 1% increase in farm size will lead to 24.5% increase in output of agroforestry farmers. This result is consistent with the findings of Kodua et al. (2022). In the inefficiency components, variables with negative coefficients have a positive effect on the meta-technical efficiency (MTE). The inefficiency observed in the agroforestry production can be attributed to environmental and economic-specific variables. The significant environmental specific variable was climate change ($P < 0.05$). Climate change has positive coefficient (-0.721), this means a 1% change in climate will result to 72.1%increase in meta technical inefficiency. Climate change can be in the form of drought, flood, strong wind, sand dunes, high temperatures, high rainfall etc. This result is in line with findings of Ng'ombe (2017).

Estimates of technical efficiency (TE) and technological gap ratios (TGRs)

Table 5 presented the results of TE, TGR and meta-technical efficiency (MTE) for male, female agroforestry farmers and pooled data respectively. Technical efficiency gains convey directly into improvements in farmers benefit and farm household incomes. The results show that the mean technical efficiencies of stochastic frontier models are 0.831, 0.647 and 0.728 for male, female agroforestry farmers and pooled data respectively. This implies that on the average agroforestry farmers achieve 83.1% (male), 64.7% (female) and 72.8% (pooled data) of their frontier output given their present technologies and input use available to them. In other words, agroforestry farms are losing 16.9%, 35.3% and 27.2% of their maximum potential output to inefficiencies in agronomic farm practices and input use. Therefore, if agroforestry farmers have to achieve 100% of their frontier output, they should focus to close the gap between their current performance levels and the maximum potential performance of their agroforestry farms by minimizing the effects of some inefficiency factors. The best performing agroforestry farmers on the other hand achieves 99% and 93% of the frontier output for male and female groups, respectively. On the other hand, the least performing agroforestry farmers achieves 21% and 11% of their potential frontier outputs for male and female groups, respectively. The technological gap ratio measures the gap between male, female agroforestry and the technological that is available for the whole agroforestry industry given the vector of inputs.

This is in line with findings of Gero et al. (2020) and Nguyen et al. (2019). This means that if agroforestry farmers were technically efficient in relation to the stochastic frontier at the farm level, the agroforestry farmers could still increase output by closing a gap between their current performance and the best farm practice for the industry. The closer the value is to 1, the gap become smaller between the individual frontier and meta-frontier.

Table 5. Technical efficiency scores (TE) and technological gap ratios (TGRs)

Variable	Mean	Minimum	Maximum	Standard Deviation
Technological Gap Ratios (TGRs)				
Male	0.900	0.34	0.99	0.14
Female	0.730	0.21	0.98	0.15
Pooled	0.821	0.23	0.96	0.17
Technical Efficiency (TE) (Group Frontier)				
Male	0.831	0.21	0.99	0.27
Female	0.647	0.11	0.93	0.23
Pooled	0.728	0.14	0.97	0.22
Technical Efficiency (MTE)(Meta-Frontier)				
Male	0.748	0.12	0.96	0.21
Female	0.473	0.04	0.89	0.20
Pooled	0.598	0.06	0.92	0.21

Source: Field Survey (2023)

As further shown in Table 5, the technological gap ratios (TGRs) are 0.90, 0.730, 0.821 are calculated for male, female agroforestry farmers and pooled data respectively. This implies that if the average male and female agroforestry farmers and the pooled data were to be technically efficient (i.e on their group frontier) they would still increase their output by closing a gap of 10%, 27%, and 18% respectively, if they were to employ the most efficient meta-technology for the entire agroforestry farming sector. This implies that the gap between the current agroforestry technologies and the meta-frontier is smaller in the male agroforestry farms than in the female agroforestry farms. However, the gap in technology ranges from a minimum of 0.14 to 0.99 for the male agroforestry farms and 0.21 to 0.98 for the female agroforestry farms. The mean technical efficiency scores for male agroforestry farms and female agroforestry farms relative to the meta-frontier efficiency scores are 0.748 and 0.473 respectively. The values of the technical efficiency scores relative to the meta-frontier means that male agroforestry farms are more efficient than female agroforestry farms. This maybe attributable to the correct and timely use of agroforestry technologies by male farmers. Furthermore, the technical efficiency (TE) scores relative to the individual group stochastic frontiers were greater than that of those relative to the meta-frontier. The difference between the two (2) efficiency scores shows the order of bias efficiencies obtained when using the group frontier relative to the technology available for the entire industry. Kodua et al. (2022) reported the position that using the estimates from the individual group frontiers for male agroforestry farms and female agroforestry farms for comparison of technical efficiencies may be misleading.

Types of agroforestry production technologies among rural farmers

Table 6 presented the various types of agroforestry production technologies among the rural farmers. The results show that the agroforestry production technologies were the retaining of forest trees on farmland had the highest frequency (f = 76) with 17% of the total percentage score, this is followed by windbreak with (f = 71) having 15.88% of the total percentage score. According to Amonum et al. (2009) who described windbreak as agroforestry system where double rows of forestry trees are planted around the boundary of a food crop farm especially on the windward side. The major advantage is that windbreak reduce erosion and also at the same time produce forest alongside food crops. The home gardens came third with 11.63% of total percentage score (f = 69). In home garden agroforestry systems, multipurpose shrubs and trees are grown in association with agricultural crops and raised with livestock in homesteads. The frequency and percentages of other agroforestry production technologies practiced among rural farmers include alley cropping (f = 52, 11.63%), shelterbelt (f =50, 11.19%), taungya farming (f = 47, 10.52%), aqua forestry (f = 42, 9.40%), and border planting (f = 40, 8.95. Annual or perennial crops are grown between the rows of trees which provides short term income before the trees bear nuts and fruits or are harvested for timber. Some shrubs and trees species commonly found in agroforestry systems are *Parkia biglobosa, Adansonia digitata*, *Vitellaria paradoxa*, *Tamarindus indica*, *Tectonia grandis*, *Elaeis guineensis*, *Citrus sinensis*, *Mangifera indica L, Azadirachta indica, Moringa oleifera, Vernonia amygdalina, Carica papaya, Jatropha* curcas L., *Eucalyptus camaldulensis, Acacia Senegal* etc.

Constraints faced by agroforestry farmers

The constraints faced by agroforestry farmers was subjected to principal component analysis and presented in Table 7. In the analysis, the constraints with Eigen-values greater than one were retained by the model, while the constraints with Eigen – values less than one were discarded. From the results, lack of credit facilities was ranked 1st based on the perception of the agroforestry farmers with Eigen value of 5.9537, and this explains 31.28% of all constraints retained by the model. Lack of fertilizer input was ranked 2nd based on the perception of the agroforestry farmers with Eigen-value of 3.2672, and this explains 50.02% of all constraints retained by the model.

Table 6. Agroforestry Production Technologies among Rural Farmers

Agroforestry Production Technologies	*Frequency	Percentage
Retaining Forestry Trees on Farmland	76	17.00
Home Garden	69	15.43
Alley Cropping	52	11.63
Shelter Belt	50	11.19
Taungya Farming	47	10.52
Wind Break	71	15.88
Aqua Forestry	42	09.40
Border Planting	40	08.95
Total	**447**	**100.00**

Source: Field Survey (2023) ***Multiple Responses**

Other constraints retained by the model include lack of agroforestry tree seedling (ranked 3rd, Eigen value = 2.5724), lack of chemical input (ranked 4th, Eigen value = 1.3469), and lack of extension contact (ranked 5th, Eigen value = 1.2540). All the constraints retained by the model jointly explained 74.66% of all constraints included in the analysis. The Chi square of 874.25 and KMO of 0.7928 was significant at ($P < 0.01$), this confirmed the justification of using the principal component model for the analysis.

Table 7. Constraints faced by farm level agroforestry farmers

Constraints	Eigen-Value	Difference	Proportion	Cumulative	Rank
Lack of Credit Facilities	5.9537	2.6865	0.3128	0.3128	1st
Lack of Fertilizer Input	3.2672	0.6948	0.1874	0.5002	2nd
Lack of Agroforestry Tree Seedlings	2.5724	1.2255	0.1237	0.6239	3rd
Lack of Chemical Input	1.3469	0.09287	0.0576	0.6815	4th
Lack of Extension Contact	1.2540	0.42068	0.0651	0.7466	5th
Bartlett Test of Sphericity Chi Square KMO Rho	 874.25*** 0.7928 1.0000				

Source: Field Survey (2023)

CONCLUSION AND RECOMMENDATIONS

The meta-frontier analysis was used to evaluate the efficiency levels of the male agroforestry and female agroforestry farms in Kaduna State, Nigeria. A cross-section data was employed with a total of 120 farms comprising of 62 male agroforestry farms and 58 female agroforestry farms. The results show that the agroforestry farmers were young, active, productive in their middle-age. All the input variables considered in the stochastic frontier and meta-frontier models have positive effect on agroforestry production for both male and female farmers. Estimated technological gap ratios (TGRs) and technical efficiency with respect to meta-frontier model demonstrates that male agroforestry farmers are nearer to the best practice technology compared to their counterparts who are female agroforestry farmers. This also means that male agroforestry farmers are more technically efficient compared to the female agroforestry farmers. The study has shown that farm specific and gender specific factors together influence the technical efficiency of agroforestry farms under the group frontier. Also, farm specific and economic together with environmental factors influence the technical efficiency in the meta-frontier model, even though some variables are statistically not significant. The results show that in the stochastic frontier model, the fertilizer input, agroforestry tree density will increase output of male and female agroforestry farmers. Also, experience in agroforestry and years of formal education will increase technical efficiency (TE) of agroforestry production among male and female farmers. Also, in the meta-frontier model, farm size, labour input, fertilizer input, agroforestry tree density will increase the output of agroforestry farmers for the industry. Also, impact of climate change had adverse effect on technical efficiency of meta-frontier analysis of agroforestry farmers for the industry. The major agroforestry production technologies observed among rural farmers include: home gardens, alley cropping, shelter belt, wind break, taungya farming, aqua forestry, retaining forest trees on farmland and border planting. The major constraints facing agroforestry farmers include: lack of credit facilities, lack of fertilizer, lack of agroforestry tree seedlings, lack of chemical input, and lack of extension contact. The study recommended the following:

(i) The use and practice of agroforestry production technologies among rural should be intensely encouraged and management skills pertaining to the use of such technologies should be improved to increase efficiency and productivity by reaping the full benefits it offers

(ii) Education and training of agroforestry farmers should be intensified by relevant stakeholders including extension officers, research institutes and ministry of agriculture, such training and education should focus on agroforestry technologies, rightful application of fertilizers, and agrochemicals in terms of appropriate quantities, product and time of application.

(iii) Knowledge management and information sharing on existing agroforestry production technologies among farmers should be promoted.

(iv) Credit facilities should be made available for agroforestry farmers at low interest rate, devoid of cumbersome administrative procedure.

(v) Agroforestry tree seedling should be given to farmers free for environmental resource management. Also, fertilizer input and chemical input should be provided for farmers at subsidized rate at appropriate time.

(vi) Feeder roads should be constructed or rehabilitated for easy access of agroforestry farms.

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EVALUATION OF FEED CONVERSION RATIOS AND GROWTH PERFORMANCE OF VARIOUS GOAT BREEDS IN A COMMERCIAL GOAT FARM SETTING IN KATHMANDU, NEPAL

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ABSTRACT

The study was conducted to evaluate the feeding status, Feed Conversion Ratio (FCR) of different breeds of goat at commercial farm's condition at Dakshinkali municipality-7, Kathmandu, Nepal from April 2022 to June 2022. A total of 32 goat kids aged approx. 3months and body weight 11±2kg were selected on the basis of Purposive sampling technique and categorized into 4 study group on the basis of breed i.e. B × K (50%), B × K (75%), B × J (50%) and B × J (75%). Feed and forage containing 13% Crude Protein per dry matter, 1.35kg Dry Matter per head per day and 12.1MJ energy per day were provided to study population and weekly weight gain of goat was recorded. The average daily weight gain was found to be 40±2gm and the Cumulative Feed Conversion Ratio (CFCR) was found to be 33.592, FCR of overall male was lower than female of study population (i.e. FCR of male = 30.006, FCR of female = 38.151). Among the breed and sex, B × K (75%) male had the lowest FCR (22.055) while B × K (75%) female had the highest FCR (47.726). Comparison based on breed revealed B×K (75%) had the least FCR (30.169) whereas, B × J (75%) had the highest FCR (36.593). Cumulative body weight gain was not uniform leading to highest on third week (21kg) while 2.8kg fall in body weight was seen on tenth week. The rise and fall in weekly body weight gain was caused due to poor farm management, parasitic infestation, seasonal change and respiratory disorder caused due to unknown viral infection.

Key words: FCR, goat, Boer, infection, weight gain

INTRODUCTION

Goat is a multipurpose livestock species that provides meat, milk, manure, fiber, and power for the transportation. There are four indigenous goat breeds in Nepal, namely Terai, Khari, Sinhal, and Chyangra, and exotic goat breeds such as Jamunapari, Barbari, Beetal, Boer and their crossbreeds (Neupane *et al., 2018)*.

Feed resources in Nepal for most of the ruminants include roughage, crop residue, concentrates, grazing and cut and carry, grain, grain by products and green fodder. Feed conversion ratio or FCR is the rate or degree at which a farm animal converts feed served into the desired output. In practical term, it is the amount or quantity of feed farm animal will eat to attain a live weight of 1kg or yield a unit of the desired product. This parameter is what determines whether a livestock farm makes a profit or otherwise. As a profit-oriented farmer, it is very important to understand the FCR of the farm animal so as to plan budget before production. It is quite irrational to just feed your farm animals without paying proper attention to the conversion ratio of the feed you are supplying them. FCR of farm animal is one of the main parameters that depict how profitable the farm is (Kharel, 1997). Since, FCR is the ratio of input and output, less the value of FCR more is the profitability. So, it is important to keep the FCR as less as possible.

This study aimed at assessing the feeding status, crude protein, gross energy, and dry matter of feed, along with the Feed Conversion Ratio (FCR) in a commercial goat farm.

MATERIALS AND METHODS

Experimental site and information of the goat farm

The experimental site was Mata Dakshinkali Agro Farm (MDAF) at Dakshinkali-7, Kathmandu, Nepal. Study was conducted from 5th April, 2022 to 7th July, 2023 for the total of 90 days. The farm is situated in Kathmandu district at geographical line of 27°35'58.5"N latitude and 85°16'11.5"E longitude at an altitude of 1644 masl. Farm had adopted semi-intensive system of rearing. Brief information of the farm is tabulating in table 1.

Population, Sample and Sampling and sampling techniques

MDAF has accommodated 250 goats among them 150 adult goats, 45 kids of age between 3-4 months and 55 kids less than 3 months of age. Boer, Khari and Jamunapari and their crosses with different blood. The study population was taken on the basis of Purposive sampling technique where 32 kids were selected on the basis of their similar body weight and age. Eight samples from each group of animals i.e. Boer Khari 50%, Boer Khari 75%, Boer Jamunapari 50%, Boer Jamunapari 75% were selected (Figure 57, 58, 59) with equal number of male and female (i.e. female: male = 1:1). The average individual body weight was approximately 11±2kg at the time of sampling (Table 2).

Table 1. Brief information of the farm

SN	Particular	Information
1	Temperature	0-18^{0}C in winter and 14-32^{0}C in summer season.
2	Direction of wind flow	South to North in day time North to South in night time
3	Orientation of the farm	South facing
4	Sunrise and sunset	5:30 am – 6:30 pm in summer; 7:30 am – 5:00 pm in winter
	Shade	Night shift shed : 80 × 30 ft Day shift shed : 143 × 20 ft, 100 × 25ft Open space : 200 × 40 ft Average Space per animal: 9.6 sq. ft
5	Waterers	Two waterers of each dimension: 8 × 2 × 1 ft Twelve waterers of each dimension: 6 × 1.5 × 1 ft One waterer of each dimension: 8 × 2.5 × 1.5 ft
6	Feeders	20 feeders of each dimension : 6 × 1 × 1 ft
7	Sanitation	Regular cleaning with jet of water at morning time.
8	Ventilation	Well-ventilated with twelve windows each on north and south face
9	Quarantine	A quarantine shed having dimension of 25×20 sufficient for 50 goats.
10	Biosecurity	Normal biosecurity measures applied

Table 2. Number of samples from each breed of goat in the farm

Breed	B×K (50%)	B×K (75%)	B×J (50%)	B×J (75%)	Total
Number of samples	8	8	8	8	32

Where, B × K (50%) = Boer Khari cross (50% blood level of Boer)

B × K (75%) = Boer Khari cross (75% blood level of Boer)

B × J (50%) = Boer Jamuna Pari cross (50% blood level of Boer)

B × J (75%) = Boer Jamuna Pari cross (75% blood level of Boer)

Feeds and Fodder used in the experimental farm

Feed ingredients given to the animals during the course of the study were Rice straw, Rice bran, Maize flour, Mustard cake, Wheat bran, Chickpea, Karu, Lentil pod husk, Molasses, Ipil-Ipil, Khanyu and adlib water. All the feed ingredients used were locally produced and concentrate feed were prepared in the farm premises. Nutritional parameters such as Dry Matter (DM), Crude Protein (CP) and Gross Energy were analyzed in National Animal Feed and Livestock Quality Management Laboratory, Harihar Bhawan, Lalitpur.

Feeding Schedule of the experimental farm

The animals were fed with calculated amount of feedstuffs on specific time period of the day (Table 3). Feed given to the animal at a specific time of the day is composed of mixture of different feed ingredients in a fixed proportion (Table 4, 5 & 6).

Table 3. Feeding schedule of the farm.

S.N.	Time	Feed
1	6:00 am	Khole
2	7:00 am	Bhusa
3	10:30 am	Lentil pod husk
4	2:00 pm	Green forage

Percentage contribution and composition of feed ingredients in bulk feed

Data collection

Individual body weight was taken every week at dusk after feeding green forages. Feed and feed ingredients were weighted daily and given to study population. Both the data of feed and body weight of animal was taken up to 13th week.

Data analysis

Collected data were listed, thus obtained data were analyzed and presented in bar graph and line chart using Microsoft Excel Tools.

Table 4, 5 & 6: Composition and percentage contribution of various feed ingredients

Table 4

BHUSA	% Contribution
Rice straw	34.03
Rice bran	16.9
Maize flour	8.47
Mustard cake	16.9
Wheat bran	8.47
Chickpea	3.38
Karu	3.38
Molasses	8.47

Table 5

Fodder tree	% Contribution
Ipil-ipil	50
Khari	50

Table 6

Musuro khosta	% Contribution
Musuro chokar	50
Maize flour	50

RESULTS AND DISCUSSION

On the basis of the data collected for 13 weeks on parameters; body weight and dry matter of the feed have, following results were obtained (Figure 1).

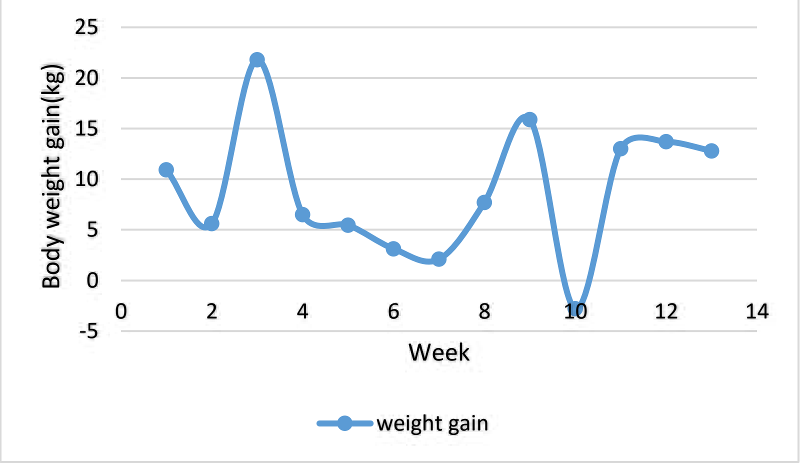

Figure 1. Weight gain of overall study population

Cumulative Feed Conversion Ratio (CFCR) of whole study population was found to be 33.5922.

Breed wise Feed Conversion Ratio

Among the breeds, Boer cross with Khari goat with the blood level of 75% i.e. (B × K (75%) had the least FCR. The order of FCR among the breeds from least to highest is B × K (75%) < B × J (75%) < B × K (50%) < B × J (50%) (Table 13). There was not much significant difference between FCR of B × K (50%) and B × J (50%).

Table 7 (A) Breed-wise FCR

Breed	**Feed Conversion Ratio (FCR)**
B × K (50%)	36.15844
B × K (75%)	30.16942
B × J (50%)	36.59376
B × J (75%)	32.31436
Average	**33.80**

Table 7 (B) Sex wise FCR

Sex wise	**Feed Conversion Ratio (FCR)**
B × K (50%) male	32.42207098
B × K (50%) female	40.8681567
B × K (75%) male	22.0558306
B × K (75%) female	47.72630664
B × J (50%) male	31.99546478
B × J (50%) female	32.63966877
B × J (75%) male	38.65906715
B × J (75%) female	34.73793319

Breed wise FCR of study population

Sex wise Feed Conversion Ratio

FCR of overall male of study population was 30.006; FCR of overall female of study population was 38.151. Analyzing the obtained data, it was found that FCR of overall male population of study population was significantly lower than that of the female group which suggested that male animal utilized the feed materials efficiently than females. Also, FCR of B × K (50%) male was significantly lower than female of the same group which suggested male were more efficient in utilizing feed stuffs and the same scenario was found in B × K (75%) and B × J (75%) also (Table 7 B).

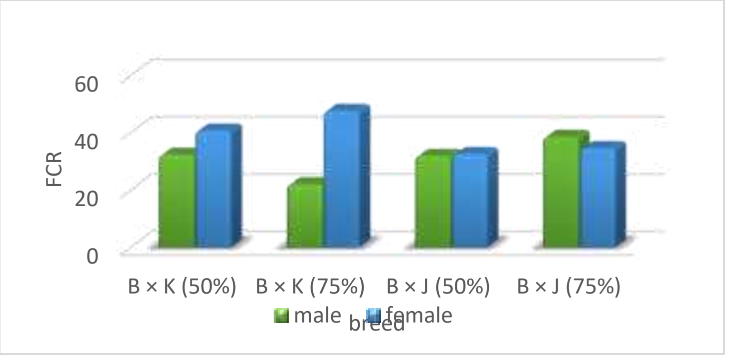

Figure 2. Graph showing breed and sex- wise FCR

The FCR was recorded highest (143) on seventh week whereas lowest on third week

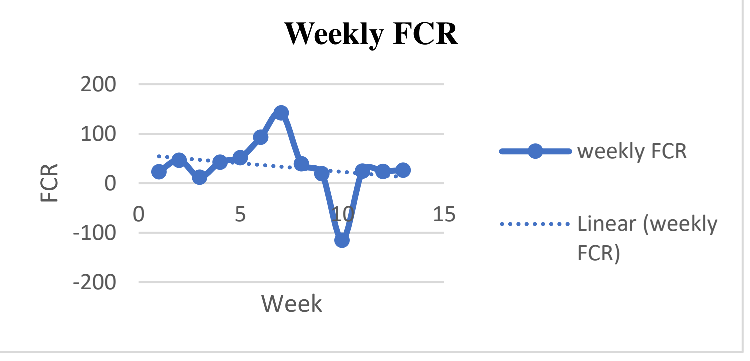

Figure 3. Line chart showing weekly FCR

The nutrient supply to the study population consists of 13% crude protein per dry matter, dry matter 1.35kg per head per day and 12.1 Megajoules of Metabolisable Energy (MJME) per day which closely resembles the requirements of Boer goats for growth and exhibits the best production characteristics. Diet with 12.0 MJME energy, 14% crude protein per kg dry matter and 1.3 kg dry matter was best for production in boer goats and their crosses (Brand *et al*., 2017).

Although the growth patterns of goat should be uniform, it was not such due to various reasons like poor farm management, parasitic infestation, seasonal change and respiratory disorder caused due to unknown viral infection (Figure 54,55)

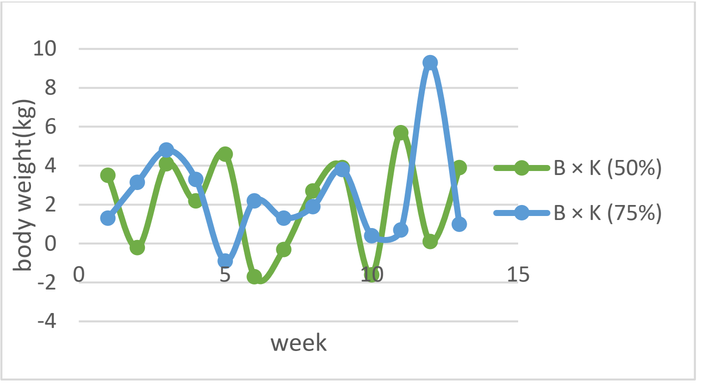

Figure 4. Chart showing growth pattern of B × K goat

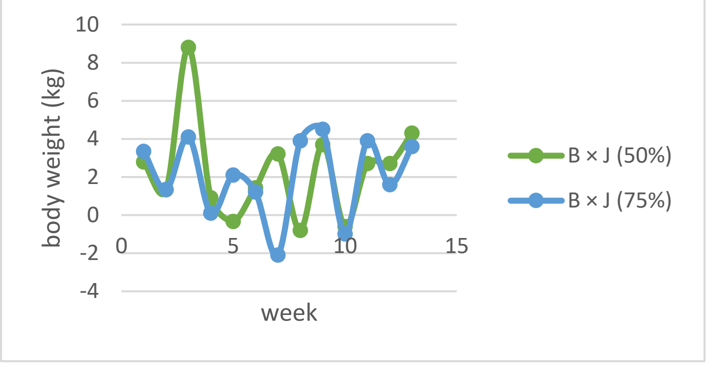

Figure 5. Chart showing growth pattern of B × J goat

Discussion

The Cumulative FCR was found to be 33.5922 which is way more than 10.83 determined in a study by Gipson *et al*. (2007) fed with Lucerne whereas it is also suggested that goat have an average FCR of 4.5 on high concentrate feed, 5.5 on good forage diet and 30 on straw ration (Admin, 2022). Although all the nutrients are provided in proper amount; health condition, disease, seasonal change led to poor feed utilization causing FCR value to increase. According to a study done by Patil *et.al.,(*2014), the average daily weight gain was found to be 70±3 gm while in this study it was 40±2g.

The weight gain decrease in second week was found probably due to flea and ticks' infestation. The treatment for ticks with 2% Cypermethrin was found effective and desirable weight gain was achieved in third week. Again, following fourth week weekly weight gain was falling up to seventh week. Later the cause was found to be respiratory distress caused due to probably unknown viral mass infection which was treated using anti-biotics, spray of inhalants for relieving cough. The treatment was found worthy and good weight gain was seen in week nine. Another major depression in body weight gain was seen after ninth week which was later found to be due to feeding of succulent and premature fodder crops and grasses evoke enterotoxaemia and grain overloading which resulted in major weight loss during tenth week. The problem was solved by avoiding such crop and minimizing grain and use of buffer (tri- sodium silicate) in concentrate feed. At the same time, though deworming was done at the start of the study the problem of *Hemonchus spp.* was seen which was another cause of major depression of body weight after ninth week after that the body weight gain was in increasing trend (Figure 1).

CONCLUSION AND SUGGESTIONS

Poor management practices, feeding and health condition of animals suppress FCR which ultimately decreases the profitability of farm. It is found that FCR value is way more than advisable due to many reasons like ill health conditions, seasonal influences, and improper feed formulation, though nutritional requirement of goats in term of energy and protein came from concentrate diet which led to problems like grain overloading and enterotoxaemia.

It is suggested that proportionate nutritional requirements, proper feed ingredients along with good farm management practices should be provided. Furthermore, anthelmintic as per diagnosis of parasitic organisms should be done in time.

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FARMERS' PERCEPTION AND ADAPTATION TOWARDS CLIMATE CHANGE ON VEGETABLE FARMING IN KATHMANDU DISTRICT

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ABSTRACT

Climate change is a global phenomenon and Nepal being an agricultural country is more affected by it. Vegetables are more sensitive to climate change and sudden rise in temperature as well as irregular rainfall at any crop growth stage can affect its yield. So, this study "Farmers' perception and adaptation towards climate change on vegetable farming in Kathmandu district" was performed from May to June, 2023 with an objective to know about adaptation strategies undertaken by the farmers to mitigate the impact of climate change and their perception towards climate change. A sample size of 100 respondent farmers was taken by using simple random sampling. The study revealed that 96% of total respondents were being affected by ongoing climate change and facing different natural hazards. So, to tackle such scenario, 86% of farmers were trying different adaptation strategy including mulching, drip irrigation, cultivation of vegetables in plastic tunnels, etc. to mitigate negative impacts of climate change. Climate change also influence the pest and disease occurrences, migration to new places, time of appearances. . The number of weeding for a crop in a season is increased from last few years. Farmers are using heavy chemicals as alternative to reduce the incidence of diseases and pests. Farmers are adjusting planting and harvesting times in response to climate change, affecting crop cycles. Disease and pest resistant and drought and adverse climatic condition tolerant varieties should be introduced to farmers by showing them its benefits. Farmers should be supported with the technical assistance related to disease, pests, and new practices like IPM and drip irrigation.

Key Words: Climate change, cultivation, mitigation strategy, vegetables

INTRODUCTION

Climate change refers to changes in meteorological conditions over decade and long-term periods (IPCC, 2014; Kaufman *et al.,* 2009; Travis *et al.,* 2018) and can have a negative impact on agricultural systems (Tesfahunegn *et al.,* 2016).

Agriculture is one of the important sectors of Nepal. It covers majority of the occupation that people are involved in. It is the basis of living for many people.

Climate change is one of the most challenging problems for agricultural country like Nepal. Changing temperatures and erratic rainfall pattern are affecting crop production in Nepal (Malla, 2008). Other changes in agriculture, such as loss of local land races of both crops and domestic animals, changes in cropping sequences, scarcity of water due to drying up of wells, and increasing incidences of disease and pest have also been noticed (Regmi and Bhandari, 2013). Climate change is expected to increasingly affect the livelihoods of farmers, especially those who are economically more vulnerable (Manandhar *et al.*, 2011). The problem of drought in the months of Kartik to Baisakh affects the planting time and growth of major crops of the country. All these factors lead to low production from agriculture sector and contributing to the vicious cycle of poverty among Nepali farmers.

The farmer's perception of climate change plays a vital role in developing mitigation and adaptation strategies for land use and farming activities (Mertz *et al.,* 2009) . In fact, some farmers in the Himalayan region successfully mitigate the impact of climate change by diversifying and rotating crops, adjusting planting times (early and late), and selecting crops suitable for the landscape and the time of year (Aase and Chapagain, 2017). Farmers' perception on climate changes and its impacts on the agricultural production have resulted in the adjustment of agricultural calendar and adoption of different adaptation strategies (Wl *et al.,* 2013).

Vegetable production is an important sector of Nepalese economy contributing around 9.71% to total Agricultural GDP (Paudel *et al.,* 2021). Climate change is adding problems in vegetable farming as farmers are unaware about adaptation of climate change mitigating factors. Therefore, a study was undertaken to figure out perception, impacts and determinants of climate change adaptation among vegetable growers of Kathmandu district.

MATERIALS AND METHODS

The study was conducted in Tarakeshowr Mucipality and Kageshowri manohara Municipality of Kathmandu District. Kathmandu lies between latitudes 27°32'13'' and 27°48'10'' north and longitudes 85°11'31'' and 85°31'38'' east. This area was purposely selected as this is the area with more vegetable farms in the district. Simple random sampling technique was used to select and collect the information of the household. A well-structured questionnaire was developed to cover the study objectives. A sample of 100 households was collected from different areas of the Kathmandu district. Sampling was made as inclusive as possible to include households from different ethnic groups, different farm size, different economic status, and different vegetable production systems. Primary data were collected by directly visiting the respondents in each household of the study area.

The data collected from both primary and secondary source were analyzed quantitatively and qualitatively. The collected information from the household survey were analyzed using the Microsoft Excel.

RESULTS AND DISCUSSION

Source of livelihood of respondents

Among 100 respondents 62% were doing commercial farming, 35% were doing semi-commercial and the rest 3% were doing subsistence farming. Agriculture was found to be the source of livelihoods of majority of the respondents. It was

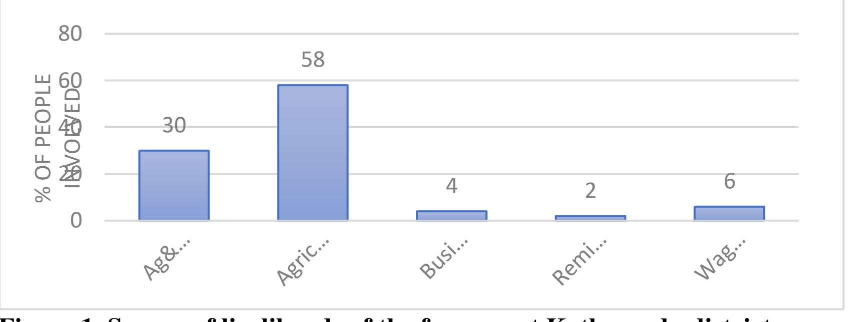

Figure 1. Source of livelihoods of the farmers at Kathmandu district

observed that 58% were dependent on agriculture, 30% in both agriculture and job, 6% in wages and agriculture, other 4% in business and agriculture both and last 2% in remittance and agriculture both (Figure 1).

Experience of living with Natural Disasters

Most of the respondents (96%) experienced natural disasters since they started to do agriculture. During this period, they encountered natural disasters like long season drought, extreme rainfall, hailstones, destructive winds, etc.

Farmers' access to training

According to the survey, it was discovered that just 11% of farmers have received training, while the remaining 89% had not undergone any training (Figure 2).

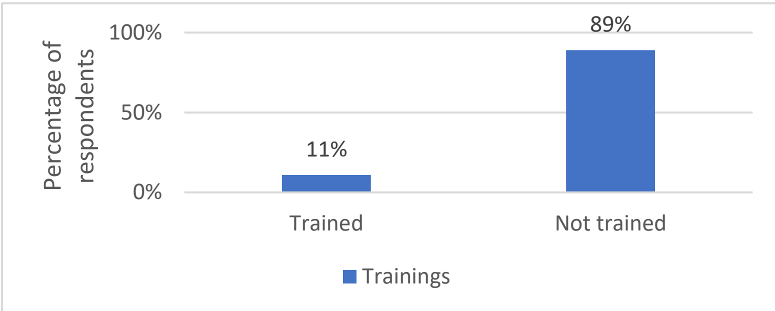

Figure2. Farmers' access to trainings in study area

Farmers' knowledge on climate change

Acquaintance with climate change

Almost all of the surveyed population had heard about the term 'climate change' but when asked about whether they understood what it meant, 82% stated 'yes'. Among them 51% knew about it from media, very few conscious farmers (30%) got knowledge of climate change through self-study and 1% respondent knew about climate change from organization. Similarly, 18% of the respondent didn't have any idea about climate change (Figure 3). Likewise, out of 38% male respondents 35 % have knowledge about climate change and out of 62% female respondents 47% have knowledge about climate change. Also, overall male (92%) respondents knew climate change to some extent then female (75%).

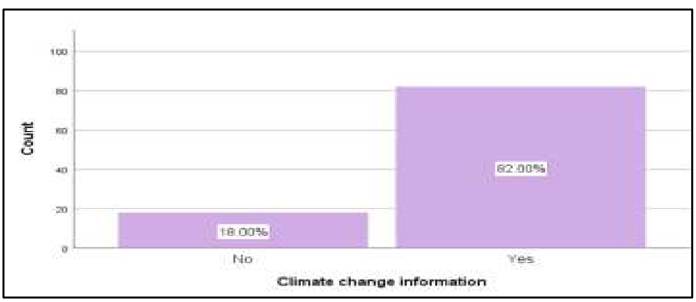

Figure 3. Respondents' understanding of climate change

Perception of farmers towards various impacts of climate change

According to survey, most of the respondents (93%), perceived that timing of rainfall is changed, which aligns with data from the DHM. Uneven rainfall caused huge loss in vegetable crops. It helped to develop many diseases.

Similarly, most of the farmers (86%) perceived that drought period is increased from last few years. Majority of respondents thought that there is decrease in frequency of hailstones, 76% perceived about decrease in frequency of hailstone

Majority of survey area was near river basin, so most (60%) of the farmers perceived that there is no change in water availability. But some conscious farmers (40%) thought there was decrease in water level in rivers. Some farmers faced problem of water scarcity due to drying wells and boring in long drought period.

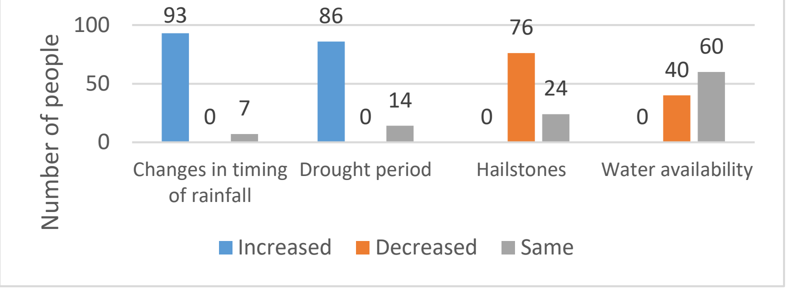

Figure 4. Perception of farmers towards various impacts of climate change

Perception of farmers towards number of hot days

The survey revealed that 82% farmers perceived increase in number of hot days. Whereas, 18% thought there was no change in number of hot days.

According to farmers, sudden increase in temperature affects vegetables adversely in the stage of fruit development. High temperature affects seed germination, plant growth, flower shedding, pollen viability, fruit setting, fruit size, fruit weight, fruit quality and color too

Impact of climate change on crop productivity

Based on field survey on impacts of climate change, 54% farmers thought that crop productivity is decreasing but 24% farmers said that yield is increasing and remaining 22% perceived that crop productivity is same.

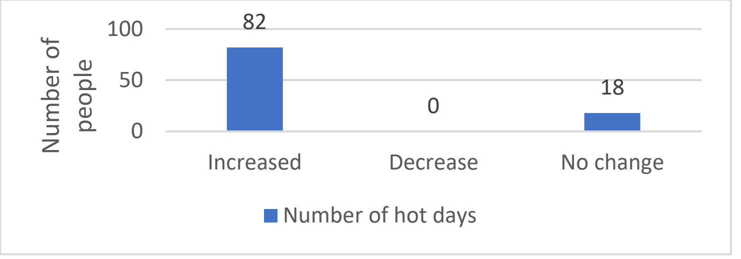

Figure 5. Perception of farmers towards number of hot days

Impact of climate change in number of weeding

The incidence of weeds has been on the rise over the past few years, leading to an increase in the need for weeding. According to survey the number of weeding for a crop in a season is increased from last few years. 68% of farmers are now performing weeding 2-3 times more than usually they did in the past.

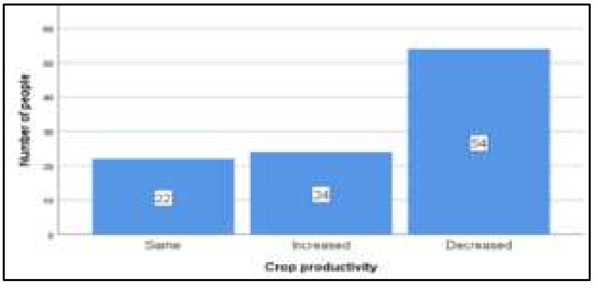

Figure 6. Crop productivity of respondents

Impact of climate change in planting time of vegetables

According to the survey, climate change had forced majority of farmers to shift (15-20 days) planting and harvesting times. Among all farmers, 63% and 26% cultivate vegetables early and late than usual practice, respectively.

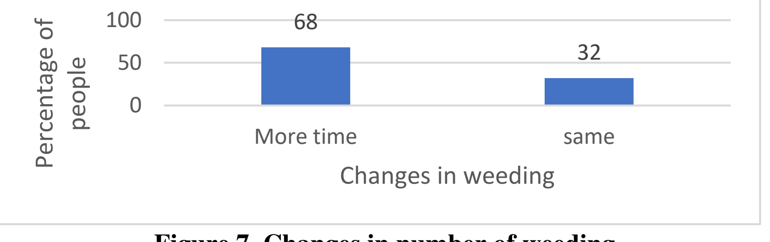

Figure 7. Changes in number of weeding

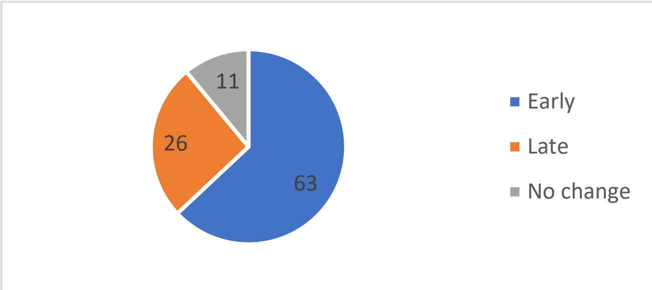

Figure 8. Impact of climate change in planting time of vegetables

Impact of climate change in harvesting time

Unusual weather pattern due to climate change had forced farmers to alter harvesting time, 42% of farmers made delayed harvest whereas 37% harvested earlier than usual practice. Very few respondents (21%) harvested vegetables at usual time.

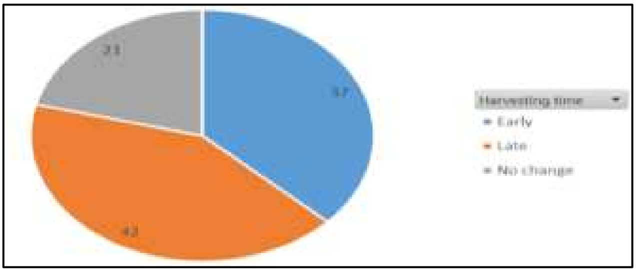

Figure 9. Impact of climate change in harvesting time of vegetables

Impact of climate change on cucurbits and solanaceous vegetables

Climate change has affected all types of vegetable farming. Cucurbits and solanaceous vegetables were most commonly grown at the time of survey. So, farmers were asked about impact of climate change on cucurbits in comparison

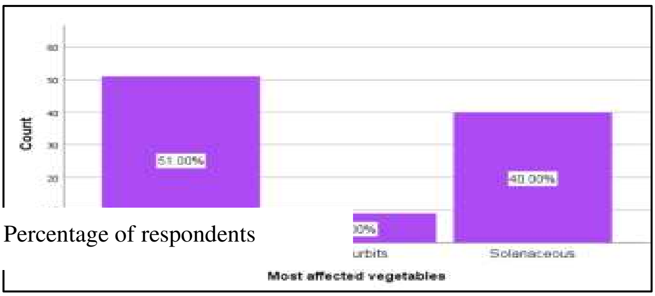

Figure 10. Farmers' perception on impact of climate change on cucurbits and solanaceous vegetables

with solanaceous vegetables. According to survey, majority of farmers (51%) perceived that both type of vegetable farming are affected equally due to climate change. 40% respondents thought that solanaceous vegetables are more affected due to climate change. Very few (9%) farmers thought that cucurbits are more affected due to climate change.

Incidence of disease and pest due to climate change

Climate change parameters had direct impact on the development and distribution of pests and diseases. Due to uneven rainfall and high temperature various types of diseases were increased in the study area. According to respondents, incidence of disease like powdery mildew, downy mildew, late blight, early blight, damping off, leaf curl disease and mosaic virus is increased.

Similarly, incidence of pest like white fly, aphids, fruit fly, red spider mite, red pumpkin beetle and thrips is also increased since few years due to increased temperature and uneven rainfall. Farmers used bio pesticides to reduce disease and pest infestations but they have not yielded desired results. So, they are using heavy chemicals as alternative to reduce the incidence of diseases and pests. Farmers turn to these chemicals as a means to protect their crops from devastating infestations that can result in significant yield losses. But when inquiries were made about the use of disease and pest resistant and adverse climatic condition tolerant varieties, no one reported using them.

Adaptation towards climate change

During the survey the respondents were asked about the thought of minimizing the climate change effects. 86% farmers are trying to adapt different measures. 90% of farmers are using tunnels for shading due to unusual weather pattern. Water conservation principle using drip irrigation system and mulching was adopted by more than 50% farmers.

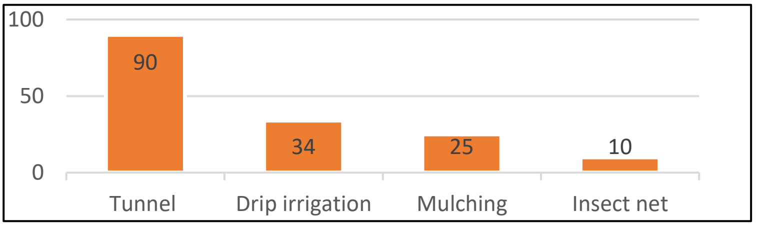

Figure 11. Farm assets of the respondents for adaptation of Climate Change

Some of the adaptation measures followed by farmers are mulching, drip irrigation, intercropping and crop rotation, changes in planting time, use of organic fertilizer, insect net, shading, shifting the time of planting. These adaptation strategies helped to increase crop yield, reduce cost of cultivation also by having positive impact on increasing climate change. Respondents in study area were doing off-season vegetable farming

Another crucial adaptation strategy employed by farmers in response to high temperatures and erratic rainfall is the alteration of planting and showing time for vegetables. So, farmers are adjusting their vegetable planting schedules to align with shifting climatic conditions.

Vegetable growers applied animal manure to restore soil fertility. They are using chemical fertilizers by combining organic fertilizers too. They are also using micronutrients to increase productivity. They are doing crop rotation with legumes. Coriander, broad leaf mustard, were intercropped with main crop like tomato which also helps as a compensation for major crop failure and provides extra income too.

CONCLUSION

This study conducted in Kathmandu district revealed that agriculture served as the primary livelihood source for 58% of the respondents. Middle-aged farmers (36-45 years) were showing the highest level of activity. Overwhelming majority of the respondents experienced climate change impacts and natural hazards. To mitigate these impacts, 86% of farmers employed adaptation strategies such as mulching and drip irrigation, addressing issues arising from increased hot days, prolonged droughts, and shifting rainfall patterns.

Furthermore, common issues of yield decline included diseases like powdery mildew, blight, damping-off, and pests such as fruit flies, whiteflies, and aphids. Farmers were adjusting planting and harvesting times in response to climate change variability affecting crop cycles.

Climate change exerts a negative influence on vegetable production and farmers' livelihoods. Major challenges included drought, erratic rainfall, high temperatures and drought, and insect / pest infestations.

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EVALUATING DIFFERENT PHEROMONE TRAPS FOR TOMATO LEAF MINER (*Tuta absoluta* MEYRICK) IN KATHMANDU VALLEY

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ABSTRACT

This study was conducted in plastic tunnel farms located in Gamcha and Jhaukhel in Bhaktapur, Lubhu in Lalitpur, and Machhegaun in Kirtipur. The research spanned from April to the first week of August 2023. The primary aim of this study was to assess the effectiveness of various pheromone traps (Light trap, Wota-t trap, and delta trap) in controlling Tuta absoluta in the specified locations. Experiments were conducted using these traps, each equipped with a Tomato leaf miner lure, and the captured Tuta moths were tallied and recorded every week for a total of 16 weeks. The results consistently demonstrated the superior performance of the Wota-t trap in terms of capturing Tuta moths in all locations, except for Lubhu, where the Light trap proved to be more effective. In contrast, the delta trap consistently yielded fewer Tuta catches compared to the other two traps during each field visit. Results showed that Wota-t traps were significantly efficient in closed environments with high Tuta populations and had the advantage of capturing very few non-targeted pests, while light traps were consistently effective, but they had the drawback of attracting non-targeted nocturnal pests. On the other hand, Delta traps consistently yielded poor results, with significantly fewer Tuta captures. In light of these findings, this research recommends that tomato farmers in Kathmandu Valley who cultivate their crops in tunnel farms should use Wota-t traps for enhanced control of Tuta absoluta infestations.

Key Words: Tomato, *Tuta absoluta*, Wota-t trap, light trap, delta traps

INTRODUCTION

In Nepal the agricultural sector contributes about 24.12 percent of the national GDP (NRB, 2023). Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops in Nepal, with considerable potential for income and employment opportunities. In terms of area and output, tomato ranks third after cauliflower and cabbage in Nepal. It is cultivated in about 20,000 hectares (ha) and around 0.3 million MT of tomato is produced annually in the country (MoAD, 2014). However, its productivity in Nepal is 19.3 MT per ha, (MoAD, 2015/16) which is far below worldwide production of 37.46 MT per ha. (FAOSTAT Database, 2016). The highest marketable yield was recorded from a hybrid all-rounder (86.6 t/ha) followed by Srijana (80.8 t/ha) in Nepal under a high tunnel (Chapagain et al., 2011). Potential production of this crop is limited by several biotic and abiotic factors such as early and late blight, tomato fruit borer, tomato leaf miner etc. Among them, recently, the South American Tomato Leaf Miner (TLM) *Tuta absoluta* (Lepidoptera: Gelechiidae) has emerged as one of the devastating pests of tomato crops all over the world (Tosevski et al., 2011). The pest has appeared as a havoc causing a significantly crop loss in Nepal. This pest was recorded for the first time in Nepal in the Kathmandu Valley during May, 2016 and found spread into tomato growing areas near Kathmandu Valley and surrounding districts; Kavrepalanchowk, Dhading and Nuwakot (Bajracharhya et al., 2016).

MATERIALS AND METHODS

Experimental location

Kathmandu, Lalitpur and Bhaktapur districts were selected as research sites for the study. The experiment was conducted in the fields of four tomato farmers to monitor and evaluate the best traps to capture the *Tuta absoluta* in field. The weather in Kathmandu Valley is warm and is a temperate zone with a mild climate. The average annual temperature and annual rainfall of Kathmandu valley is 17.78˚C and 1343 mm, respectively.

Weather of the study sites

Weather data such as temperature (maximum and minimum) and precipitation were collected from April to July from the Department of Hydrology and Meteorology (DHM), Babar Mahal, Kathmandu. The maximum and minimum temperature and average precipitation of Gamcha are 35.5 ˚C, 6.4 ˚C and 5.62 mm, respectively. The maximum and minimum temperature and average precipitation of Jhaukhel are 32.2 ˚C, 8 ˚C and 7.29 mm respectively. The maximum and minimum temperature of Lubhu is 32.2˚C, 4.4˚C and 5.02 mm respectively. The maximum and minimum temperature and average precipitation of Kirtipur are 31.9 ˚C, 7.1 ˚C and 5.38 mm, respectively.

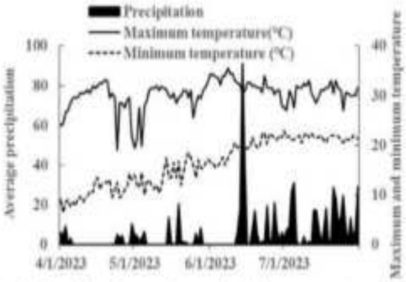

Figure 2: Graph showing maximum and minimum temperature (°C) and average precipitation (mm) of Gamcha during study period of 2023

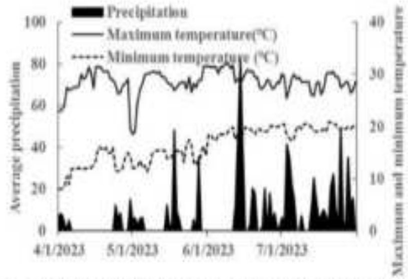

Figure 3: Graph showing maximum and minimum temperature (°C) and average precipitation (mm) of Jhaukhel during study period of 2023

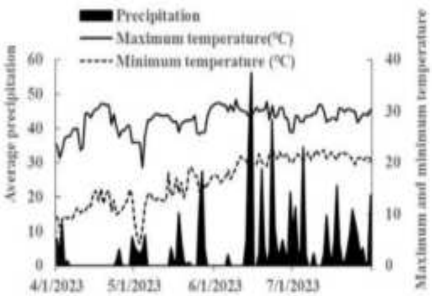

Figure 4: Graph showing maximum and minimum temperature (°C) and average precipitation (mm) of Lubhu during study period 2023

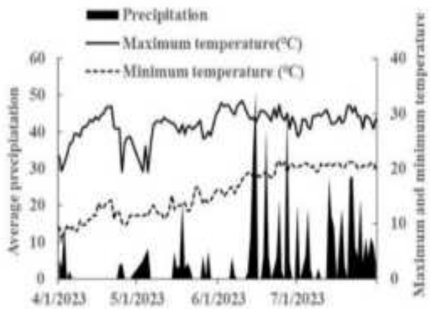

Figure 5: Graph showing maximum and minimum temperature (°C) and average precipitation (mm) of Kirtipur during study period 2023

Experimental Design

The experiment was done in four different locations consisting of three treatments.

Table 1. Treatments used in experimental location

S.N.	Location	Treatment
1.	Gamcha, Bhaktapur	Wota-t trap, Light trap, Delta trap
2.	Jhaukhel, Bhaktapur	Wota-t trap, Light trap, Delta trap
3.	Lubhu, Lalitpur	Wota-t trap, Light trap, Delta trap
4.	Machhegaun, Kirtipur	Wota-t trap, Light trap, Delta trap

Trap installation

The traps were installed on 9th and 10th April, 2023 on Bhaktapur, 11th April, 2023 in Lubhu and 12th April, 2023 on Kirtipur. According to the crop growth stage the traps were fitted at different height i.e. 25 cm during trap set up on 9th April and raised to 45 cm on 7th May. The distance between each trap was 7±1 meter. Soap water solution added to light and wota-t trap and was also replaced after counting the moth population at weekly interval. Delta trap was changed every 14-days interval. The TLM lure was fitted in each trap and was changed at one month interval.

Data collection

The primary data was collected directly from the field at weekly intervals. The moths attracted to the different treatments in different locations were counted and recorded for further analysis. The delta trap was changed on fortnightly and lures was changed once a month.

Statistical analysis

The collected information was compiled systematically and chronologically. The data was analyzed by using Microsoft Excel and SPSS (Statistical Package for the Social Sciences). The results were presented in the form of a bar diagram, graph, table etc.

RESULTS AND DISCUSSION

Evaluation of different traps

Average number of *Tuta absoluta* moths captured in different traps

The number of *Tuta* moths caught by different traps with *Tuta absoluta* sex pheromone lure in varied markedly in different locations of Kathmandu Valley. Wota-t trap was found as the most effective during most of the field visits. The efficacy of the Wota-t trap is unquestioned as per the data collected but the light traps were almost equally effective as it was more effective in trapping moths at Lubhu in total.

During the study period, the highest number of *Tuta* moths captured was observed in Lubhu, Lalitpur. In Lubhu, Lalitpur, monocropping of tomato was a common practice which larger area compared to other locations. If tomatoes are continuously grown in the same field without rotation, the pest population can build up over time. The recent invasion history in Afro-Eurasian and Middle Eastern countries implies that areas with large monocultures of tomato and/or that provide alternative hosts favor *T. absoluta* expansion (Biondi et al., 2018). In Gamcha and Jhaukhel Bhaktapur, a mixed cropping pattern was followed. Tomato and Cucurbits were cultivated under a plastic tunnel of the entire field. The average number of moths trapped in both places was almost similar and a higher number of moths were captured in wota-t trap. But in Machhegaun, Kirtipur the tomato cultivated area was less and nearby farms were cultivated with cucurbits, so the number of moths trapped was relatively less. Nonetheless, the wota-t trap was found to be the most effective than other traps.

The finding of this study are in line with the research conducted by (Gautam et

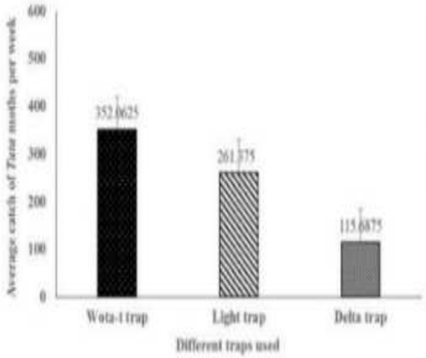

Figure 6: Average catch of *Tuta* moths captured in different traps in Gamcha, Bhaktapur

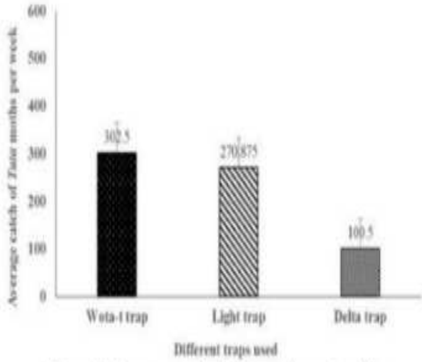

Figure 7: Average catch of *Tuta* moths captured in different traps in Jhaukhel, Bhaktapur

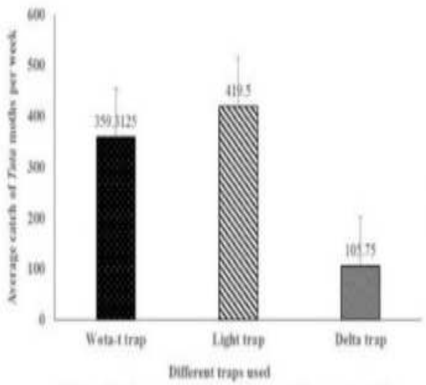

Figure 8: Average catch of *Tuta* moths captured in different traps in Lubhu, Lalitpur

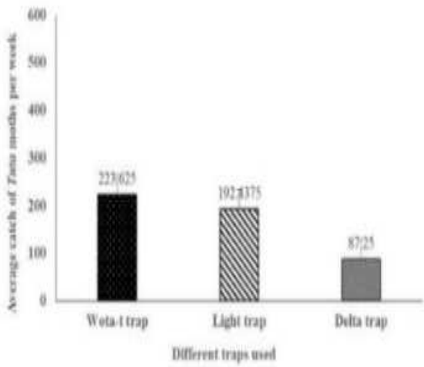

Figure 9: Average catch of *Tu*ta moths captured in different traps in Machhegaun, Kirtipur

al., 2018), in Kavre district of Nepal, which is geographically very close to Kathmandu valley with similar climatic conditions. They found Wota-T trap as the most effective method for catching *Tuta absoluta* where trapped *Tuta* population ranged from 51-972 in each Wota-T trap.

Also, Adhikari et al. (2019) in the Kavre district found that para-pheromone TLM lures in Wota-t trap were mostly used by the tomato growers' farmers because of its effectiveness than other traps.

According to Arturo (Cocco et al., 2012) light traps are the most effective for controlling tomato leaf miner infestation over a larger area because they were found to catch more *Tuta* moths in both Winter-summer plantations as well as Summer-winter plantations and controlled the infestation over the leaves and stem of tomato effectively in the research done in Sassari, Italy.

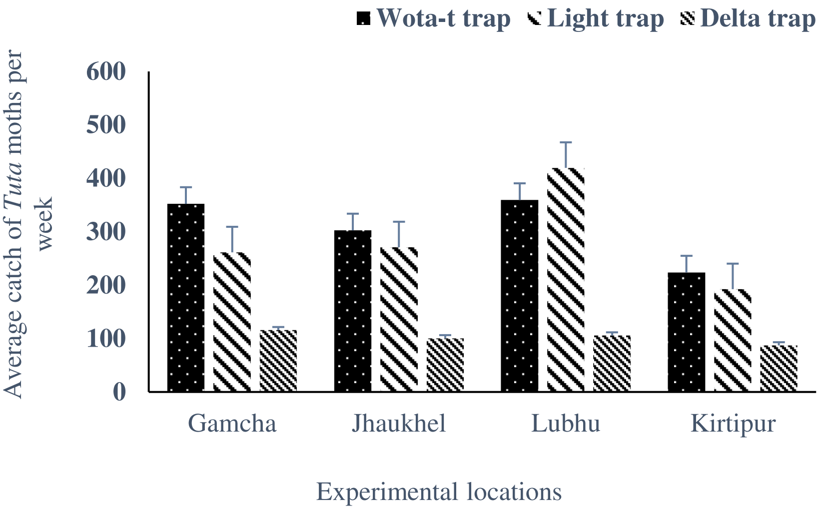

Figure 10. Average number of *Tuta absoluta* moths captured in different traps

Seasonal appearances of *Tuta absoluta* moths

Figure 11 shows the fluctuation of *Tuta* moth captured by the different traps (Wota-t trap, Light trap, Delta trap) in different months. The maximum number of *Tuta* moths captured by different traps were in the month of May and the minimum number of *Tuta* were captured in July. Wota-t, light and delta traps were dominant in the month of May. This result resembled a similar result of an experiment where fluctuation of the pest peaked during mid-June and decreased later on (AL- Sawy et al., 2016). It also shows that the population fluctuation of *T. absoluta* has two stages. The first stage was extended from April to May. It was characterized by an upsurge in the number of captured moths till the peak of the population on average was 729 moths per week. The second stage recorded a decline in the population from May to June. Again, from June to July saw a gradual plunge in the population of *Tuta absoluta*. Figure 12 shows the fluctuation of *Tuta* moth captured by the different traps (Wota-t trap, Light trap, Delta trap) in different months. The maximum and minimum number of *Tuta* moths captured in wota-t trap (May and July), light trap (July and May) and delta trap (June and April). For the period between April to July, trends of moth catches were found very contrasting in wota, light and delta traps. In wota-t traps the moths population increases from April to May and gradually decrease from May to July. But in light trap there were a smaller number of moths caught in the months of April to May and then the population of moths were found gradually increased from May to July. Similarly, in the delta trap, there is a gradual increase of *Tuta* moths from April to June and again slight decrease during July.

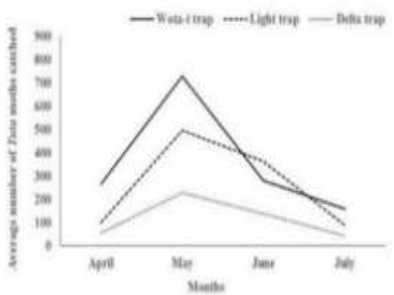

Figure 11: Seasonal appearance of *Tuta absoluta* moths captured on different months in Gamcha, Bhaktapur

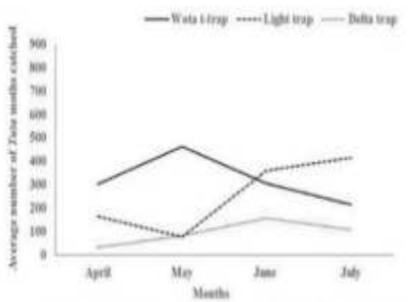

Figure 12: Seasonal appearance of *Tuta absoluta* moths captured on different months in Jhaukhel, Bhaktapur

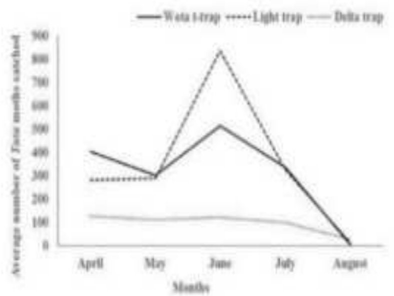

Figure 13: Seasonal appearance of *Tuta absoluta* moths captured on different months in Lubhu, Lalitpur

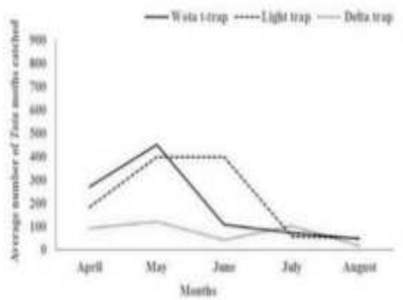

Figure 14: Seasonal appearance of *Tuta absoluta* moths captured on different months in Machhegaun, Kirtipur

Figure 13 shows the fluctuation of *Tuta* moth captured by the different traps (Wota-t trap, Light trap, Delta trap) at different months. Wota-t trap and Light trap caught maximum number of *Tuta* moths as compared to delta trap. The maximum and minimum number of *Tuta* moths captured in wota-t trap (June and August), light trap (June and August), and delta trap (April and May). During the study period, the moths caught were less in the initial days of trap installation. Suddenly the number of moths catches increased from May to July. The study revealed that the highest average number of *Tuta* were captured in June i.e. 839.5 and the least number of moths caught in August i.e. 6

Figure 14 shows the fluctuation of *Tuta* moth captured by the different traps (Wota-t trap, Light trap, Delta trap) at different months in Machhegaun, Kirtipur. The maximum and minimum number of *Tuta* moths captured in wota-t trap (May and August), light trap (May to June and August) and delta trap (May and August). It shows that the traps caught a maximum number of moths during the initial days of trap installation in May. Later on, there was observed a sharp decline in the number of *Tuta* moths from June to August possibly because of the declining number of *Tuta* as a result of effective initial catch.

Chi-square test was done to find out the association between different types of traps with location. χ^2 calculated values| 442.612| > χ^2 tabulated values|22.46| where (P=0.001). From data analysis, a highly significant difference was recorded in the mean weekly observation. That implies there is a significant difference in the number of *Tuta* catches depending on the types of pheromones traps and the location where the traps have been placed.

CONCLUSION

The study showed that there are many insects pests of tomato in the field and among them, *Tuta absoluta* appeared to be the most challenging one among the tomato growing farmers. Nepalese farms, particularly tomato fields, are becoming a hotspot for *Tuta absoluta,* mostly because farmers are unaware of the indiscriminate use of pesticides, the presence of several months, as well as the season and suitable conditions for pest attacks. During the interval of 4-5 months, the number of *Tuta* moths captured in different seasons varies according to the location due to environmental factors and the cropping pattern.

Wota-t trap appeared to be the most attractive for monitoring *T. absoluta* moths and enhanced the effectiveness of pheromone-baited traps. Therefore, this trap can be used as one of the best pheromone-based management strategies for the management of *Tuta* moth.

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ASSESSING THE EMERGING HAVOC OF SNAILS AND SLUGS ALONGWITH THEIR MANAGEMENT IN RUPANDEHI AND NAWALPARASI DISTRICTS OF NEPAL

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ABSTRACT

Among 100 Terrestrial snails and slugs found in Nepal spanning 42 genera and 24 families, the Giant African Land snail stands out as the most destructive pest of vegetable crops in tropical and subtropical regions. A comprehensive study, involving direct observations and a questionnaire survey was conducted from 12th June to 2nd July 2023. The findings, based on responses from 141 participants, reveal a significant surge in snail and slug populations over the past 4-8 years in two districts. Based on these informants the most preferred habitats in the study area include gardens followed by bari (Small field), roadside, riverside, and water sources. The survey study in Rupandehi and Nawalparasi indicates that the majority of respondents do not observe snails and slugs throughout the year. However, their prevalence notably increases during the rainy season, from June to September. The Giant African Land snail was reported to be more prominent than slugs and horntail snails in both districts. These pests were found in various habitats, including gardens, bari, walls, roads, and paddy fields (referred to as Khet), with the highest number of sightings in gardens and bari. Respondents reported that they feed on a range of vegetable crops, including cucurbits, Cole, brinjal, okra, and taro, and cause 50% damage to nursery seedlings. The most common management practices reported include collecting and disposing of them in garbage-carrying vehicles, nearby rivers, and roads as well as crushing live individuals, spreading salt on them, and spraying alcohol and detergents. Regarding predators, respondents from Rupandehi identified the Greater coucal as the most prominent predator of GALS and slugs, while in Nawalparasi, the Great egret was reported to be the most common predator of snails and slugs. Only a few respondents from both districts used molluscicides such as metaldehyde and pesticides like cypermethrin to manage the snail and slug populations.

Key words : Gastropods, giant African land snail, snail, slugs, invasive species, Mollusca

INTRODUCTION

Snails and slugs belong to the Mollusca family. In Nepal, approximately 100 terrestrial snail and slug species from 42 genera and 24 families have been reported. The primary distinction betweensnails and slugs is the presence of a shell in snails, which offers protection against predators, whileslugs rely on other means to evade threats. Both leave a slimy trail as they move. Among these, the African giant snail (*Achatina fulica*) stands out as one of the most destructive pests in subtropical and tropical regions, causing extensive damage to kitchen gardens, farms, and vegetable gardens (Jha, 2019). It is found in various environments, including urban settlements, kitchen gardens, agricultural lands, forest edges, riverbanks, shrublands, riparian zones, garbage deposits, wetlands, and hiding places, where they reproduce rapidly. Giant African land snails feedon over 500 varieties of plants (Ramdwar, M. *et al*., 2018), causing significant economic losses inNepal (Budha & Naggs, 2008). Snails were introduced to Nepal from India in the 1930s and havesince spread widely in the Terai region from Jhapa to Kanchanpur (Budha & Naggs, 2008). Managing established snail populations is challenging, as they can thrive in harsh conditions between 2 to 30 degrees centigrade. Notably, they are absent in Kathmandu, despite the occasionaltransportation of eggs with vegetables and crops from snail-prevalent regions. Research by Budha and Naggs (year?), suggests that these snails establish themselves through pipes and water channels. A pressing issue in kitchen gardening is snail infestation, which can devastate crops such ascauliflower, cabbage, spinach, cucumber, pumpkin, bottle gourd, potato, radish, and tomato. Pestsreproduce rapidly, making it difficult to protect crops once they establish themselves in an area (Dreistadt *et. al*, 2016). Despite the economic losses in agriculture, snails can serve as a nutrient source in fish and pig farming. Research indicates that snails are a valuable food source for fish, and their flesh is consumed by pigs, poultry, ducks, crows, and more. In Nepal, farmers typically resort to local control measures when dealing with infestations, involving the collection and disposal of snails in nearby bodies of water or on roads to be crushed by passing vehicles. Additionally, some farmers use salt to eliminate snails (Jha, 2019).

MATERIALS AND METHODS

The research was conducted in Siddhartha Nagar Municipality, and Omsatiya Rural Municipality in Rupandehi district, whereas in Nawalparasi district, Ram gram Municipality and Pali Nandan Rural Municipality were selected for study.

Sample and sampling technique

The study was conducted in purposefully selected two districts, Rupandehi and Nawalparasi, due to the significant involvement of the local population in kitchen gardening and vegetable cultivation. Initially, I compiled a list of individuals actively engaged in vegetable farming and kitchen gardening from the Agricultural Knowledge Centers (AKCs) in the Rupandehi and Nawalparasi districts. From this list, we employed a random sampling technique through a lottery method to select a total of 141 farmers for our survey. Among these participants, 76 were from the Rupandehi district, and 65 were from Nawalparasi district.

Research Design

Pre-Survey

Before the actual survey, we conducted a preliminary study involving a total of 5 households. This pre-survey provided valuable insights that aided in the preparation of the questionnaire.

Household survey

The Household Survey was conducted through face-to-face interviews, utilizing a pre-tested semi-structured interview schedule. This survey involved the collection of primary data from a total of141 farmers in the study area. Out of these, 76 respondents were from Rupandehi district, and 65 were from Nawalparasi district. The interviews were primarily focused on gathering demographic information and acquiring insights into the farmers' knowledge regarding snails, the damage theycause, and the control measures employed.

Key informant interview

Additionally, key informant interviews were conducted with professionals from agricultural organizations such as officers of AKC. The information gleaned from these interviews served as valuable corroboration for the data obtained from the household survey.

Data collection

Primary data was collected from farmers within the study area through various research instruments, including door-to-door interviews using structured questionnaires, focus group discussions, key informant interviews, and direct field observations. Secondary data was also collected from various sources, including:

- **Documents and Publications:** Reference was made to documents and publications from the Ministry of Agriculture and Livestock Development (MoALD), the Nepal Agricultural Research Council (NARC), and other governmental agencies to supplement the research.
- **Journal Articles:** Relevant journal articles from institutions such as the Agriculture and Forestry University (AFU), Tribhuvan University (TU), and international journals provided additional valuable secondary data.
- **Books, Annual Reports, and Research Papers:** Information was gathered from books, annual reports, and research papers to enrich the secondary data collection efforts.

Data Analysis

Survey data was processed in Microsoft Excel, and then used for analysis. Statistical tools including averages, percentages, and means, were applied for comparison. Data presentation was enhanced through the creation of charts and tables.

RESULTS AND DISCUSSION

Abundance of snails and slugs

Snails were reported in almost all surveyed settlements in Rupandehi and Nawalparasi districts. A higher number of respondents mentioned the presence of snails in their area for the last 0-4 years and 4-8 years, with very few reporting snail presences for the last 12-24 years (Table 2). A similar pattern was observed in a survey in Janakpur district (Jha, 2019).

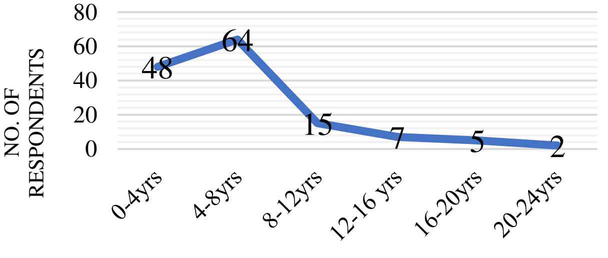

Figure 1. Duration of possible abundance of snails and slugs (N=141)

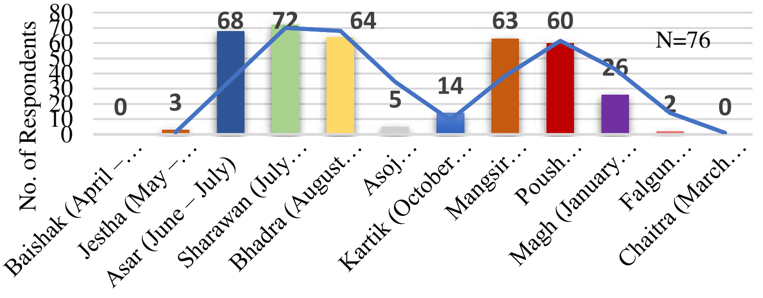

Figure 2. Monthly occurrence of snails and slugs in Rupandehi (September-October) and Kartik (October-November), followed by a resurgence during the cool season, before decreasing once more in the subsequent months

Monthly occurrence of snails and slugs

As depicted in Figure 2, snails and slugs exhibit their highest prevalence during the rainy season,spanning from Asar to Bhadra (June-September) in Rupandehi. Subsequently, their abundance declines during Ashoj. As illustrated in Figure 3, snails and slugs exhibit their highest prevalence during the rainy season, spanning from Asar to Bhadra (June-September) in Nawalparasi. Subsequently, their abundance declines during Ashoj (September-October) and Kartik (October-November), followed by aresurgence during the cool season, before decreasing once more in the remaining months. A similartrend was observed by Jha (2019), Raut & Ghose (1979, 1984), and Raut & KC. (1999), indicating that snails, including the Giant African Land Snail and Horntail Snail, occur seasonally,affecting crops. Moreover, slugs predominantly favor wet and damp seasons (Bhandari, 2021). The study also reveals that slug egg survival decreases with rising temperatures, as observed bothin laboratory and outdoor experiments (Hata *et al*, 2017). Similarly, the population of snails and slugs correlates with edaphic factors, with populations decreasing as soil temperature rises and soil moisture decreases (Kaur *et al*, 2017).

Abundance of snails and slugs in different habitats

Snails and slugs were found in various types of habitats, including gardens, fields (referred to as "khet" and "bari"), paddy fields, and near water sources. The highest numbers of snails and slugs in Rupandehi were observed in gardens and fields, while the least were found in paddy fields andnear water sources. They were also frequently spotted along roadsides and on house walls (Figure4). Figure 5 reveals that the highest number of snails and slugs were reported from bari and water sources, while a moderate number was found in gardens, and very few wereobserved in paddy fields and near "khet" areas in Nawalparasi district.

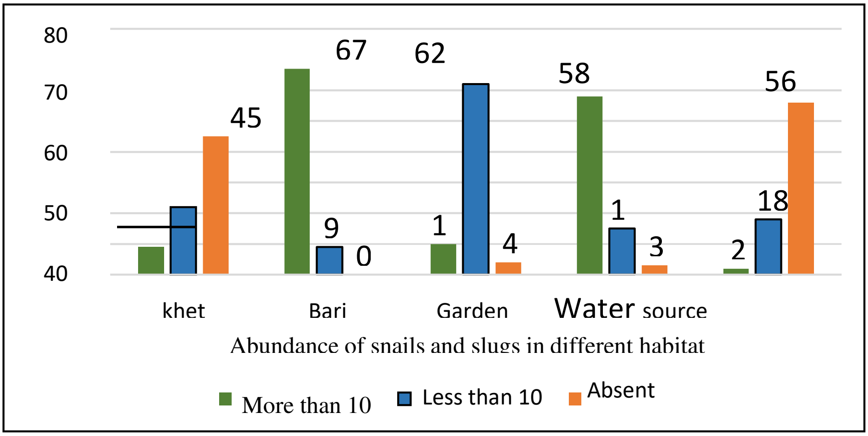

Figure 3. Abundance of snails and slugs in different habitats at Rupandehi

Research conducted by Raut and Baker in 2002 and Jha in 2019 has shown that the highly invasive GALS snail is commonly sighted in locations such as building walls, roadside gardens, "bari" fields, water sources, and other moist areas. These habitats are often observed in old walled buildings and boundary walls, as noted by Budha & Naggs in 2008. However, there have been no studies conducted on the population of slugs in relation to these habitats.

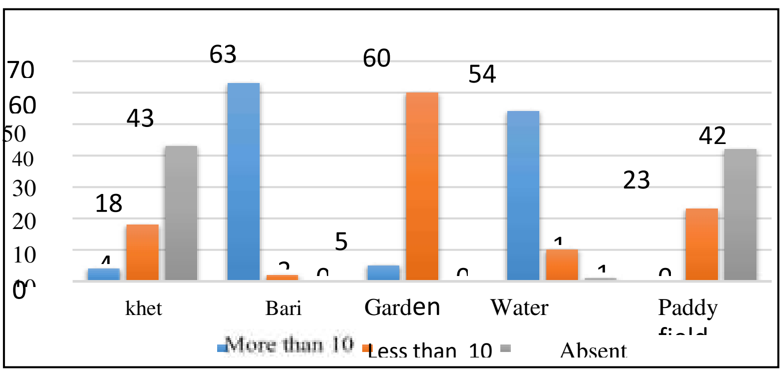

Figure 4. Abundance of snails and slugs in Nawalparasi

Prevalence of snails and slugs

Figure 6 illustrates that in Rupandehi district, the Giant African Land Snail was identified as the most damaging snail to crops, followed by the Horntail Snail, which is considered a moderate threat. Slugs were reported as causing the least harm to crops in both kitchen gardens and vegetable fields, as per the respondents' observations. Based on Figure 7, the majority of responses indicate that the Giant African Land Snail is the most prevalent in Nawalparasi district, followed by the Horntail Snail in a moderate position, while slugs were reported to be the least abundant. In2013, Budha documented the presence of alien and invasive fauna in Nepal, including GALS, horntail snails, and some slugs. In 2015, Budha listed a total of 64 alien fauna in Nepal. The rapid spread of GALS in Nepal has been well-documented, as noted by Budha and Naggs in 2008 whenthey created the first distribution map of the species. Since then, this snail has been introduced toalmost all Terai districts. The Giant African Land Snail is considered a serious vegetable pest and a major issue in kitchen gardens, as reported by Budha and Naggs in their 2005 article.

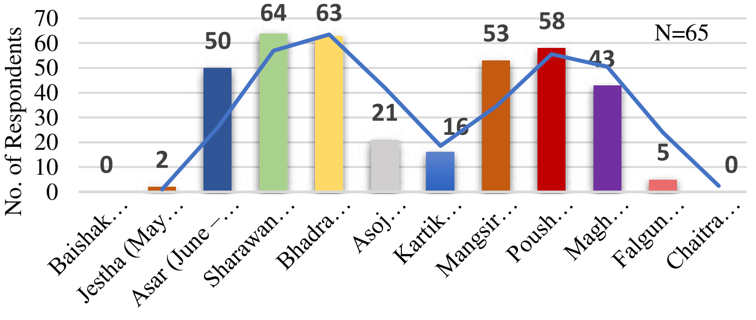

Figure 5. Abundance of snails and slugs in different months at Rupandehi

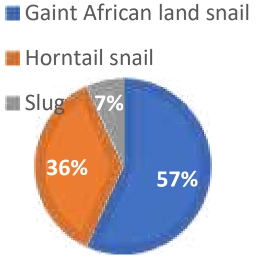

Figure. 6 Prevalence of snails and slugs in Rupandehi

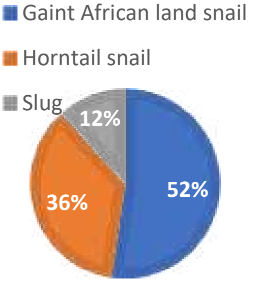

Figure.7 Prevalence of snails and slugs in Nawalparasi

Knowledge of most susceptible crops to snails and slugs

From the Rupandehi district, 76% were aware of the most preferred crops of snails and slugs, while 24% were not sure, as they had observed damage to various types of plants without a single clear preference. According to their responses, cucurbits were the most susceptible, followed by Cole crops and other vegetables such as okra and brinjal. Snails and slugs were reported to cause approximately 50% damage to the seedlings of these vegetable crops. Out of the 65 respondents from Nawalparasi, 68% reported that green leafy vegetables, cucurbits, and Cole crops are highly susceptible to snail damage, along with taro, okra,and brinjal to a lesser extent. Meanwhile, 32% of respondents were not aware of the most susceptible crops and mentioned that snails feed on various plants in the field (Figure 8). It's noteworthy that even a small number of 3-4 snails and slugs can devastate vegetables within a 2 sq. ft area. Snails, particularly the GALS, can completely destroy crops such as cauliflower, cabbage, cucumber, sponge gourd, potato, tomato, brinjal, and others (Buddha *et al.*,2005). Vegetable crops are predominantly affected by snails and slugs (Bhandari, 2021).

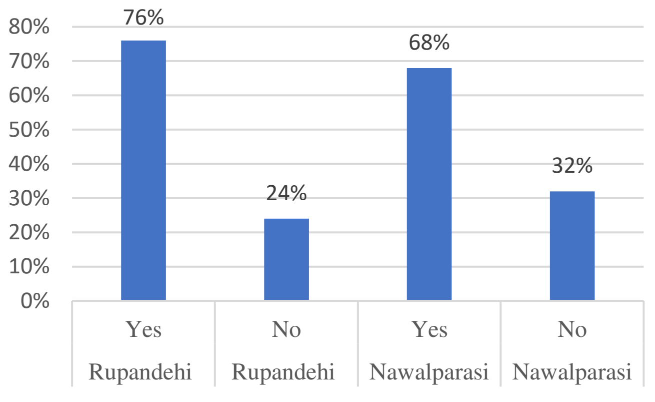

Figure 8. Knowledge of most susceptible crops to snails and slugs local control measure

The locally adopted control measures include collecting and disposing of snails in the river, crushing live individuals, discarding them on roads, placing them in garbage carried by tractors, and applying alcohol and detergent. Among these methods, crushinglive individuals was identified as the most effective control technique employed by the residents of Rupandehi (Figure 9). Out of the 65 respondents interviewed, 64 individuals provided their responses regarding control measures for snails prevalent in their area. Locally adopted control measures include collecting and disposing of snails in the river, crushing live

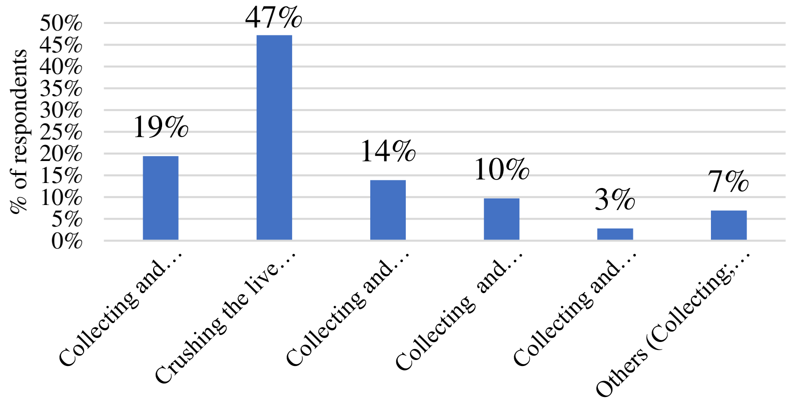

Figure 9. Local control measure for snails and slugs in Rupandehi

individuals, and discarding them on roads. Additionally, some respondents mentioned the use of alcohol and detergent. Among these methods, crushing live individuals was identified as the most effective control technique adopted by the local people of Nawalparasi (Figure 10). In a study conducted byJha in 2019, it was observed that the local people in Janakpur employed control measures such ascrushing the snails, pouring salt over them, removing their hiding places, and searching for eggs. Among these measures, pouring salt was
reported as the most effective control method.

Enemies of snails and slugs

Among the mentioned predators, which included the Great egret and Greater coucal, the majority of respondents from Rupandehi reported that the Greater coucal is the predator of Giant African Land Snails (GALS) and slugs (Figure 11). Similarly, respondents from Nawalparasi mentioned several potential predators, including the Great egret, crow, and Greater coucal, with the highest percentage of people reporting that the Great egret is the predator of Giant African Land Snails (GALS) and slugs (Figure 12). Additionally, it's worth noting that GALS are known to be consumed by various animals, such as crows, monitor lizards, Common man goose, and pigs,as documented by Budha and Naggs in 2005. The greater coucal feeds on large varieties of foodswhich include snails and slugs too

(Kit Lan, 2020). Great exert has been reported to feed on snails and slugs (NYNHP, 2023).

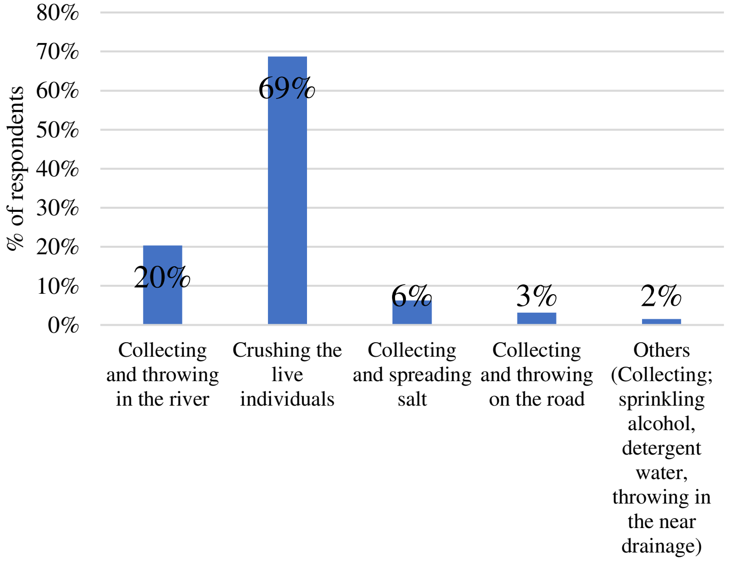

Figure 10. Local control measures for snails and slugs in Nawalparasi.

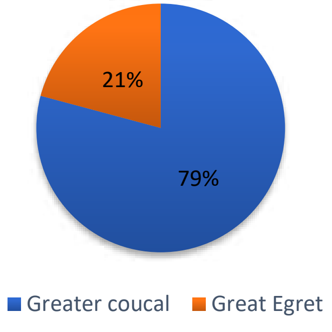

Figure11.Enemies according to locals of Rupandehi

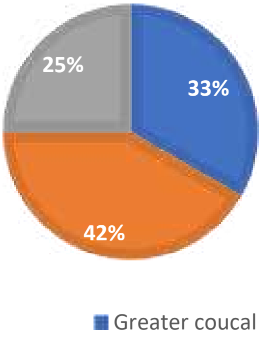

Figure12. Enemies according to locals of Nawalparasi

Use of chemicals to mitigate snail and slug populations

According to the respondents, those who use chemicals from Rupandehi typically employ Metaldehyde GR 6%, which is available in the market under the name "King Foe" and is recommended by Argo vets. Some respondents also mentioned using other pesticides, such as Cypermethrin and Dimethoate 30% EC, to control snails and slugs. Only 20 individuals from Nawalparasi reported using chemicals to manage snails and slugs, including molluscicides recommended by Argo vets. Some respondents mentioned using Cypermethrin and other pesticides for snail and slug control (Figure 18).According to a study by Hata *et al*., in 1997, growers and farmers commonly used conventional bait pellets containing molluscicides like methiocarb and metaldehyde.

CONCLUSION

Based on the findings of this study, it is evident that the populations of snails and slugs have experienced a substantial increase in both districts over the past 4-8 years. This conclusion is drawn from the insights gathered from 141 respondents, who consistently reported that these troublesomepests inflict the most damage to crops during the monsoon and cool seasons, particularly in the month of Asar (June-July) & Shrawan (July-August). Furthermore, the study shed light on the preferred habitats of these pests, with gardens and farmlands being their primary residence, followed by roadside areas, house walls, and locations near water sources. Respondents from both districts unanimously identified the Giant African Land snail as the most prevalent among these pests, with slugs and horntail snails being less common in their respective localities. The researchalso revealed that these pests exhibit a penchant for a diverse range of vegetables, including Cole crops, cucurbits, brinjal, okra, and taro, all of which are frequently subjected to their damaging activities. In response to this agricultural challenge, respondents employed various methods for pest management, including collecting and disposing of the pests in garbage-carrying vehicles or nearby rivers, crushing them, applying salt, tossing them onto roads, and using alcohol ordetergents. Among these strategies, crushing emerged as the most widely adopted method.Additionally, the study identified the Greater Coucal, Great Egret, and crows as the primary predators of snails and slugs in the study area. It is noteworthy that only a small percentage of respondents from both districts resorted to chemical methods for pest management, indicating a preference for non-chemical approaches among the local populace.

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BENEFIT COST ANALYSIS OF MAJOR FRUITS AT BAGMATI PROVINCE

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ABSTRACT

A study was carried out in four districts of Bagmati province to access the B:C ratio of major fruits. Benefit cost ratio is one of the major economic indicators that influence the farmer to carry out the cultivation of crop. A total of 104 farmers were used as respondent. The B:C ratio was maximum for papaya with 4.07 and least for lime with 1.07 over the period of 25 years. About the reasons of doing fruit cultivation, 46.9% said it to be highly profitable, 23.5% for increasing demand, 17.3% for easy to manage, 7.1% for marginal land utilized and 4.2% for other reasons. 63.38% of the respondents requested for technical assistance regarding fruit cultivation. 66.67% of the respondents get assistance and support from provincial government. 75.2% were satisfied with what they are doing and 86.7% are seeking extension and modification.

Keywords: B:C ratio, Bagmati, fruit cultivation

INTRODUCTION

Nepal is an agriculture country with 65.5% actively population engaged on agriculture and contributing more than 27.1% GDP of the country (MoAD, 2017/18). Government of Nepal has given emphasis for the promotion of high value but low volume cash generating crops. Fruit crops are important crops for vital nutrients and vitamins. Because of the climatic variations, different fruits are grown on the altitudinal basis. Moreover, we can grow tropical to temperate type of fruits since we are gifted with 4 physiographic/horticultural zones. The total productive area coverage under fruits is 120023 with annual production of 1177640 metric tons with productivity of 9.81 t/ha in whole Nepal (MoAD, 2018/19). The major fruit transaction is carried out in Bagmati province because of its highest population of about 5529452. Not only this, this province is center of attraction to tourist. Thus, commercial fruit farming is being practiced in this province from the long time. Despite this, Nepal imports large quantity of fruit investing of billions of currencies. Even though the farmers are engaged in commercial fruit cultivation and the support from government has intense positive impact of increment in yield i.e. 9.81 mt/ha in 2018/19 (MoAD, 2018/19). With the education and health awareness among the consumers have led the increased demand every year which compelled the country to invest more money on importing the fruits from outside the world. In order to be in line with the increased fruit demand, there needs to motivate the farmers on fruit cultivation and Bagmati province need to utilize the marginalized steep lands on commercial fruit production. The farmers will be convinced once they get acquainted with cost of the production along with the B'C ratio of specific commodity. The study related to production cost analysis of major fruits grown throughout the Bagmati province was carried out which will be helpful to design and implement the eco-friendly improvised technologies at Bagmati province in order to motivate the farmers towards orcharding enterprises.

MATERIALS AND METHODS

Location of the study: A survey was done at four districts viz, Chitwan, Sindhuli, Dolakha and Ramechhap of Bagmati Province, Nepal with a total of 104 farmers to access the B:C ratio of major fruits. Primary data were collected through household survey, key informants' interview and focused group discussion. Secondary data were collected from various national repositories, district profiles and all other valid sources. A well-structured questionnaire was prepared and pre-tested in 10% of the households before household survey.

Survey tools and techniques: Key Informant Interview (KII) to 15 person and 4 Focus Group Discussion (FGD) were be primarily used for the study.

Data analysis: Data collected through qualitative methods through FGD, KII and field observation were coded and tabulated. The data was entered in MS-excel 2013 and analyzed using Statistical Package for Social Science version 23.

RESULTS AND DISCUSSION

Fruit growing status and varieties grown: Around 61% of respondents in study district were involved in papaya cultivation, 58.2% in banana, 65.3% in sweet orange, 68.4% in mandarin, 67.3% in lime and 76.5% in kiwi cultivation. The name of varieties of these fruits is given in table 1. Farmers usually prefer early establishing/fruiting cultivars with both high yield in terms of quality and quantity.

Table 1. Name of the varieties used by the farmers

Fruits	Varieties
Papaya	Red lady
Banana	Malbhog, G9, Harichhal, William hybrid
Sweet orange	Pongon, Satusma, OKitchu, Unshuii , NCPR 27 84
Mandarin	Otapongan, Okitchu, Unshuu
Lime	Golden lime, Local
Kiwi	Hay wart, Local

Source: HH survey, 2021

Benefit cost analysis of mandarin: It was found that the cost of mandarin was found to be NRs. 145143.7 for first year and NRs. 113804 for second year. The cost of production increased by 10% each year up to 10 years and remain same for about 25 years. Whereas the production starts from fourth year and production increased up to 15 years and then decreased by 20% and remain same for about 25 years. From the survey it was found out that B:C ratio was found to be maximum at 7th year i.e. 2.55 and about B:C ration of 1.54 was found up to 25 years of the mandarin establishment (Table 2).

Table 2. Benefit cost analysis of mandarin

S. N.	Particulars	Year											
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11-15	16-25
1	Production(kg/plant)				5	17	27	45	45	50	50	50	40
2	Production(MT/ha)				1.48	5.04	8.01	1.33	1.33	1.48	1.48	14850	11880
3	Total income		0	0	51975	176715	280665	467775	467775	519750	519750	519750	415800
4	Total cost (After third year cost increases by 10%)	145143	113804	125184.4	137702	151473	166620.4	183282.5	201610.7	221771.8	243949	268343	268343
5	Profit/loss		-113804	-125184.4	-85727	25241	114044	284492.5	266164.3	297978.2	275801	251406	147456
6	**B:C ratio**				**0.37**	**1.1**	**1.6**	**2.5**	**2.3**	**2.3**	**2.1**	**1.93**	**1.54**

Source: HH survey, 2021

Benefit cost analysis of banana: It was found that the cost of banana production was found to be NRs. 164142.6 for first year and NRs. 121776.6 for the second year. The cost of production increased by 10% for the third year and the banana plantlets are replaced from the fourth year for high yield. Whereas the production starts from second year and is maximum on third year. From the survey it was found out that B:C ratio was found to be maximum at 3rd year i.e. 1.32 and about 1.27 on third year (Table 3).

Table 3. Benefit cost analysis of banana

S.N.	Particular	Phases		
		1st year	2nd year	3rd year
1	Production(kg/plant)		8	9
2	Production(kg/ha)		7920	8910
3	Total income		277200	311850
4	Total cost	164142.6	121776.6	133954.3
5	Profit/loss	-164143	155423.4	177895.7
6	**B:C ratio**		**1.27**	**1.32**

Source: HH survey, 2021

Benefit cost analysis of sweet orange: It was found that the cost of sweet orange production was found to be NRs. 116400.2 for first year and NRs. 88903.8 for second year. The cost of production increased by 10% each year up to 15 years and remain same for about 25 years. Whereas the production starts from fourth year and production increased up to 15 years and then decreased by 20% and remain same for about 25 years. From the survey it was found out that B:C ratio was found to be maximum at 8th year i.e. 3.06 and about B:C ration of 1.80 was found up to 25 years of the sweet orange establishment (Table 4).

Table 4. Benefit cost analysis of sweet orange

S.N.	Particular	Investment Phases											
		1st	2nd year	3rd	4th	5th	6th	7th	8th	9th	10th	11-15	16-25
1	Production(kg/plant)				5	18	30	40	46	48	45	45	36
2	Production(kg/ha)				1500	5400	9000	12000	13800	14400	13500	13500	10800

3	Total income				57,000	189,000	315,000	420,000	483,000	504,000	472,500	472,500	378,000
4	Total cost (From third year cost increased by 10%)	116400.2	88903.8	97794.18	107573.6	118331	130164.1	143180.5	157498.5	173248.4	190573.2	209630.5	209630.5
5	Profit/loss	-116400	-88903.8	-97794.2	-50573.6	70669.04	184835.9	276819.5	325501.5	330751.6	281926.8	262869.5	168369.5
6	**B:C ratio**				**0.52**	**1.59**	**2.42**	**2.93**	**3.06**	**2.90**	**2.47**	**2.25**	**1.80**

Source: HH survey, 2021

Benefit cost analysis of lime: It was found that the cost of lime production was found to be NRs. 189408.2 for first year and NRs. 136343.45 for second year. The cost of production increased by 10% each year up to 15 years and remain same for about 25 years. Whereas the production starts from fourth year and production increased up to 15 years and then decreased by 20% and remain same for about 25 years. From the survey it was found out that B:C ratio was found to be maximum at 6th year i.e. 2.43 and about B:C ration of 1.07 was found up to 25 years of the lime establishment (Table 5).

Table 5. Benefit cost analysis of lime

S.N.	Particular	**Investment Phases**											
		1st	2nd	3rd	4th	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11-15**	**16-25**
1	Production(kg/plant)			5	17	27	45	45	50	50	50	40	45
2	Production(kg/ha)			1800	6120	9720	16200	16200	18000	18000	18000	14400	16200
3	Total income			540000	183,600	291600	486000	486000	540000	540000	540000	432000	345600
4	Total cost (From third year cost increased by 10%)	189408.2	136343.45	1499	1649	181473.1	199620.4	219582.4897	241540.7	265694.8	292264.3	321490.7	321490.7

				77.8	75.6								
5	Profit/loss	-189408	-136343.45	-95977.8	18624.43	110126.9	286379.6	266417.51	298459.3	274305.2	247735.7	110509.3	24109.3
6	**B:C ratio**			**0.63**	**1.11**	**1.60**	**2.43**	**2.21**	**2.23**	**2.03**	**1.84**	**1.34**	**1.07**

Source: HH Survey, 2021

Benefit cost analysis of papaya: It was found that the cost of papaya production was found to be NRs. 170355.3 for first year and NRs. 125741.8 for the next five year. The cost of production remains same from second year to fifth year and the papa plants are replaced from the sixth year for higher yield. The production starts from second year and is maximum on fourth year and decline again on 5th year. From the survey it was found out that B:C ratio was found to be maximum at 5th year i.e. 6.61 and minimum of about 4.07 on second year (Table 6).

Table 6. Benefit cost analysis of papaya

S.N.	Particular	Investment Phases				
		1st year	2nd year	3rd	4th	5th
1	Production(kg/plant)		16	20	26	22
2	Production(kg/ha)		12800	16000	20800	17600
3	Total income		512000	640000	832000	704000
4	Total cost	170355.3	125741.8	125741.8	125741.8	125741.8
5	Profit/loss	-170355.3	386258.2	514258.2	706258.2	578258.2
6	**B:C ratio**		**4.07**	**5.08**	**6.61**	**5.59**

Source: HH survey, 2021

Benefit cost analysis of kiwi: It was found that the cost of kiwi production was to be NRs. 380632.5 for first year and NRs. 155666.5 for the second year and the production cost was increased by 10% each year up to 15 years and remain same for about 25 years. The production starts from fourth year and is maximum on 10th to 15th year and later on decreased by 20% for about 25 years. From the survey it was found out that B:C ratio was found to be maximum at 10th year i.e. 4.04 and about 2.94 B:C ratio can be obtained up to 25 years (Table 7).

Table 7. Benefit cost analysis of kiwi

S.N.	Particular	Investment Phases											
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11-15	16-25
1	Production(kg/plant)				3	10	20	30	35	40	45	45	45
2	Production(kg/ha)				720	2400	4800	7200	8400	9600	10800	10800	8640
3	Total income				90,000	300,000	600,000	900,000	1,050,000	1,200,000	1,350,000	1,350,000	1080000
4	Total cost	380632.5	155666.5	171233.15	188356.5	207192.2	227911.4	250702.5	275772.8	303350	333685	367053.5	367053.5
5	Profit/loss	-380633	-155667	-171233.15	-98356.5	92807.85	372088.6	649297.5	774227.2	896650	1016315	982946.5	712946.5
6	**B:C ratio**				**0.47**	**1.44**	**2.63**	**3.58**	**3.80**	**3.95**	**4.04**	**3.67**	**2.94**

Source: HH survey, 2021

CONCLUSION

Almost 61% of respondents in studied districts were involved in papaya cultivation, 58.2% in banana, 65.3% in sweet orange, 68.4% in mandarin, 67.3% in lime and 76.5% in kiwi cultivation. Farmers usually prefer early establishing / fruiting cultivars with both high yield in terms of quality and quantity.

It was found that the cost of mandarin was found to be NRs. 145143.7 for first year and NRs. 113804 for second year and B:C ratio was found to be maximum at 7th year i.e. 2.55 and about B:C ration of 1.54 was found up to 25 years of the mandarin establishment. Similarly, the cost of banana production was found to be NRs. 164142.6 for first year and NRs. 121776.6 for the second year and B:C ratio was found to be maximum at 3rd year i.e. 1.32 and about 1.27 on third year.

In addition, the cost of sweet orange production was found to be NRs. 116400.2 for first year and NRs. 88903.8 for second year and B:C ratio was found to be maximum at 8th year i.e. 3.06 and about B:C ration of 1.80 was found up to 25 years of the sweet orange establishment. Similarly, the cost of lime production was found to be NRs. 189408.2 for first year and NRs. 136343.45 for second year and B:C ratio was found to be maximum at 6th year i.e. 2.43. Moreover, the cost of papaya production was found to be NRs. 170355.3 for first year and NRs.

125741.8 for the next five year and B:C ratio was found to be maximum at 5th year i.e. 6.61 and minimum of about 4.07 on second year. Similarly, the cost of kiwi production was to be NRs. 380632.5 for first year and NRs. 155666.5 for the second year and B:C ratio was found to be maximum at 10th year i.e. 4.04 and about 2.94 B:C ratio can be obtained up to 25 years.

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EVALUATION OF ELITE POTATO CULTIVARS ON RED ANT (*Dorylus orientalis*) MANAGEMENT AND TUBER YIELD

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ABSTRACT

On-station experiment was carried out to identify appropriate potato cultivars for red ant management and increase the tuber yield of potato at Agriculture Research Station (ARS), Jaubari, Ilam, Nepal (2900 masl) during two consecutive years 2018 and 2019. Eight different promising potato genotypes [1. BLR-20 2. PRP-296667.2 3. PRP-14267.11 4. PRP-8561.11 5. PRP-016367.7 6. PRP-16567.5 7. Khumal Seto (standard check and 8. Ilam local (Jhyale)] selected from diseased screening nursery were included in the study. Experiment was conducted in previously red ant infected potato field in Completely Randomized Block Design (RCBD) with three replications. The experimental plot size was 5.4 m^2 (3m x 1.8m) where planting tubers was done at 60 cm row to row and 25 cm plants to plant spacing. Fertilizers were applied at the rate of 100:100:60 kg NPK/ha and 20 t/ha compost. Well sprouted tubers with weight 30-40 g were planted during the second week of February. The cultural operations were carried out as per the recommendation of National Potato Research Program (NPRP). Harvesting was done during the last week of July. Data on yield attributing traits, late blight disease, number of red ant damaged tubers, maturity days, red ant infested yield and healthy tuber yield were recorded. The potato cultivar PRP-16567.5 produced the lowest red ant score (1.00 red ant score in 1-5 scoring scale), less (0.33 – 1.66 %) red ant incidence percentage, minimum (0.04 – 0. 22 t/ha) red ant infected tuber yield and highest (31.19 – 35.22 t/ha) potato tuber yield followed by PRP-14267.11 (1.00 red ant score, 2.00 – 2.16 % red ant incidence percentage, 0.31 – 0. 33 t/ha red ant infected tuber yield and 27.27 – 27.67 t/ha potato tuber yield. Therefore, planting of PRP-16567.5 as well as PRP-14267.11 potato cultivars is appropriate for higher potato tuber yield and lower down red ant incidence at Jaubari area.

Key words: *Solanum tuberasum* L., yield, red ant, tuber, cultural operations,

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important and predominant tuber crops in Nepal and occupies fifth position in terms of area coverage and 2nd place in production as well as 1st position in productivity (NPRP, 2018). Potato is one of the most important vegetable crops in plains and lower hills while it is a staple food in high hills and mountains of Nepal. Nutritionally potato is rich in carbohydrates (61.5-91.5%) which is essential for energy, protein (1.6 g), dietary fiber, vitamin C (25 mg), starch (16.3 g), and minerals like phosphorous, calcium, and chlorine (Bose and Som, 1986). It is cultivated as winter crop in tropical and subtropical region and as summer crops in the temperate region of Nepal. It is one of the rare non-cereal foods that meet the nutritional requirement of the fast-growing population particularly in the developing country like Nepal (CIP, 1995). It has significant role in the income generation, food production and overall poverty alleviation as it has a high cash value and short cropping duration. Potato plays an important role in food security and livelihood due to its high cash, food and nutritive value (Gautam *et al*., 2011).

The productivity of potato in Nepal is 16.73 mt/ha (ABPSD, 2022) which is lower than its potentiality (about 30 mt/ha of released varieties) due to many biotic and abiotic factors (ARS, 2019). Several production factors are responsible for reduction of production and productivity of potato could be due to loss of valuable local genotypes; lack of improved cultivation practices; weed infestation causing potato crop loss up to 80% (Ghimire and Chaudhari, 2010), inadequate supply of quality seed; occurrence of pest (red ants, potato tuber moth and White grub) and disease especially late blight causes great damage in developing countries and low soil and nutrient management practices. Apart from other factors red ants (*Dorylus orientalis*) have been playing a significant role and have become serious to manage with some of the common chemicals and even with a single control method. Agriculture Research Station (ARS), Jaubari is located at an altitude of 2900 masl where potato were planted during February – March. Farmers in Jaubari used the local potato genotypes susceptible to insect pests and diseases problems with low production potentialities. Where red ant insect pest is major yield reducing biotic factors (ARS, 2019). In past, several hazardous chemicals pesticides were recommended for red ant management without considering its side effect to human beings and other living creatures. Since the government organizations have been playing a significant role in creating awareness against pesticides, present situation in Nepal is favorable for the initiation of traditional methods and practices for insect pest management. While, the use of the resistance/tolerant potato varieties is more stable, sustainable and cost-effective from the technical, ecological, economic and environmental view point. So, this study and works has been proposed to find out and disseminate resistance/tolerant potato varieties against potato pests. This could be a very useful tool for the research and extension for enhancing economic return of the high hill's community in the future.

MATERIALS AND METHODS

The experiments were conducted at Agricultural Research Station (ARS), Jaubari, Illam, Nepal during 2018 and 2019 to identify the appropriate potato cultivars for red ant management and the tuber yield of potato at the high hill of Ilam district. Eight different promising potato genotypes [1. BLR-20 2. PRP-296667.2 3. PRP-14267.11 4. PRP-8561.11 5. PRP-016367.7 6. PRP-16567.5 7. Khumal Seto (standard check and 8. Ilam local (Jhyale)] selected from diseased screening nursery were included in the study. Experiment was conducted in previously red ant infected potato field in Completely Randomized Block Design (RCBD) with three replications. The experimental plot size was 5.4 m^2 (3m x 1.8m) with 60 cm row to row and 25 cm plants to plant spacing accommodating 30 seed potato tubers per plot. The plots were fertilized with 100:100:60 kg NPK/ha and 20 t/ha compost. Well sprouted tubers size of 30-40 g were planted during the second week of February. The cultural operations were carried out as per the recommendation of National Potato Research Program (NPRP). Harvesting was done during the fourth week of July. Data taken were days to 50% emergence, ground coverage (%), number of main stem/plants, number of tubers per plant, red ant damage scoring (1-5 scale), red ant incidence (%), red ant infested yield (kg/plot), number of tubers/plant and total yield (kg/plot). Ground coverage was measure 100% when all the plants covers almost all the ground, then based on the canopy of plant to cover the ground percentage was estimated. Plant uniformity was observed in 1-5 scale, where 5 was given to almost uniform plants. Late blight scoring was done in 1-9 scale where 1 was given for no infection of disease (resistant) and 9 was given when the disease was observed up to stems i.e. highly susceptible. Similarly damaged of ant was measured as 1-5 scoring scale as; 1=No infestation to 5= severe infestation. The percentage of insects damaged potato tuber was calculated as follows:

$$Red\ ant\ incidence\ \% = \frac{No. of\ red\ ant\ infected\ tuber}{Total\ No\ of\ tuber} \times 100$$

The collected data were entered on MS-excel, calculated and data analysis was done using GEN-STAT software and mean separation was done by LSD at 5% level of significance.

RESULTS AND DISCUSSION

Yield attributing traits

The effect of promising potato cultivars on yield attributing traits is presented in table 1. Days to 50% emergence was found non-significant whereas ground coverage and main stem per plant was found significant in both the year. Days to 50% emergence ranges from minimum 62.00 days in Ilam local cultivar (Jhyale) to maximum 76.00 days in cultivar BLR-20 during 2018 and in 2019 it varies from minimum 64.00 days in same Ilam local (Jhyale) cultivar to maximum 77.00 days in cultivar PRP-016367.7. The results indicated that potato cultivar Ilam local (Jhyale) took short duration (62.00 – 64.00 days to 50 % emergence). Ground coverage and number of main stems per plant played significant roles for the tuber yield of potato. Maximum ground coverage percentage (86.18 % in 2018 and 84.76% in 2019) was observed from the cultivar PRP-16567.5 followed by the potato cultivar PRP-14267.11 (83.60 % in 2018 and 84.25 % in 2019). Number of main stems per plant was significantly highest (4.33 main stem number/plant) in the cultivar PRP-16567.5 during 2018 and 2019 followed by the potato cultivar PRP-14267.11 (3.66 main stem number /plant in 2018 and 4.33 main stem number /plant in 2019).

Table 1. Evaluation of elite potato cultivars on yield attributing traits of potato at ARS, Jaubari (2018 and 2019)

Treatments	Days to 50% emergence		Ground coverage (%)		Main stem # /plant	
	2018	2019	2018	2019	2018	2019
BLR-20	76.00	72.00	75.00	70.83	3.66	4.33
PRP-296667.2	74.00	76.00	74.73	73.15	3.33	3.66
PRP-14267.11	65.00	74.00	83.60	84.25	3.66	4.33
PRP-8561.11	65.00	66.00	73.80	74.89	3.66	3.66
PRP-016367.7	74.00	77.00	71.37	74.20	3.33	3.66
PRP-16567.5	69.00	68.00	86.18	84.76	4.33	4.33
Khumal Seto (standard check)	69.00	67.00	74.67	71.18	2.66	3.33
Ilam local (Jhyale)	62.00	64.00	60.24	62.85	2.66	2.66
GM	69.25	70.50	74.94	74.51	3.41	3.28
F-test	NS	NS	*	*	*	*
LSD 0.05	-	-	9.21	10.16	0.28	0.33
CV%	18.60	22.20	12.68	31.35	12.35	14.80

GM-Grand mean NS – Non significant * – Significant **– Highly significant

Plant uniformity, plant height and late blight scoring

The effect of promising potato cultivars on vegetative parameters such as plant uniformity and plant height as well as late blight scoring is presented in table 2. Plant uniformity (1-5 scale) of the tested potato cultivars in both the experimental year was found statistically at par with each other. However, it was ranged from 2.00 to 3.00 scoring scale in both the experimental year. Plant height of the tested potato cultivars significantly varies from shortest 32.01 cm to tallest 60.72 during 2018 and 28.25 cm shortest to 56.10 cm tallest in 2019. The potato cultivar PRP-14267.11 found tallest (60.72 cm) followed by PRP-16567.5 (59.40 cm), PRP-8561.11 (58.08 cm) and BLR-20 (57.20 cm) in 2018. During in 2019 potato cultivar PRP-16567.5 was found tallest (56.10 cm) followed by PRP-14267.11 (49.32 cm). Effect of potato cultivars were found highly significant (p=0.01) differ in late blight disease outbreak. The potato cultivars BLR-20, PRP-14267.11, PRP-8561.11 and PRP-16567.5 were found resistance (1 scoring scale in 1 -9 scale) to late blight disease in both the experimental year. The Khumal Seto (standard check) and Ilam local potato cultivars were found more (2.33 - 2.66 scoring scale in 2018 and 2.66 - 3.00 scoring scale in 2019 in 1-9 scale) susceptible to late blight disease.

1.1.1.1.1 Table 2. Evaluation of elite potato cultivars on plant uniformity, plant height and late blight scoring at ARS, Jaubari (2018 and 2019)

Genotypes	Plant uniformity (1-5 scale)		Plant height (cm)		Late blight scoring (1-9 scale)	
	2018	2019	2018	2019	2018	2019
BLR-20	2.66	3.00	57.20	32.65	1.00	1.00
PRP-296667.2	2.00	2.66	43.45	32.31	1.33	1.66
PRP-14267.11	3.00	2.66	60.72	49.32	1.00	1.00
PRP-8561.11	2.00	2.00	58.08	38.19	1.00	1.00
PRP-016367.7	2.66	2.00	38.17	31.30	2.00	1.33
PRP-16567.5	3.00	2.66	59.40	56.10	1.00	1.00
Khumal Seto (st. check)	2.66	2.66	37.95	31.18	2.66	3.00
Ilam local (Jhyale)	2.00	2.66	32.01	28.25	2.33	2.66
GM	2.49	2.53	48.37	37.41	1.54	1.58
F-test	NS	NS	*	*	**	**
LSD	-	-	13.62	7.18	0.96	1.08
CV (%)	27.45	24.90	17.71	20.45	56.38	49.35

GM-grand mean *– Significant **– Highly significant

Red ant damaged and infested yield

The effect of promising potato cultivars on red ant scoring, incidence and infested yield of potato is presented in table 3. The potato cultivars had significant effects on the red ant occurrence on 2018. The elite potato cultivar PRP-16567.5 had the lowest red ant score (1.0) scale, red ant incidence (0.33%) and less infected tuber yield (0.04 t/ha) respectively followed by the cultivar PRP-14267.11 (1.00 red ant score, 2.16 % red ant incidence and 0.33 t/ha red ant infected tuber yield) whereas the Ilam local (Jhyale) potato cultivar had the highest red ant infestation score (2.00), red ant incidence (10.85%) and the highest (2.05 t/ha) infested tuber yield. Similarly, the potato genotypes had significant effects on the red ant occurrence on 2019. The potato cultivar PRP-16567.5 had the lowest red ant score (1.0) scale, red ant incidence (1.66 %) and less infested tuber yield (0.22 t/ha) respectively followed by the cultivar PRP-14267.11 (1.00 red ant score, 2.00 % red ant incidence and 0.31 t/ha red ant infected tuber yield) whereas Ilam local (Jhyale) potato cultivar had the highest red score (1.66), red ant incidence (10.58%) and the highest (1.98 t/ha) infected tuber yield.

Table 3. Evaluation of elite potato cultivars on red ant damage, incidence and infested yield of potato at ARS, Jaubari (2018 and 2019)

Cultivars	Red ant scoring (1-5) scale		Red ant incidence %		Red ant infested yield (t/ha)	
	2018	2019	2018	2019	2018	2019
BLR-20	1.33	1.66	5.56	7.00	1.25	1.49
PRP-296667.2	1.33	1.33	5.38	4.54	1.56	1.28
PRP-14267.11	1.00	1.00	2.16	2.00	0.33	0.31
PRP-8561.11	1.33	1.66	5.59	7.70	1.20	1.81
PRP-016367.7	1.33	1.33	6.90	6.86	1.54	1.43
PRP-16567.5	1.00	1.00	0.33	1.66	0.04	0.22
Khumal Seto (standard check)	1.33	1.66	5.72	6.64	1.24	1.87
Ilam local (Jhyale)	2.00	1.66	10.85	10.58	2.05	1.98
GM	1.33	1.20	5.31	5.87	1.15	1.29
F-test	**	*	**	**	**	**
LSD	0.56	0.42	1.57	1.89	0.36	0.39
CV (%)	28.16	12.57	32.30	26.18	39.0	34.10

GM-grand mean *– Significant **– Highly significant

Maturity days, tuber number and tuber yield

The tuber number and tuber yield of tested elite potato cultivars is presented in table 4. The maturity days and number of tubers per plant of tested potato cultivars were found non-significant where as significant difference was recorded in tuber yield per hectare among the potato cultivars tested. Tuber number per plant varies from 7.00 to 11.00 in 2018 and 9.00 -12.00 in 2019. Significantly, maximum tuber yield (31.19 t/ha and 35.22 t/ha, respectively in 2018 and 2019) was recorded in PRP-16567.5 potato cultivar that was followed by PRP-14267.11 (27.27 t/ha and 27.67 t/ha, respectively in 2018 and 2019), BLR-20 (23.12 t/ha and 26.78 t/ha, respectively in 2018 and 2019) and PRP-296667.2 (22.94 t/ha and 26.28 t/ha, respectively in 2018 and 2019). Significantly lower yield was found in Ilam local (Jhyale) cultivar in both the year. It was observed as 14.94 t/ha and 13.18 t/ha respectively in 2018 and 2019.

Table 4. Evaluation of elite potato cultivars on yield of potato at ARS, Jaubari (2018 and 2019)

Cultivars	Maturity days		Tubers # per plant		Tuber yield (t/ha)	
	2018	2019	2018	2019	2018	2019
BLR-20	125.00	127.00	9.00	10.00	23.12	26.78
PRP-296667.2	125.00	127.00	9.00	11.00	22.94	26.28
PRP-14267.11	130.00	130.00	10.00	10.00	27.27	27.67
PRP-8561.11	129.00	130.00	7.00	9.00	20.84	24.73
PRP-016367.7	123.00	125.00	8.00	9.00	19.14	21.64
PRP-16567.5	130.00	128.00	10.00	11.00	31.19	35.22
Khumal Seto (st. check)	125.00	127.00	11.00	12.00	18.99	23.36
Ilam local (Jhyale)	123.00	125.00	10.00	9.00	14.94	13.18
GM	126.25	127.37	9.25	10.12	22.30	24.85
F-test	NS	NS	NS	NS	**	**
LSD 0.05	-	-	-	-	4.48	5.76
CV%	18.64	23.28	44.35	36.18	15.83	19.54

GM- Grand mean NS – Non significant * – Significant

The two-year study revealed that vegetative parameters: days to 50% emergence, ground coverage %, main stem number per plant, plant uniformity (1-5 scale), maturity days as well as tuber number per plant were found statistically non-significant with each other. Ground coverage %, main stem number/plant and plant height (cm) were found significant. Late blight disease scoring (1-9 scoring scale scale), red ant scoring (1-5 scoring scale scale), red ant incidence (%), red ant infested yield and tuber yield per hectare were found statistically highly significant. The significant variation in vegetative as well as yield parameters has been reported by different researchers (Khanal *et al*., 2017, Pant *et al*., 2017 and Upadhyay *et al*., 2017). Significant differences for almost all the vegetative as well as yield parameters showed the wider genetic diversity as well as variability and potentiality among the tested potato genotypes (Chapagain *et al*., 2014, Giri *et al*., 2016). Variation in plant uniformity (50 - 90%), ground coverage (50 - 95%), late blight score (1 – 8 scale in 1-9 scoring scale), red ant incidence (2 – 20%) and tuber yield (9.47 – 32.80 t/ha) were found among 84 potato genotypes tested in Agriculture Research Station, Jaubari, Ilam (ARS, 2017).

Damage of red ant was associated with the tuber quality and tenderness of the potato genotypes. The released potato cultivar Khumal Seto was found susceptible to late blight diseases (2.66 – 3.00 score in 1-9 scoring scale) and red ant insect pest (5.72 – 6.64 % red ant incidence) with comparatively low potato tuber yield (18.99 – 23.36 t/ha). The elite potato cultivar PRP-16567.5 had the lowest red ant score (1.00 scale), red ant incidence (0.33 – 1.66 %) and less red ant infected tuber yield (0.04 – 0.22 t/ha), respectively followed by PRP-14267.11 (1.00 red ant score, 2.00 – 2.16 % red ant incidence percentage and 0.31 – 0. 33 t/ha red ant infected tuber yield). The total yield was associated with size of the tubers and the losses caused by diseases and insect pests. Significantly, maximum tuber yield (31.19 t/ha – 35.22 t /ha) was found in PRP-16567.5 potato cultivar that was followed by PRP-14267.11 (27.27 – 27.67 t/ha) and BLB-20 (23.12 – 26.78 t/ha) potato cultivars. This indicates that potato cultivars PRP-16567.5 and PRP-16567.5 were found better from the red ant management and tuber yield point of view in high hill of Ilam district of Nepal.

CONCLUSION

The study concluded that the potato genotypes had played an influencing role on the yield attributing traits, insect pest occurrences and tuber yield of potato. Potato genotypes significantly affected the plant height, late blight damaged, red ant occurrence and damaged as well as the potato tuber yield. The potato cultivar PRP-16567.5 produced the lowest red ant score (1.00 red ant score in 1-5 scoring scale), less (0.33 – 1.66 %) red ant incidence percentage, minimum (0.04 – 0. 22 t/ha) red ant infected tuber yield and highest (31.19 – 35.22 t/ha) potato tuber yield followed by PRP-14267.11 (1.00 red ant score, 2.00 – 2.16 % red ant incidence percentage, 0.31 – 0. 33 t/ha red ant infected tuber yield and 27.27 – 27.67 t/ha potato tuber yield. Therefore, planting of PRP-16567.5 as well as PRP-14267.11

potato cultivars is appropriate for higher potato tuber yield and lower down red ant incidence at Jaubari area of Ilam district.

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ASSESSMENT OF CLIMATE CHANGE VULNERABILITY AND ITS IMPACTS ON SUMMER VEGETABLE PRODUCTION IN TRISHULI-NARAYANI RIVER CORRIDOR, NEPAL

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ABSTRACT

Climate change poses a significant threat to communities reliant on natural resources, particularly those dependent on agriculture. Summer vegetables, a major crop in Nepal, are acutely affected by changing weather patterns, impacting food security, income stability, and overall livelihood sustainability. This study employed a participatory approach to assess climate vulnerabilities and impacts on summer vegetable farmers in the Trishuli-Narayani River corridor. Using techniques like climate hazard ranking, seasonal vulnerability calendars, and forced field analysis, the study engaged 71 farmers from six sites across Chitwan, Dhading, and Nuwakot districts. The study identified location-specific vulnerabilities. Heavy rainfall emerged as the most concerning climate hazard for farmers in lower altitude areas (e.g., Chitwan), while heat stress posed the greatest threat at higher elevations (e.g., Dhading and Nuwakot). Furthermore, the study revealed that specific summer vegetables were perceived as more vulnerable than others. For instance, tomatoes were ranked as the most affected crop in Chitwan, while cucumbers were seen as highly susceptible to climate risks in Dhading and Nuwakot. A forced field analysis identified various factors contributing to vulnerability, with social factors (SF), physical factors (PF), and natural factors (NF) being the most prominent across the region. The level of vulnerability varied by district, with Chitwan exhibiting moderate vulnerability (NF=2.09, PF=2.51, SF=2.71), Dhading experiencing higher vulnerability (NF=3.13, PF=3.34, SF=2.55), and Nuwakot facing challenges driven primarily by economic and human factors (NF=2.29, PF=2.29, SF=1.88). Farmers have adopted various adaptation strategies to cope with these vulnerabilities. These strategies include afforestation within farms (a prominent practice in Nuwakot) (AF=5.31) and canal reconstruction (frequently implemented in Chitwan) (CR=3.26). However, the study highlights a gap between vulnerability scores and mitigation measures, suggesting a need for more robust adaptation strategies. The participatory approach employed in this study yielded valuable insights into the specific climate challenges faced by local farmers. This underscores the importance of engaging communities in climate change assessments and tailoring adaptation plans to address their unique needs. These findings not only contribute to a deeper understanding of climate change impacts on summer vegetable production in Nepal but also hold significant global implications for vulnerable regions facing similar challenges. The study emphasizes the urgency of proactive measures to navigate a changing climate and ensure the sustainability of agricultural livelihoods.

Key words Adaptation strategies, climatic hazards, participatory tools, vulnerability assessment

INTRODUCTION

The reality of climate change pervades everywhere, transcending myth and manifesting in every corner of the globe. Communities reliant on natural resources stand particularly vulnerable to its impacts (Kaushik & Sharma, 2015). Previous studies have demonstrated the profound effects of climatic abnormalities on vegetable cultivation (Potop et al., 2014). Intensified extreme weather events such as variations in rainfall, rising temperatures, and prolonged droughts threaten crop yields, alter pest and disease dynamics, and disrupt traditional farming practices (Grigorieva et al., 2023). Vulnerability refers to the susceptibility of a system or community to climate change impacts, including variability and extremes. It's a function of exposure (the nature and extent of climate variations experienced), sensitivity (the degree to which the system is affected), and adaptive capacity (the ability to cope with impacts) (Boureima et al., 2013; Füssel, 2009). Climate-sensitive sectors like agriculture face risks of land loss, livelihood disruption, and even loss of life (Tiani et al., 2015; van Aalst et al., 2008; Fakhruddin et al., 2020).

Summer vegetable production is directly affected by variations in rainfall, rising temperatures, droughts, and extreme weather events (Kumari et al., 2018). In

Nepal, summer vegetables are cultivated during the pre-monsoon and monsoon seasons, which generally span April, May, June and July. Erratic rainfall disrupts irrigation schedules and leads to water stress, while rising temperatures exacerbate heat stress in vegetables, affecting flowering, fruit set, and yield (Bisbis et al., 2018). Drought limit water availability and stunt plant growth, while extreme weather events like storms, hail, and pest outbreaks can damage crops and reduce yields (Kumar & Reddy, 2021).

Vulnerability is not just about natural hazards like floods and droughts, but also social factors like poverty and discrimination. It depends on exposure, sensitivity, and adaptive capacity. Exposure refers to the degree a system experiences hazards based on location (Hutton et al., 2011). Sensitivity is the degree to which the system is affected, while adaptive capacity is the ability to cope with impacts using available resources (Locatelli et al., 2008). Climate vulnerability is a complex phenomenon influenced by various factors, particularly livelihood resources such as economic, social, demographic, and political factors. Exposure, sensitivity, and adaptive capacity depend on access to and control over these resources. For instance, communities dependent on environmental resources like water, forests, and land are highly vulnerable when these resources are depleted. Economically disadvantaged people have fewer resources and alternatives to address climate impacts, increasing their vulnerability (Kaushik & Sharma, 2015). Social and demographic factors like strong social networks can also influence how communities cope with impacts. Infrastructure, policies, and institutions also play a role. Thus, it is important to learn and understand the diverse set of influences such as social, cultural, economic, institutional, political and psychological factors that support and enhance people's livelihoods (Tiani et al., 2015). Participatory assessments offer a valuable approach for communities, practitioners, and policymakers to gain firsthand insights into local climate challenges. This empowers them to advocate for and develop effective solutions (Hinds, 2013). This paper details a participatory assessment using the Participatory Climate Vulnerability Assessment (PCVA) methodology, specifically designed to examine climate vulnerabilities (Ahmed et al., 2012). The PCVA approach helps us understand how susceptible summer vegetable production is to climate impacts within the Trishuli-Narayani River corridor. Our objective is to explore and comprehend climate-related vulnerabilities within the study area and generate transferable knowledge applicable to similar regions.

MATERIALS AND METHODS

The study was conducted within the Trishuli-Narayani river corridor, encompassing three districts in Nepal: Chitwan (27.61°N, 84.88°E) located in the lowlands, Dhading (27.90°N, 85.19°E) in the mid-hills, and Nuwakot (27.68°N, 85.42°E) in the high hills. This variation in elevation, ranging from roughly 27.61°N to 27.90°N latitude and 84.88°E to 85.42°E longitude, plays a role in the climatic vulnerabilities experienced by farmers. For instance, lowland areas like Chitwan might face more intense erratic rainfall compared to higher elevations in Nuwakot (Rai et al., 2022; Luitel et al., 2020; Dandekhya et al., 2017). Climatic data was outsourced from Department of Hydrology and Metrology, Babarmahal, Kathmandu.

Participatory Climate Vulnerability Assessment (PCVA)

To assess the vulnerability of summer vegetable production to climate change, the study employed a PCVA approach across the three districts. PCVA aims to identify the weaknesses of the agricultural system in the face of a changing climate. Recognizing the complexities of climate change adaptation and vulnerabilities, the study utilized a multifaceted approach integrating various participatory tools (Moret 2014). These tools were used to assess the vulnerability components (Table 1).

A total of 71 summer vegetable farmers participated in the study from Chitwan, Dhading and Nuwakot, with a composition of 69% male and 31% female respondents. FGDs were conducted across six distinct locations, with two sites selected from each of the three districts. This approach ensured active involvement from diverse demographics within the communities, including the elderly, youth, women, and local ethnic groups. Various participatory tools were used to gather data and insights from farmers (Table 2).

Table 1. Vulnerability components and assessment tools

Vulnerability components	Assessment tool
Exposure	Seasonal vulnerability calendar
Sensitivity	Hazard ranking, ranking vegetables on climate risk
Adaptive Capacity	Force field analysis (identifying driving and counteracting forces

Table 2. Description of the methodology of the study

Participatory tools	Purpose	Method used
Problem ranking of climatic hazards and other abnormalities	Identify prominent climatic hazards	Farmers listed various problems affecting vegetables (e.g., windstorms, heat stress, high rainfall) and pairwise ranking identified the most severe hazard.
Seasonal vulnerability calendar	Understand vulnerabilities and coping strategies	Discussed risks and effects for each summer month (April-July) and farmers' adaptation strategies documented.
Ranking summer vegetable on the basis of climatic risk	Assess perceived vulnerability of different vegetables	Farmers ranked seven summer vegetables (1-7) based on perceived climate risk (1 = most sensitive)
Forced field analysis	Understand driving forces and counteracting measures	Listed driving vulnerabilities and counteracting measures based on farmers' perception and farmers ranked each factor (0-4) based on influence (0 = least, 4 = most).

(Adapted based on (Pangali Sharma et al., 2022); (Poudel et al., 2020) and (Dazé, 2014))

RESULTS AND DISCUSSION

Climatic trends of Chitwan

Based on the provided climate data for Chitwan district from 1989 to 2021 the average yearly temperature in Chitwan fluctuates around 24°C with no clear increasing or decreasing trend over the years yet the warmest year on record was 2021 (25.2°C) and the coolest was 2012 (22.3°C). Rainfall shows significant variation across the years, ranging from a low of 1209.3 mm (47.6 in) in 2019 to a high of 2644.9 mm (104.1 in) in 1998. Interestingly, four out of the last five years (2017-2021) have rainfall below the overall average, hinting at a possible decrease in recent years.

Climatic trend of Dhading

Based on the climate data for Dhading district from 1989 to 2021, Dhading district has an average yearly temperature of around 21°C. The hottest year was 2021 (22.9°C) and the coldest was 1990 (19.9°C). Rainfall in Dhading district is also highly variable, ranging from 979 mm (38.5 in) in 2015 to 3025.2 mm (119.1 in) in 1999.

Climatic trend of Nuwakot

Based on the data provided from 1989 to 2021, Nuwakot appears to have a temperate highland tropical climate with an average yearly temperature of around 22°C. The warmest year was 2021 (23.2°C) and the coldest was 2004 (21°C). Nuwakot exhibits similar variations in rainfall, with the lowest amount recorded in 2009 (880.3 mm) and the highest in 2000 (2572.7 mm).

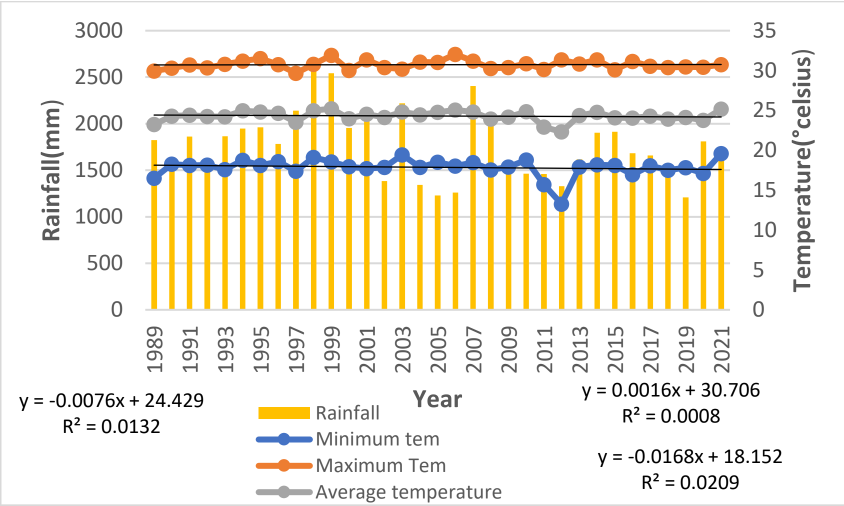


Figure 1. Annual temperature and rainfall of Chitwan (1989-2021)

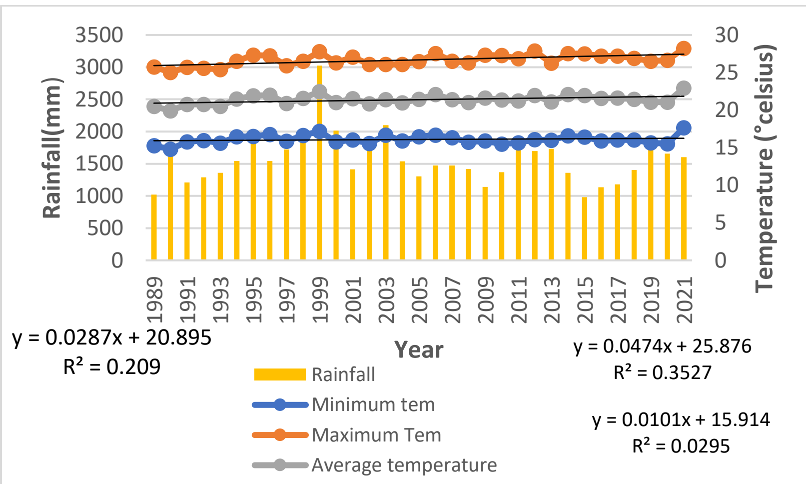


Figure 2. **Annual temperature and rainfall of Dhading (1989-2021)**

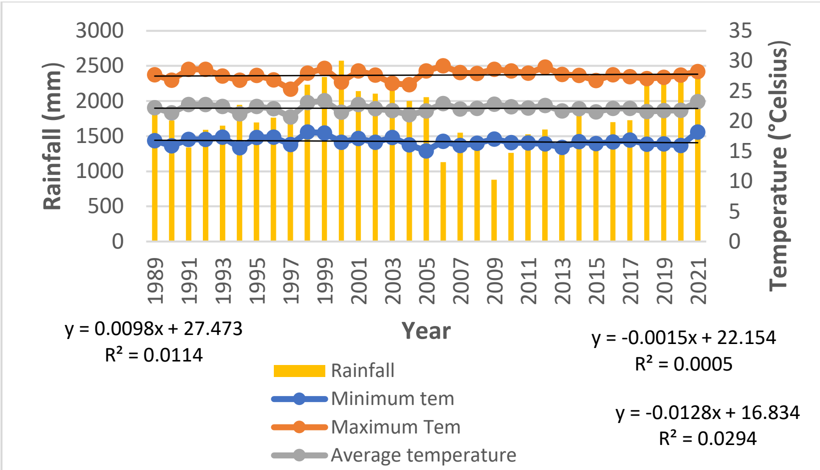


Figure 3. Annual temperature and rainfall of Nuwakot (1989-2021)

Problem ranking of climatic hazards and other abnormalities

The ranking of climatic hazards and other abnormalities varied across the three districts studied (Chitwan, Dhading, and Nuwakot) (Figure 4, Figure 5 and Figure 6), highlighting the location-specific nature of climate change impacts. In Chitwan, high rainfall emerged as the most concerning issue, followed by heat stress, windstorms, decreased pollination, soil erosion, new weed (e.g. *Mikania micrantha*) infestation, and finally insect and disease infestations. Dhading ranked heat stress as the most problematic, followed by high rainfall, soil erosion, windstorms, and then new weed infestation. Nuwakot identified heat stress as the most concerning climatic hazard, followed by soil erosion, insect and disease infestations, decreased pollination, new weed (e.g., *Parthenium hysterophorus*, etc.) occurrences, windstorms, and lastly high rainfall. In this study, high rainfall emerged as a major climatic hazard at lower altitudes, i.e., Chitwan, while heat stress due to climate change in summer vegetables was a major issue seen in higher altitudes, i.e., Dhading and Nuwakot.

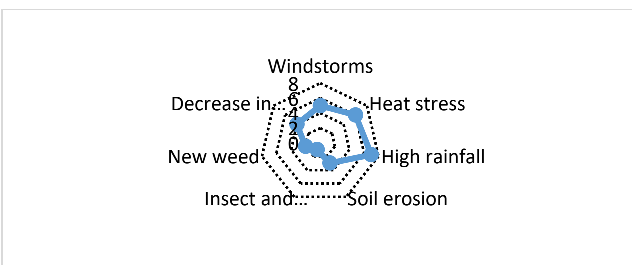


Figure 4. Climatic and other problems ranking of Chitwan district, Nepal

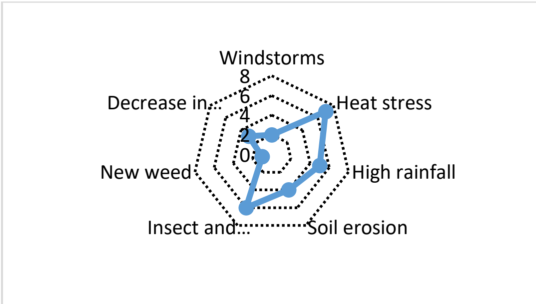


Figure 5. Climatic and other problems ranking of Dhading district, Nepal

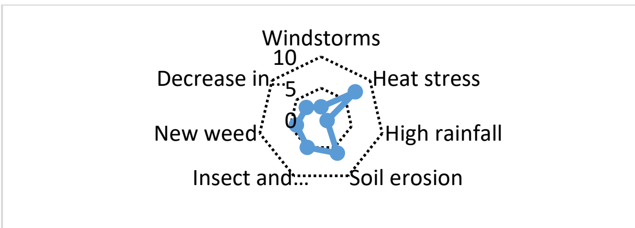


Figure 6. Climatic and other problems ranking of Nuwakot district, Nepal

Seasonal calendar

The seasonal calendars developed with farmers reveal the various challenges they encounter throughout the summer vegetable growing season, along with the coping strategies they employ (Table 3). In Chitwan, diverse insect infestations and adverse weather conditions necessitate interventions such as manual insect control, altering crop selection, and afforestation measures. Practices during dry periods include frequent irrigation, constructing boreholes, mulching, and implementing agroforestry and afforestation initiatives. During high rainfall periods, strategies include drainage, afforestation, riverbank embankments, and adjusting crop varieties. Farmers in Dhading address issues of drought and high temperatures accompanied by concerns about plant wilting and increased insect activity, through irrigation strategies, early harvesting, and cultivating resistant varieties. In Nuwakot, windstorms and drought in April and May necessitate increased irrigation and alternative water sources like boreholes and rainwater harvesting. By May to June, high temperatures become prominent, prompting measures like well construction and mulching. July brings waterlogging and insect infections, demanding drainage, pesticide use, and resistant crop varieties.

Farmers adjust their cropping calendars and interventions based on seasonal changes in response to climatic hazards.

Table 3. Seasonal calendar of climate hazards and adaptation measures in summer vegetable farmers in Chitwan, Dhading and Nuwakot districts of Nepal

District	Hazards and interventions	April	May	June	July
Chitwan	Hazards and impact	Painted Lady Butterfly caterpillar in bitter gourd, black cutworm in pumpkin, wind, hailstorm, risk of forest fire	Shield bug in sponge gourd, various insects in brinjal, dryness, low rainfall, hot winds on the farm	Black long worm affecting pumpkin roots, yellow worm in bitter gourd, dryness, wind, high temperatures	Flower wilting in bottle gourd, flood, landslide, high temperatures
	Adaptation interventions	Manual insect control, insecticide use, irrigation, weeding, fertilization, afforestation, forest fire awareness, crop variety adjustment	Manual insect control, crop variety adjustment, afforestation	Crop variety adjustment, proper irrigation, fertilization, afforestation	Crop change, afforestation, river management, riverside embankment
Dhading	Hazards and impact	Drought, high insect infection	Drought, high temperatures, plant wilting	High temperatures and plant wilting	Water logging, high insect infection
	Adaptation interventions	Increased irrigation frequency, pesticide usage or traps for insects	Irrigation, well construction, early harvesting, use resistant varieties	Early harvest, resistant varieties	Water drainage, pesticide usage, earthing up, resistant varieties
Nuwakot	Hazards and impact	Windstorms, drought	Drought, high temperatures	High temperatures	Waterlogging and high insect infection
	Adaptation interventions	Increased irrigation frequency, boring construction	Well construction, mulching	Irrigation	Water drainage, pesticide usage, insect-resistant varieties

These findings suggest that specific vegetables may require more targeted adaptation strategies in certain regions.

Ranking the effects of climate change in different summer vegetable

The pervasive negative impact of climate change is undeniable, exhibiting varied effects across different crops. The ranking of summer vegetables based on climate risk indicates the perceived vulnerability of different vegetables to climate change (Table 4). A within-study analysis showed that cucumber was perceived as the most severely impacted crop in Nuwakot and Dhading. Conversely, tomato was ranked as the most affected crop in Chitwan. Pumpkin, bottle gourd, and sponge gourd were seen as moderately affected by climate change. Interestingly, eggplant in Nuwakot, cucumber in Chitwan, and bitter gourd in Dhading appeared to be the least affected.

Table 4. Ranking of effects of climate change on different vegetables in Chitwan, Dhading and Nuwakot districts of Nepal

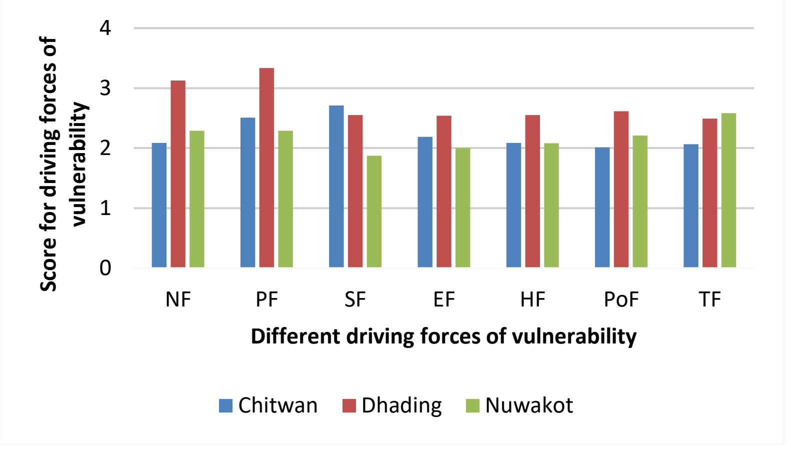
Study Area	Vegetables						
	Cucumber	Pumpkin	Bottle-gourd	Bitter-gourd	Sponge-gourd	Egg-plant	Tomato
Chitwan	7	3	4	5	5	2	1
Dhadhing	1	3	4	7	5	6	2
Nuwakot	1	3	2	6	4	7	5

Forced field analysis

The force field analysis identified various factors contributing to the vulnerability of summer vegetable farmers to climate change (Figure 6). Spanning Chitwan, Dhading, and Nuwakot districts, the study encapsulated seven distinct driving factors of climatic vulnerability. In Chitwan, a moderate level of vulnerability was identified, with social dynamics (high) and physical factors being the most prominent. The multifaceted nature of vulnerability in Chitwan is evident, with NF at 2.09, PF at 2.51, and SF at 2.71. This highlights the importance of strengthening community ties and infrastructure development in building resilience. Dhading exhibited higher vulnerability due to natural factors, physical factors, and social factors with NF at 3.13, PF at 3.34, and SF at 2.55. Technological factors and policy factors play a crucial role in enhancing resilience in this district with TF valued at 2.49 and PoF at 2.62. Vulnerability in Nuwakot stemmed from economic factors and human factors, along with moderate levels of natural and physical factors i.e. NF at 2.29, PF at 2.29, and SF at 1.88. Technological factors were identified as a key area for intervention. This analysis underscores the need for tailored adaptation strategies that address the specific vulnerabilities faced by farmers in each district, aligning with previous research on the intricate interplay of various factors shaping vulnerability.

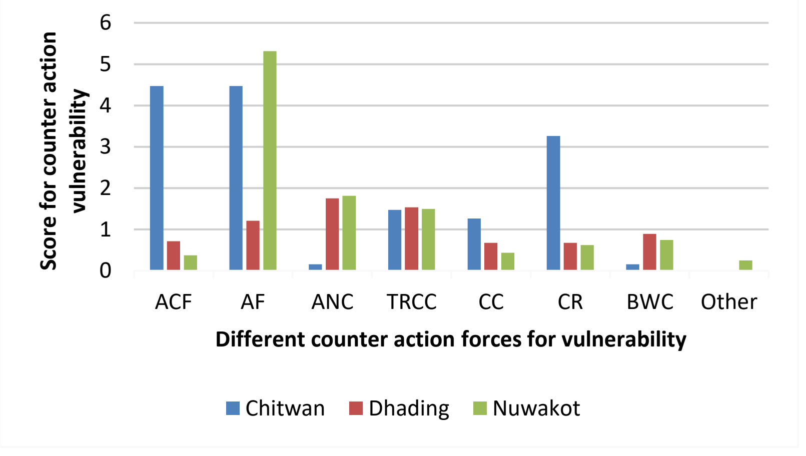
The study also explored the strategies employed by farmers to mitigate the vulnerabilities identified (Figure 8). In Chitwan, afforestation to control floods and canal reconstruction were the primary counteraction forces implemented to address social and physical factors with ACF recorded at 4.47 and CR at 3.26.

Dhading prioritized raising awareness of natural calamities and providing training related to climate change to counter the



Note: NF= Natural Factor, PF = Physical Factors, SF = Social Factors, EF = Economic Factors, HF = Human Factors, PoF = Policy Factors, TF= Technological Factors

Figure 7. Driving forces of vulnerability among summer vegetable farmers in Trishuli-Narayani River corridor, Nepal



Note: ACF= Afforestation to control flood, AF= Agroforestry in Farm, ANC= Awareness of natural calamities, TRCC= Training related to climate change, CC= Canal construction, CR= Canal reconstruction, BWC= Boring or well construction, Other = Other interventions

Figure 8. Counter action forces of vulnerabilities among summer vegetable farmers in Trishuli Narayani River corridor, Nepal

challenges posed by natural and economic factors. ANC is noted at 1.75 and TRCC at 1.54. Nuwakot's main strategies to address economic and human resource limitations were afforestation within farms and construction of boreholes or wells. AF stands at 5.31 and BWC at 0.75, highlighting the emphasis on environmental and infrastructural enhancements. These findings showcase the proactive efforts undertaken by farmers to build resilience against climate change.

DISCUSSION

This study provides a comprehensive understanding of the impacts on summer vegetable production in three different physiographic regions of Nepal. The participatory approach, involving 71 farmers, ensures the findings are grounded in the lived experiences of those directly affected by a changing climate.

Climatic trends and district variations

While all three districts face challenges, the specific climatic trends and their impacts vary. Chitwan exhibits a possible increase in temperature, potentially leading to heat stress for summer vegetables (Devkota et al., 2019). Declining rainfall patterns throughout the districts pose challenges for water availability (Rai et al., 2022). Nuwakot, being a highland district, might experience cooler temperatures compared to Chitwan, offering a potential advantage for heat-sensitive vegetables (Joshi and Joshi, 2017), however, the high variability in temperature and rainfall across all districts makes planning difficult for farmers, necessitating adaptation strategies.

Participatory tools and corroborating evidence

The study employed a range of valuable tools, including Climate Hazard Ranking, Seasonal Calendars, Vegetable Vulnerability Ranking, and Force Field Analysis. These tools facilitated the gathering of nuanced data and insights from the farmers themselves. For instance, the Climate Hazard Ranking identified drought, insect infestations, and heat stress as major concerns, which aligns with previous research (Pangali Sharma et al., 2022; Poudel et al., 2020). Similar studies documented these threats alongside soil erosion and hailstorms (Maharjan et al., 2017). Research by Malla (2008) further highlights the significant impact of humidity, rainfall, and temperature stress on pest and disease prevalence in Nepali agriculture.

Seasonal challenges and farmer adaptation

The Seasonal Calendars, co-created with farmers, reveal the diverse challenges encountered throughout the growing season and the coping strategies employed. This aligns with findings by Paudel et al. (2014), Dhanya & Ramachandran

(2015), and Launio et al. (2020), who documented farmers' adjustments to cropping calendars and interventions based on seasonal variations and vulnerability assessments. Notably, farmers themselves have observed significant changes in seasonal patterns over time, necessitating adjustments in management practices (Launio et al., 2020). Previous research supports this, highlighting how farmers adapt by modifying cropping calendars and interventions based on vulnerability assessments (Rahman et al., 2017) and employing diverse on-farm management practices (Pandey et al., 2015).

Vulnerability ranking and targeted interventions:

The ranking of summer vegetables based on climate risk emphasizes the perceived vulnerability of different vegetables. Similar findings from the Ganga River basin (Singh et al., 2021) indicate a spectrum of climate change impacts on various vegetables, underlining the need for specific adaptation strategies tailored to both crop and region. These findings underscore the urgent need for targeted interventions and policy measures to support vulnerable farming communities. Previous studies (Hoang et al., 2023; Darjee et al., 2023) emphasize the importance of strengthening community ties, infrastructure development, and raising awareness of climate threats. Additionally, providing training related to climate change adaptation strategies is crucial.

Force field analysis and tailored adaptation

The Force Field Analysis conducted in this study identifies various factors contributing to farmer vulnerability, including natural phenomena, social dynamics, physical limitations, and economic constraints. Similar to Luo et al. (2024), this study highlights the need for tailored adaptation strategies that address the specific vulnerabilities faced by farmers in each district. Parallel research by Luo et al. (2024) further corroborates these findings, highlighting natural phenomena like vegetation cover and humidity as significant drivers of vulnerability.

CONCLUSION

Recent warming trends, particularly in Chitwan, could lead to heat stress for summer vegetables, reducing yields and quality. Declining rainfall patterns throughout the district’s present challenges for water availability, potentially increasing irrigation needs and production costs. The significant variability in temperature and rainfall makes planning difficult for farmers. They need to adapt by using heat-resistant varieties, adjusting planting schedules, and employing water management practices like mulching or water harvesting. While Nuwakot's higher elevation might offer some advantage for heat-sensitive vegetables, targeted adaptation strategies are crucial considering the varying climate hazards across locations. The ranking of climate hazards varied across the three districts. Lower elevation areas like Chitwan faced more insect and disease issues, while higher elevations experienced greater heat stress. This emphasizes the need for geographically targeted adaptation strategies. Seasonal calendars revealed diverse challenges throughout the growing season, including water stress, pest infestations, and extreme weather events. Farmers adjust their cropping calendars and employ different interventions based on those changing vulnerabilities, demonstrating their capacity for adaptation. Ranking exercises showed that some summer vegetables were perceived as more vulnerable to climate change compared to others. For instance, cucumber was seen as highly vulnerable in Nuwakot disease and pest, while eggplant was considered less affected. This highlights the need for crop-specific adaptation strategies. The study also highlights the value of participatory tools in assessing climate change vulnerability. These tools facilitated a nuanced understanding of the challenges faced by farmers, enabling the development of tailored adaptation strategies. Overall, the study contributes to a deeper understanding of climate change impacts on summer vegetable production in Nepal and offers valuable insights for informing effective adaptation strategies at the local level.

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PERFORMANCE EVALUATION OF KIDS FROM PREGNANT DOES SUPPLEMENTED WITH MOLASSES MINERAL SYRUP

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ABSTRACT

Goats are vital to Nepal's agricultural economy, with their population witnessing significant growth in recent years. Among indigenous breeds, Khari goats are particularly valued for their reproductive efficiency and adaptability. However, nutritional deficiencies, especially during pregnancy, hamper their productivity. This study investigates the efficacy of molasses mineral syrup supplementation in addressing nutritional deficiencies during late pregnancy. The research, conducted over five months at the Goat Research Station in Bandipur, Tanahun, focuses on Khari does in their second parity. Three treatment groups were established: a control group receiving standard feed, and two groups supplemented with different doses of molasses mineral syrup. Key parameters including kid birth weight, growth rate, and milk production were evaluated to assess the impact of supplementation. Results indicate a clear association between molasses mineral syrup supplementation and improved performance indicators. Kids born to supplemented does exhibited higher birth weights, with increasing dosage correlating with greater gains. Similarly, growth rates were significantly enhanced in supplemented groups, highlighting the potential for improved productivity. Furthermore, dams supplemented with molasses mineral syrup demonstrated increased milk production, benefiting both offspring growth and overall herd productivity. The study contributes valuable insights for enhancing the nutritional management of pregnant does in Nepal.

Keywords: Khari goats, Molasses mineral syrup, late pregnancy, productivity

INTRODUCTION

Goats play a crucial role in the agricultural economy of Nepal, and their commercial significance has been steadily increasing in recent years. According to Ministry of Agriculture and Livestock Development, Nepal (2022), there are approximately 142.42 million goats in Nepal, a substantial increase from the mere 10.99 million recorded a decade ago in 2068. Among the indigenous goat breeds, the “Khari” breed stands out due to its better twinning ability, shorter age at puberty, and reduced kidding interval compared to other local goat breeds (*Tiwari et al*., 2013; Pokharel & Neopane, 2006). However, despite their importance, goats in Nepal face challenges related to under nutrition, especially in the context of limited animal feed availability.

Ruminant livestock production in developing countries heavily relies on locally available feeds, which often consist of crop residues and fodder. Unfortunately, these feed resources are frequently of poor quality and deficient in essential nutrients such as protein, vitamins, and minerals (*Hart et al.,* 2016). As a result, the productivity of goats remains suboptimal, affecting both meat and milk production.

During late pregnancy, the energy requirements of pregnant does increase significantly. This period is critical for the development of healthy kids and successful lactation (Sutton & Alderman, 2000). Young does have even higher energy demands during this phase. Addressing these nutritional needs is essential to enhance overall productivity and ensure the well-being of both the does and their offspring. It has been shown that restricting nutrition in goats during pregnancy induces various physiological, endocrinological, and behavioral abnormalities in both does and kids (*Laporte-Broux et al*., 2011; *Terrazas et al.*, 2012).

Molasses, a byproduct of sugar production, has gained attention as a potential dietary supplement for ruminant livestock. It offers a cost-effective way to improve feed palatability while providing essential energy and protein. *Osman et al.* (2020) conducted a seminal study focusing on Nubian goat kids, wherein they demonstrated the efficacy of molasses supplementation in enhancing growth performance, bolstering protein metabolism, and optimizing rumen fermentation. The inclusion of molasses in the diets of goats could be a practical solution to mitigate the effects of under nutrition and enhance overall performance.

Previous studies have highlighted the benefits of molasses supplementation in ruminant diets. *Senthikumar et al.* (2016) reported that molasses is suitable for all ruminant livestock and contributes positively to energy levels and protein intake. Additionally, it can serve as an effective feed additive to enhance palatability, encouraging better feed consumption.

Mineral deficiencies are a major limiting factor in the productivity of goats (*Tiwari et al.*, 2013). Addressing these deficiencies through appropriate supplementation could potentially improve reproductive outcomes and overall productivity. Thus, this research aims to evaluate the effects of molasses mineral syrup supplementation on key performance indicators such as kid birth weight, kid weaning weight, and milk production in late-pregnant Khari goats.

This study seeks to fill the knowledge gap regarding the nutritional management of pregnant goats in Nepal and provide evidence-based recommendations to enhance goat productivity. Through this research, we aim to contribute to the sustainable development of the goat farming industry in Nepal by improving the nutritional status and reproductive performance of Khari goats.

MATERIALS AND METHODS

Study site:
The study was conducted at the National Goat Research Program in Bandipur, Tanahun, Nepal.

Study duration:
The experimental period spanned five months, comprising two distinct phases: the pre-kidding phase, which lasted for two months, and the post-kidding phase, which extended for three months.

Species of animal involved:
The experimental animals were Khari does in their second parity.

Treatment groups and number of animals:
A total of 24 Khari does in late pregnancy were randomly assigned to one of three treatment groups, with eight does per group:

- **Control Group (T0):** This group received a concentrate feed at 1% of their body weight along with ad libitum access to seasonal fodder. This group served as the baseline for comparing the effects of the molasses mineral syrup.
- **Treatment 1 (T1):** In addition to the same concentrate feed and fodder provided to the control group, this group received an extra 25 ml of molasses mineral syrup daily.

- **Treatment 2 (T2):** This group was given the same concentrate feed and fodder as the control group, plus an additional 50 ml of molasses mineral syrup daily.

Molasses mineral syrup preparation:
The molasses mineral syrup was prepared by thoroughly mixing molasses, mineral mixture, and water in the proportions of 32%, 8%, and 60%, respectively. The ingredients were combined in a large mixing vessel and stirred continuously until a homogenous solution was achieved.

Recording of data:
Data collection focused on the following key parameters:

- **Kid Birth Weight:** Recorded immediately at birth.
- **Kid Growth**: Measured at 15-day intervals until the kids reached 90 days of age.
- **Milk Production:** Daily milk production of the does was monitored and recorded throughout the experimental period.

Data analysis:
The data collected were analyzed using the Analysis of Variance (ANOVA) technique with Microsoft Excel and Minitab 17. Treatment means were compared using the Least Significance Difference (LSD) test at a 5% significance level.

RESULTS AND DISCUSSION

The results from this study clearly indicate that supplementation with molasses mineral syrup significantly enhances both the birth weight and growth rate of kids, as well as the milk production of dams. Figure 1 describes the birth weight of kids born from dams

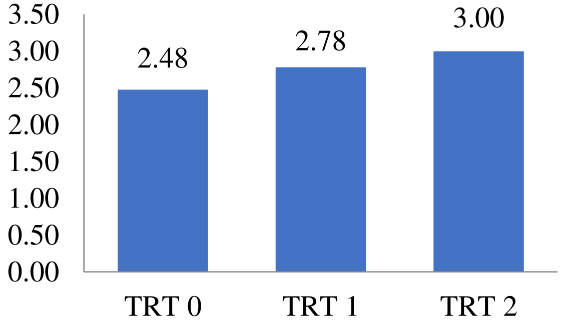

Figure 1: Birth Weight of kids born from the dams supplemented with Molasses Mineral Syrup

supplemented with molasses mineral syrup. The control group (T0), which received only a concentrate at 1% of body weight plus ad libitum seasonal fodder, had an average kid birth weight of 2.48 kg. The group supplemented with 25 ml of molasses mineral syrup (T1) had a higher average birth weight of 2.78 kg. The group receiving 50 ml of molasses mineral syrup (T2) showed the highest average birth weight at 3.00 kg. These results indicate that supplementation with molasses mineral syrup during late pregnancy positively influences the birth weight of kids, with higher supplementation levels leading to greater increases in birth weight. This finding is consistent with *Ghimire et al.* (2019), who reported that higher amounts of mineral supplementation during late gestation increase the birth weight of kids, leading to better growth outcomes. As shown in Figure 2, the body weight progression of kids over 90 days displayed significant differences among the treatment groups. Kids from does supplement with 50 ml of molasses mineral syrup (T2) consistently showed the highest body weights at each measured interval, followed by those supplemented with 25 ml (T1), and the control group (T0). By 90 days, the average body weights were approximately 10 kg for T0, 11.5 kg for T1, and 13.5 kg for T2. These findings highlight that higher levels of molasses mineral syrup supplementation positively impact the growth rates of kids, with the 50 ml dosage resulting in the greatest weight gain. This aligns with *Osman et al.* (2020), who demonstrated the efficacy of molasses supplementation in enhancing growth performance, bolstering protein metabolism, and optimizing rumen fermentation in Nubian goat kids. Similarly, *Malau-Aduli et al.* (2004) found that supplementation during the third trimester of pregnancy resulted in higher birth weights and three-month weights of kids.

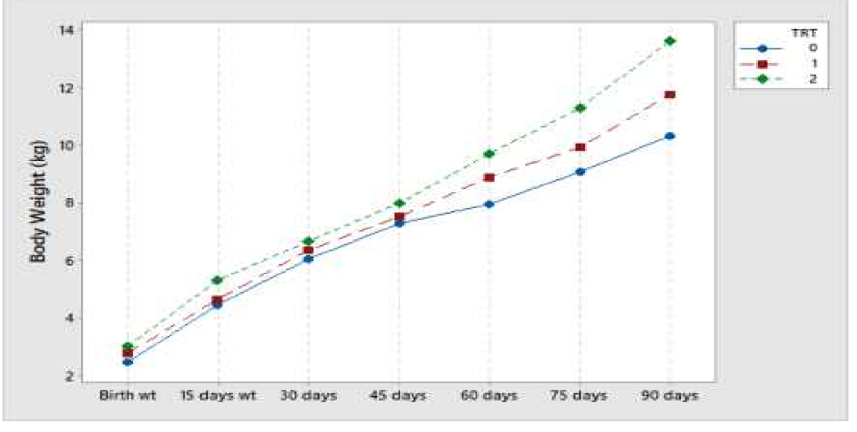

Figure 2. Body Weight of kids born from the dams supplemented with Molasses mineral syrup

Table 1 presents the body weight gain (kg) of kids born from the dams supplemented with molasses mineral syrup. The control group (T0) exhibited a total weight gain of 7.84 ± 0.55 kg. Kids supplemented with 25 ml of molasses mineral syrup (T1) had a total weight gain of 9.00 ± 0.55 kg, while those supplemented with 50 ml (T2) showed the highest total weight gain of 10.60 ± 0.27 kg. Noticeable differences in weight gain were observed particularly during the 45 to 60 days interval ($p < 0.005$), 75 to 90 days interval ($p < 0.005$), and overall, from birth to 90 days ($p < 0.001$). These findings underscore the significant positive impact of molasses mineral syrup supplementation on the growth of kids, with higher supplementation levels yielding greater weight gains.

Table 1. Body Weight gain (kg) of kids born from the dams supplemented with Molasses Mineral Syrup

Treatment	Kid Body Weight Gain (kg) from						
	Birth to 15 days	15 to 30 days	30 to 45 days	45 to 60 days	60 to 75 days	75 to 90 days	Birth to 90 days
T_0	1.99±0.25	1.58±0.16	1.24±0.28	0.69±0.27^{b}	1.11±0.26	1.22±0.26^{b}	7.84±0.55^{b}
T_1	1.85±0.27	1.73±0.19	1.18±0.19	1.34±0.20^{ab}	1.07±0.27	1.84±0.19^{ab}	9.00±0.55^{ab}
T_2	2.29±0.19	1.33±0.16	1.34±0.23	1.71±0.17^{a}	1.59±0.17	2.32±0.19^{a}	10.60±0.27^{a}
p value	0.428	0.289	0.879	0.009	0.227	0.005	0.001

Figure 3 presents a comparative analysis of the treatment's impact over the experimental period. The bar graph illustrates the weight gain of kids from birth to 90 days, divided into three intervals: 0-45 days, 45-90 days, and 0-90 days. The graph indicates that higher levels of molasses mineral syrup supplementation resulted in greater weight gains in kids. Kids in the TRT 2 group (50 ml supplementation) consistently showed the highest weight gain across all intervals, followed by TRT 1 (25 ml supplementation), and TRT 0 (control group). This trend is especially clear in the 45-90 days interval, where the weight gain difference between the groups is more pronounced. Overall, the data shows the positive impact of molasses mineral syrup on the growth of kids, with the highest supplementation level yielding the greatest weight gains.

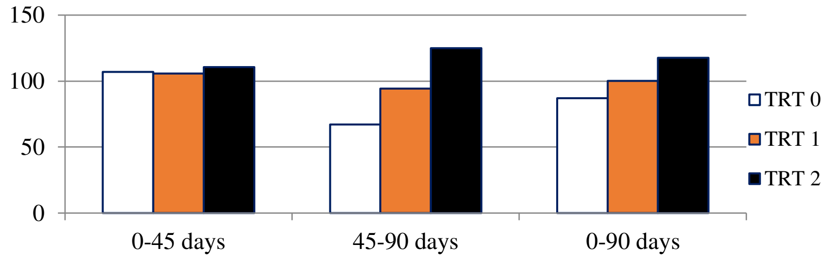

Figure 3. Average Daily Body Weight Gain (ADG, g/day) of kids born from the dams supplemented with Molasses Mineral Syrup

The table 2 presents the average daily milk production (in liters) of dams from birth to 90 days across three treatment groups (T0, T1, and T2). The data indicates a significant increase in milk production in the T2 group compared to T0 and T1 across all periods. The control group (T0) had a relatively stable production ranging from 1.06±0.05 liters in the first 15 days to 0.72±0.03 liters from 75 to 90 days. The T1 group, which received intermediate supplementation, showed an increase in milk production, starting at 1.20±0.06 liters and ending at 0.81±0.04 liters in the same period. The T2 group, receiving the highest supplementation, exhibited the most significant increase, with milk production starting at 1.46±0.09 liters and remaining at 1.04±0.08 liters by the end of the 90-day period. These trends were statistically significant, as indicated by the p-values provided ($p < 0.05$), suggesting a positive impact of molasses mineral syrup on milk production. These trends were statistically significant, as indicated by the p-values provided ($p < 0.05$), suggesting a positive impact of molasses mineral syrup on milk production. This finding is supported by *Mishra et al.* (2016) and *Tekeba et al.* (2013), who reported increased milk yield in cows supplemented with UMMB licks and blocks, as well as Mengistu & Waseyehon (2017), who found that UMMB supplementation increases production while maintaining animal performance and feed efficiency.

Table 2. Average daily milk production of the does supplemented with mineral molasses syrup

Treatment	Kid Body Weight Gain (kg) from						
	Birth to 15 days	15 to 30 days	30 to 45 days	45 to 60 days	60 to 75 days	75 to 90 days	Birth to 90 days
T_0	1.99±0.25	1.58±0.16	1.24±0.28	0.69±0.27^{b}	1.11±0.26	1.22±0.26^{b}	7.84±0.55^{b}
T_1	1.85±0.27	1.73±0.19	1.18±0.19	1.34±0.20^{ab}	1.07±0.27	1.84±0.19^{ab}	9.00±0.55^{ab}
T_2	2.29±0.19	1.33±0.16	1.34±0.23	1.71±0.17^{a}	1.59±0.17	2.32±0.19^{a}	10.60±0.27^{a}
p value	0.428	0.289	0.879	0.009	0.227	0.005	0.001

The graph in Figure 4 illustrates the cumulative milk production (in liters) of dams over a period of 90 days across three treatment groups (T0, T1, and T2). The x-axis represents the days post-birth, while the y-axis represents the cumulative milk production. The blue line shows the cumulative milk production for the control group. The line has a consistent upward slope, indicating a steady increase in milk production over time. However, it remains the lowest among the three groups throughout the entire period. Similarly, the red line represents the cumulative milk production for the intermediate treatment group. This group shows a higher cumulative milk production compared to T0, with a steeper slope indicating more rapid milk production. It consistently produces more milk than T0 from the start and continues to diverge slightly more as time progresses. Similarly, the green line depicts the cumulative milk production for the enhanced treatment group. This group shows the highest cumulative milk production among all groups, with the steepest slope. The production in T2 increases more rapidly and significantly outpaces both T0 and T1 as time progresses. Overall, Figure 4 clearly indicates that the dams in the T2 group, which received the enhanced treatment, produced the highest amount of milk over the 90-day period, followed by T1, and then T0. This suggests that the treatments had a positive effect on milk production. *Panadi et al.* (2018) also reported lower feed conversion ratios in goats supplemented with UMMB and MUMB, indicating efficient feed conversion to milk, consistent with the findings of this study. *Kawas et al.* (2010) and *Singh et al.* (1999) highlighted the benefits of multi-nutrient blocks based on molasses and urea, which stimulate rumen fermentation and supply necessary nutrients, complementing deficiencies in low-quality forages. This suggests that molasses mineral syrup may enhance rumen function and nutrient absorption, contributing to improved growth and milk production.

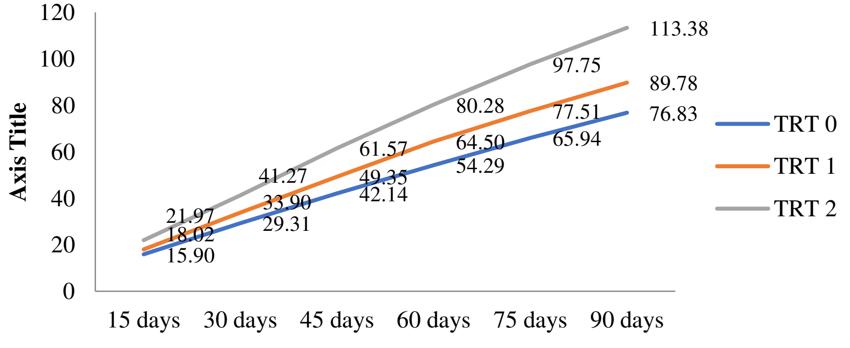

Figure 4. Cumulative milk production of does supplemented with mineral molasses syrup

The significant differences in weight gain observed in specific intervals (Table 1) suggest critical windows during which supplementation has the most pronounced effects. The 45 to 60 days and 75 to 90 days intervals showed noticeable differences, indicating these periods may be particularly sensitive to nutritional interventions. These findings suggest that targeted supplementation during these critical growth phases can optimize weight gain and overall development in kids.

CONCLUSION

This study demonstrated that molasses mineral syrup supplementation during late gestation period significantly improved the birth weight and growth rate of kids, as well as the milk production of dams. These results provided valuable insights for optimizing nutritional strategies in goat farming to enhance productivity and overall herd health.

The data suggested that higher levels of supplementation yield greater benefits, making a strong case for incorporating molasses mineral syrup into the feeding regimes of pregnant and lactating does.

Future research should explore the specific mechanisms through which molasses mineral syrup exerts these benefits, assess its long-term impacts on reproductive performance and overall animal health, and determine the optimal supplementation levels for different breeds and production systems.

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REVIEW ARTICLES

FOOD SECURITY AND CLIMATE CHANGE: A CHALLENGE TO HUMANITY

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ABSTRACT

This review presents issues of food security and climate change comprehensively as a global challenge**.** It discusses on global and local situations of food security and its components such as food production, food availability, food access and food utilization**.** This paper discusses on impacts of climate change on agricultural production as well as food security and livelihoods both at the global and local levels. Suggestions are made for climate- and disaster- resilient future of humanity at local and global levels.

Key words: Resilience, impacts, food price, food production, agriculture

INTRODUCTION

Commonly, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences. The ability of individuals to obtain sufficient food on a daily basis ensures food security. As stated by FAO two decades ago (2004) "food security exists when all people, at all times, have physical and economic access to enough, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy lifestyle". United Nations has declared food security as a human right. It is therefore the responsibility of all member states of the UN to develop and implement policies, legislation and programmes to ensure food security of its citizens. Food security is indispensable in all parts of the globe. Discussion should therefore begin with an analysis of the food security at national level. There are four interlinked components of food security, i.e. food production, food availability, food access and food utilization. These components should be addressed while analyzing food security situation in a given location from the household to community and national levels.

Food insecurity and malnutrition are impacted by climate change. During the last three decades, climate change is estimated to have caused at least 160,000 deaths and 5 million disability-adjusted life years from four factors alone: malnutrition, malaria, diarrhea, and flooding (Cohen, 2008). The most recent trends in agricultural production loss have been attributed to disasters across all agricultural sectors as reported by FAO (2021*)*. The report has covered 457 disasters in 109 countries across all regions and income categories. Income categories include, as mentioned by FAO (2021), the lower- middle- income countries (LMICs), upper-middle- income countries (UMICs) and the high-income countries (HICs). Of 457 disasters mentioned above, 389 disasters were reported to hamper agricultural production and consequently food security in LMICs.

1. FOOD SECURITY

1.1. Global scenario of food security

According to the World Resources Institute (WRI), global per capita food production has been increasing substantially for the past several decades. In 2019, an estimated two billion people in the world were food insecure, lacking regular access to safe, nutritious, and sufficient food (FAO, IFAD, UNICEF, WFP & WHO, 2020). Major drivers of food insecurity include economic conditions such as chronic poverty (Smith, El Obeid, & Jensen, 2000) and changes in food prices (Jolliffe, Seff, & De La Fuente, 2018), as well as non-economic factors such as rainfall instability, conflict, and disease (Hangoma et al., 2024).

In 2006, Microsoft National Broadcasting Company (MSNBC) reported that globally, the number of people who are overweight has surpassed the numbers who are undernourished – the world had more than one billion people who are overweight exceeded an estimated 800 million who were undernourished. According to a 2004 article from the BBC, China, the world's most populous country, is suffering from an obesity epidemic. Worldwide around 852 million people are chronically hungry due to extreme poverty, while up to 2 billion people lack food security irregularly due to varying degrees of poverty (FAO, 2003). According to the Food and Agriculture Organization approximately 868 million people were undernourished between 2010 and 2012 (FAO, 2012). About 852 million of these undernourished people lived in developing countries with over sixty per cent residing in South Asia and Sub-Saharan Africa (Cohen, 2008). These numbers were expected to increase as food yields potentially decline and production patterns shift as a result of climate change. In 2022, 2.5 billion adults were overweight, including 890 million who were living with obesity, while 390 million were underweight. Globally in 2022, 149 million children under 5 were estimated to be stunted (too short for age), 45 million were estimated to be wasted (too thin for height), and 37 million were overweight or living with obesity. Nearly half of deaths among children under 5 years of age are linked to undernutrition. These mostly occur in low- and middle-income countries (WHO, 2024).

1.2. Local scenario of food security in Nepal

Nepal is a least developed country (LDC) having a population of more than 28 million people. While food security in Nepal has improved in recent years, 3.86 million people (13.2 %) are food-insecure, with 3 percent of households did not have enough food; among these 66.3 percent reported that the situation was due to increasing prices of food Among all households, 78.2 percent listed increasing prices of food as a main concern (OCHA, 2022). Overall, households in rural areas of the country—where food prices tend to be higher—are more likely to be food-insecure than people living in urban areas, according to the survey.

Malnutrition remains a concern in Nepal. More than 40 percent of Nepalese children younger than five years of age are stunted and 10 percent suffer from wasting as a result of acute malnutrition, the UN World Food Program (WFP) reports. Pregnant and lactating women (PLW) also suffer from malnutrition, as well as micronutrient deficiencies. Approximately 1.4 million PLW are malnourished and 48 percent suffer from anemia, according to the UN agency (USAID, 2019).

Around 31 per cent people in the country live below poverty line. Around 49 per cent of under-five children are chronically malnourished. Globally, Nepal ranks 144th out of 182 countries in terms of its Human Development Index (UNDP, 2010). Annual population growth rate of the country is 2.2 per cent. It is estimated that the country's population in 2025 will reach 40.5 million; and will face difficulty to fulfill the food requirements. Looking at this scenario, Nepal will face serious food insecurity in future.

Nepal used to be a food exporting country before 1980 AD. Human Development Report has revealed that in the decades of seventies (NHDR, 1998) the rural communities in the Terai and Hills, particularly indigenous community had their dependency on forest products like food, fiber, utensil, medicine, fodder, mulch and so on in compliance of food security. However, forest coverage in the country is in declining trend, i.e. from 60 per cent in 1950s, 38 per cent in 1978/79 to 29 per cent in 2007.

In Nepal, mostly women are taking responsibilities of managing food security in their families. Recently, climate change has badly affected the agriculture production system and biodiversity conservation. It has directly affected women and children in having access to food. When the family faces problem of food insecurity male members uses to migrate to cities or countries for income generation, while women, elderly members and children stay at home. In that situation, women shoulder the responsibility of taking care of children and elderly members of the household performing on-farm activities, income generation and household chores. Obviously, women are hardly hit by the climate change indirectly.

1.3. Impacts of disaster on food security and nutrition

Disasters extend beyond the economic realm having deleterious consequences for food security and nutrition. For the first time ever, this edition of the FAO report (2021) converts economic losses into caloric and nutrition equivalents. For instance, it estimates that crop and livestock production loss in LDCs and LMICs between 2008 and 2018 were equivalent to a loss of 6.9 trillion kilocalories per year. This equals the annual calorie intake of seven million adults.

Access to adequate food and nutrition are fundamental human requirements for using human capacity. Food insecurity and inadequate nutrition lead to multiple negative consequences to health including high morbidity, high susceptibility to diseases and higher mortality. It however depends upon various factors. Food security has been analyzed in terms of existing agriculture systems including new agricultural techniques, introducing improved and climate resilience crop varieties, access of people to bio-gas, income, agriculture labor, land ownership, land management, food availability, food storage and preservation, nature of works, livestock, poultry, aquaculture, food and taboos, feeding time and caste system.

2. CLIMATE CHANGE

The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of its causes. The Inter-governmental Panel on Climate Change (IPCC) has defined climate change as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces or persistent anthropogenic changes in the composition of the atmosphere or in land use system (IPCC, 2007).

Climate change is the variability in average weather and ultimately a state of the climate system over a specified time frame. This variability is normally evidenced by changes in the mean temperature, precipitation, rainfall levels and amount of CO_2 in the atmosphere. Changes in climate can be caused by natural factors such as sun light intensity and volcanic activity among others or anthropogenic factors such as burning fossil fuels, deforestation, green house farming and other human activities.

Climate change is becoming the real threat to the lives in the world that largely affects water resources, agriculture, coastal regions, freshwater habitats, vegetation and forests, snow cover and melting and geological processes such as landslide, desertification and floods, and has long-term effects on food security as well as human health. According to FAO (2007) agriculture, forestry, and fisheries are highly sensitive to climate change; and climate change is very likely to have a serious impact on their productive functions. As a consequence, production of food, feed, fiber, energy, or industrial crops, livestock, poultry, fish and forest products may decrease.

2.1. Climate change patterns

- Changes in climatic events - rainfall, snowfall, temperature, attack of diseases, intensity of insects on crops are taking place all over the world.
- Changes are not similar in all places.
- Changes vary from one climatic zone to another.
- Weather events are changing in an unpredictable way.
- Sometimes, too much, too little, very early or very late, gaps in between, and so on.
- Seasonal pattern of weather events has been lost.
- Based on the broadest scale, the rate at which energy is received from the sun and the rate at which it is lost to space determine the equilibrium temperature and climate of the Earth. The energy is distributed around the globe by winds, ocean currents, and other mechanisms to affect the climates of different regions.

2.2. Impacts of climate change

Current conclusion of the IPCC (2007) regarding global climate change is as follows:

- Human activities are releasing greenhouse gases into the atmosphere.
- Rising levels of greenhouse gases are already changing the climate.
- Global temperature will likely rise by about 1.4 – 5.8°C by the year 2100

- Climate change is likely to have a significant impact on the global environment.
- Human society will face new risks and pressures on:
    - Food security
    - Water security
    - Physical infrastructures will be damaged.
    - Economic activities, human settlements, and human health will be impacted.
    - The poor and disadvantaged populations are the most vulnerable to these effects.
    - People and ecosystems will need to adapt to future climatic regimes.

Impact of climate change on livelihoods

a. Temperature increased

- Less moisture, less grass on grazing lands, less productive livestock in rangeland.
- Early harvesting of crops.
- Many new crops are possible but need other support.

b. Sea level raised

- Most affected are those whose houses are small.
- Service and working-class people are more vulnerable than others.

c. Snowfall – intensity, timing, and volume changed

- Glacier - rivers can be flooded at any time regardless of season.
- Settlements on riverbanks are more vulnerable.
- No or very less snow deposit on upland agriculture land results in less moisture on soil.
- Services from upland ecosystem reduced, possibility of desertification of upland higher.

2.3. Possible solutions of climate change

- Identification of complete solution is not possible.
- It is a global phenomenon with local implications.
- One country or one location alone cannot control the global phenomenon.

a. **Mitigation:** Preclusions before the incidents – minimize greenhouse gases, resettlements, climate friendly planning, and support system.
b. **Adaptation:** Long term thinking, planning, managing support system, changing practices permanently.
c. **Coping strategy:** Immediate action after the incidents – changing crops, changing practices, find out immediate temporary solutions to natural calamities.

3. SCENARIO OF CLIMATE CHANGE

3.1. Global scenario of climate change

As already mentioned above, the mean global surface temperature increased 0.74^{0} C during the 20^{th} century. Since 1971 rates of land surface temperature have been increasing at an alarming rate between 0.23 and 0.28^{0} C per decade. These continuing trends, coupled with changes in rainfall patterns and greater frequency of extreme weather events, are likely to have diverse effects on world population through declined agricultural and forest production and damaged wetland support systems. Glacier retreat and glacier Lake outburst flood (GLOF) are the most important and widely discussed issues as the potential risks. Compared to other sectors under impacts of climate change in Nepal, more studies have been carried out on glacier, their retreat and formation of glacial Lakes which are vulnerable to outburst. With melting of glaciers, risk of GLOF, water availability will rise and decrease sharply. It has effect on irrigation, power supply and aquatic ecosystem (IPCC, 2007). As global scenario of climate change, this situation is particularly applied in Nepal.

Effects of climate change on agriculture are particularly sensitive as the agriculture produces food and provides the primary source of livelihood for large portions of the society. Climate change influences crop and livestock production, hydrological balances, input supplies and other components of agricultural systems (Moench *et al.,* 2003). Agriculture, forestry, fisheries and wetlands are highly sensitive to climate change; and climate change is very likely to have serious impact on their productive functions. As a consequence, production of food, feed, fiber, energy, or industrial crops, livestock, poultry, fish, forest products and wetland services may decrease. Climate change has been affecting all dimensions of food security, namely food production, food availability, accessibility to food and food utilization. Climate change has also created risks to the food security of the large number of populations particularly in the least developed and developing countries in Africa, Asia and Latin America, where forest, wetlands, river, lake / sea and agriculture (including fishery) are the primary sources of food and nutrition as well as livelihoods.

Wetlands influence the climate as integral parts of river basins through their impact on the hydrological cycles at both global and regional scales, and through regulating the atmospheric chemistry to a disproportionate extent in terms of their area. Some wetlands sequester large amounts of carbon (mostly as peat but also in biomass) over very long periods (from centuries to millennia), whereas others produce significant amounts of methane and nitrous oxide. Thus, wetlands can both mitigate climate change and act as its drivers.

Climate change and its impacts on wetlands are poorly understood. Climate change has widespread impact on wetlands: small wetlands are drying up and disappearing. Obviously, climate change has direct impact on water resource. Permanent wetlands are getting transformed into seasonal ones due to greater variation in the water levels. Ultimately, biodiversity within the affected wetlands has been perished.

Higher maximum temperature, more hot days and heat waves could lead to increased heat stress and increased incidence of pest and diseases in many wetlands' plants and animals. Wetlands biodiversity and the wetland ecosystem services, which people depend on, are indeed under threat from the impacts of climate change. Though wetlands are the "victim" of climate change, the wetlands are at the same time crucial to mitigate climate change by reducing greenhouse gases. They have an important and underestimated role in both carbon storage and greenhouse gas regulation. The enhanced capability of wetlands to store carbon is largely a result of their productivity. Excluding peat lands, wetlands are among the most productive ecosystems in the world. Wetlands are often anaerobic, which greatly reduces the rate of decomposition relative to aerobic systems. Due to these facts, production usually exceeds decomposition in the wetlands, and results in the net accumulation of organic matter and carbon. Wetland ecosystems are essential and offer natural infrastructure for strengthening climate change adaptation. Wetlands can reduce adverse effects of climate change, such as food shortage, by providing vital biodiversity resources. Conversion of wetlands for other purposes, over exploitation of resources, pollution of water, excessive use of agrochemicals, invasion of alien species, encroachment for settlement and farming and sedimentation of the water bodies are some of the reasons behind the loss of wetlands. Climate change is becoming an added stress for wetlands in particular.

3.2. Scenario of climate change in Nepal

Climate change causes poverty, depletion of natural resources, and unsustainable management practices. There is a big gap in protected areas management with impact in ecosystem management. The nature of impacts however is complex because ecosystem components are interlinked. It is also very specific in local context. Nepal is one of the richest countries in terms of bio-diversity and unique geographical position in the world but it is one of the five most affected countries by climate change. With 5833 species of flowering plants, including about 248 species of endemic plants and 700 species of medicinal plants, Nepal's landmass is home to 26 species of mammals, 9 species of birds and 3 species of reptiles that are declared endangered; and are being protected by Nepalese laws (Dahal, 2008). Millions of people in Nepal are at risk from the impacts of climate change including reductions in agricultural production, food insecurity, strained water resources, loss of forests and biodiversity as well as damaged infrastructure (WBG, 2021). Therefore, these valuable species and resources need to be protected keeping in view the effects of climate change on landscape ecosystem and natural resources.

As mentioned above Glacier retreat and glacier Lake outburst flood (GLOF) are the most important and widely discussed issues as the potential risks. Compared to other sectors under impacts of climate change in Nepal, more studies have been done on glacier, their retreat and formation of glacial Lakes vulnerable to outburst. With melting of glaciers, risk of GLOF, water availability will rise and then decrease sharply, which will have effect on irrigation, power generation and aquatic ecosystem. This scenario of the impact of climate change is widely visible in Nepal. Nepal has observed the trend of annual increase in temperature per decade by 0.41^0C which is higher than the global average increase of 0.23 to 0.28^0 C per decade. The maximum temperature records from 1971-1994 in Nepal show a warming trend after 1977. Maximum temperature increased from 0.06 °C to 0.12°C/ year in most of the Middle Mountain and Himalayan regions whereas in the Siwalik and Terai regions, temperature seemed to be increasing by less than 0.03°C/yr. (Shrestha, *et al.,* 1999). Significant variability in precipitation was observed on annual and decadal time scales in Nepal but distinct long-term trends were not found (Shrestha*, et al.,* 2000). The Ijma Glacial Lake, second largest glacial lake in Nepal Himalayas lying at the height of 5000 m above average sea level, is one of the potentially dangerous glacial lakes. The size of Ijma Lake recorded in the year 2002 showed that the size of the lake expanded by 28 per cent as compared to its extent in the year 1992 (Rai, 2007). The effects of global warming and climate change are more vulnerable in the Himalayan region of the globe with melting of ice, glacier, and worst of the entire incidence if glacial lake outburst floods take place having devastating impact on eco-system. The effect of climate change is more acute in poor developing counties like Nepal.

Changes in rainfall patterns and occurrence of erratic monsoon precipitation, drought, and floods in the hills and serve cold winters in the terai have already been experienced and widely reported by farmers in Nepal (Rajbhandari and Shrestha, 2013b, Namita, 2014; Selvaraju, 2014). Agriculture is the source of income or livelihoods of two third population in Nepal (MoAD, 2022). Agriculture in Nepal is dependent on weather and climatic conditions. So, the economy of the country is more sensitive to climate change. Today rainfall starts earlier and ends late, as a result paddy planting month has been dry and late planting has resulted in reduced paddy yield. Farmers have been trying to adapt to the changing climate to maintain the yield of rice, the main staple food in Nepal. Nepali farmers have adopted measures such as conservation of local cultivars, alternative practices to reduce water stress, soil erosion, changes in cropping pattern and crop adjustments (Rajbhandari and Shrestha, 2014). Thus, it has become obligatory to find out and implement some effective adaptation strategies at the local level to cope with the climate variability and change as provisioned in agricultural development strategy (ADS) document (ADB 7762-NEP, 2013).

Climate change affects green sectors more than other sectors of the economy. Agriculture production depends on nature or rainfall and gets affected by the change in the climatic parameters such as extreme weather events. Geographic distribution of rainfall and snowfall and increased frequency, duration and intensity of droughts are also visible (FAO, 2004). Rajbhandari and Shrestha (2014) reported that the local climate at Rupa Lake area had changed over the past few decades; and as a direct consequence farming communities across the area were affected negatively. Similar results were reported by studies carried out in other parts of the country (Regi and Adhikari, 2007; Regi *et al.,* 2008; Gentle and Mareseni, 2012; Rai and Rajbhandari, 2013; Namita, 2014; Silvaraju, 2014). Vulnerability of the farming system in Nepal is very high to climate fluctuations. Droughts in 2006 resulted in an estimated reduction of 21 per cent in rice area planting due to low and uneven rainfall distribution during rice planting and early crop growth (Gumma, *et al.,* 2011). The 2008/09 winter drought in Nepal was one of the worst on record when rain monitoring stations across the country received less than 50 per cent of average precipitation during the period of November 2008 to February 2009 (MoAC; WFP; FAO, 2009). The drought resulted in a significant decrease in wheat and barley production, the two major winter crops, in the country with a decrease of 14.5 and 17.3 per cent, respectively compared to the previous year (MoAC; WFP; FAO, 2009). The interactions with local farmers in Makawanpur and Kaski districts revealed similar situation that productivity in the area was declining corresponding to extreme and unreliable weather conditions (Nepal, 2014; Rajbhandari and Shrestha, 2013).

Even a small variability in the climatic parameters like rainfall and temperature for a short period of few weeks or months could largely affect food production and thereby food security in most parts of the country. Local- level impacts such as loss of local land races, plant and animal species, changes in cropping patterns, scarcity of water due to drying up of wells/ decrease in natural water tables, decrease in agricultural productivity have been widely reported in Nepal. Moreover, during the last few years it has been observed that due to recurrent incidence of drought, flood, epidemic of disease and pests, and lack of adequate knowledge of coping mechanism among farmers, especially marginalized community and women; sometimes they lost their total crop production which they relied upon (Rajbhandari and Shrestha, 2013). The situation is becoming more alarming due to the insufficient research, documentation, early warning system, gaps in policies, weak implementation of existing policies and poor support mechanism like crop/livestock insurance policies and subsidies. Though Nepali farmers play a minor role in increasing GHGs globally, climate change has significantly affected their livelihoods and local natural resources available in their communities. Owing to this, farmers have followed some mitigation measures based on their indigenous local knowledge and traditional practices (Rajbhandari and Shrestha, 2014). They however lack strong climate change adaptation and mitigation strategies, which have further added to a range of factors that contribute to increased vulnerability and poverty.

Climate change is posing a threat at present and for future generation of our society. It has further threatened the food insecurity status of low-income strata people of Nepal. It has worsened the living conditions of especially resource-poor households dependent on subsistence farming, fisheries and forest resources. All of these factors have increased food insecurity. Rural communities, particularly those living in already fragile environments, have been facing an immediate and ever-growing risk of increased crop failure. It has caused loss of livestock, and reduced availability of forest products. Frequently more intense and extreme weather conditions have had adverse impacts on food production, availability, accessibility and supply in rural areas. That ultimately has magnified food insecurity.

CONCLUSION

The underlying causes of hunger, poverty and malnutrition in Nepal include low agricultural productivity, weak market connections and coordination, poor infrastructure and inadequate government resources. Gender, ethnicity and caste relationships also play an important role in food security as a majority of women and many marginalized group members, who often do not have access to their own land, cash or other assets, work in agriculture.

Despite many difficulties for agricultural production and value chain development, there are many opportunities for agriculture-led growth in Nepal to ensure food security. A climate smart multi-sector integrated and sustainable public-private partnership (PPP) approach should be implemented efficiently with people-the-first (PTP) policies to build and strengthen agri-business and market systems in Nepal.

LOOKING FORWARD: A DISASTER-RESILIENT FUTURE

Investing in resilience and disaster risk reduction, especially data gathering and analysis for evidence-informed action, is of pivotal importance for ensuring crucial role of agriculture in achieving a sustainable future with ensured food and nutrition security. Holistic responses and cross-sectoral collaboration are key in the disaster response. Countries must adopt a multi-hazard and multi-sectoral systemic risk management approach to anticipate, prevent, prepare for and respond to disaster risk in agriculture. Strategies need to integrate not only natural hazards, but also anthropogenic and biological threats, such as the COVID-19 pandemic, and must be based on an understanding the systemic nature and interdependencies of risks.

Innovations such as remote sensing, geospatial information gathering, drones and disaster robotics, and machine learning are powerful new assessment and data gathering tools that have much to offer in the quest to reduce disaster risks in agriculture. Moreover, there is a need of appropriate and effective GEDSI policies and programmes in each country to effectively address the impacts of climate change and food / nutrition security on women, and other disadvantaged groups of people.

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REVIEW ON SOIL BIOENGINEERING IN ADVANCING SUSTAINABLE LAND MANAGEMENT: INNOVATIONS AND CHALLENGES IN NEPAL

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ABSTRACT

In Nepal, a country profoundly vulnerable to natural disasters, the agricultural sector faces significant challenges due to landslides, floods, earthquakes, and extreme climatic events. These natural calamities, particularly acute in mountainous regions, exacerbate soil erosion, diminishing the fertility and integrity of topsoil. The monsoon season further intensifies these issues, leading to increased desertification and the transformation of fertile lands into riverbeds. This study delves into the role of vegetation in soil bioengineering as a sustainable solution to these challenges. It focuses on how plant roots anchor soil, reduce runoff, and bolster resistance against lateral earth pressures. Emphasizing the use of indigenous plant species for their multifunctional benefits, the paper explores specific plant requirements, prevalent bioengineering techniques, and successful initiatives within Nepal. However, it also identifies key challenges such as limited data availability, the specific applicability of techniques, and concerns regarding short-term structural integrity. The paper concludes by advocating for comprehensive, strategic bioengineering methods that integrate traditional knowledge and long-term monitoring, aiming to enhance Nepal's agricultural resilience against environmental adversities.

Key words: Agriculture, bioengineering, soil conservation, soil erosion, landslides

INTRODUCTION

Nepal, situated amidst the dynamic landscape of the Himalayas, is inherently prone to a variety of natural disasters. This susceptibility is heightened by its complex topography, vigorous river systems, and the annual cycle of monsoonal rains. Consequently, the nation frequently confronts devastating landslides, destructive floods, and seismic events such as earthquakes and avalanches (Tuladhar et al., 2015). These natural disasters have profound implications, particularly for the agricultural sector, which forms the backbone of Nepal's economy and sustenance.

Agriculture in Nepal, especially in its terraced mountainous regions, is severely impacted by soil erosion. Factors contributing to this erosion include rainfall-induced erosivity, inherent soil erodibility, and land management practices that often fail to counteract these natural processes (Koirala et al., 2019). The annual monsoon season exacerbates these challenges, leading to extensive land inundation and river course alterations. The resultant deposition of sand and debris not only contributes to the desertification of cultivable lands but also transforms fertile croplands into barren riverbeds, posing a significant threat to food security and livelihoods (MoFE, 2021b).

Particularly affected are the Siwalik Hills and the Terai belt, regions that face acute soil erosion and flooding issues. In the Siwalik Hills, the erosion rate is alarmingly high, compounded by the exploitation of natural resources such as riverbed materials, forest products, and timber, further destabilizing the landscape (Ghimire et al., 2013; The Kathmandu Post, 2019). The Terai belt, known for its fertile plains, confronts similar challenges, jeopardizing its agricultural productivity.

In this context, soil bioengineering emerges as a sustainable and ecologically sound approach to land management. By leveraging the natural properties of vegetation, soil bioengineering presents an innovative solution to mitigate the impacts of soil erosion and enhance agricultural resilience. This paper aims to explore the potential of soil bioengineering techniques in the Nepalese context, highlighting the role of indigenous plant species and the integration of traditional knowledge with modern practices for sustainable land management. Future studies should focus on collecting region-specific data to tailor bioengineering practices to Nepal's diverse geographical areas. Recognizing the need for region-specific approaches, this paper will explore the application of soil bioengineering techniques tailored to Nepal's diverse landscapes. Additionally, it will consider the economic impacts of these practices and the importance of integrating them with traditional agricultural methods.

ROLE OF VEGETATION IN BIOENGINEERING

Vegetation is the assemblage of plant life in a particular area. It encompasses all the plants, from robust trees to tiny mosses, that call that place their habitat. It's not just about the diversity of plant species, but also their abundance, their arrangement, and how they interact with each other and the environment. The key aspects of vegetation are species diversity, plant community structures like trees, herbs, shrubs, fungus, and the presence of different layers like canopy, understory, and underground. Vegetation plays key ecological functions like nutrient recycling, water cycle, microclimate and climate regulations, and habitat provision for heterotrophs like insects, birds, and mammals. Vegetation assumes vital roles in soil formation, hydrological characteristics, and engineering function.

Vegetation cover significantly improves the predictability of the relationships between soil health, soil loss, and rainfall characteristics, emphasizing the importance of maintaining ground cover to minimize runoff and erosion (Gardner and Gerrard, 2003). Plant roots act as essential anchors, firmly holding surface soil and preventing them from being easily eroded (ICIMOD, 2012). Plants and soil have mutual benefits against each other. By reinforcing the soil, plant roots increase their shear strength. Large and mature plants provide support against lateral earth pressure, preventing the outward movement of slope materials (ICIMOD, 2012). Moreover, the plant cover acts as a protective shield by absorbing the kinetic energy of raindrops, mitigating their erosive impact on the surface (ICIMOD, 2012). Plants also play a role in absorption, drawing up water from the ground, which helps maintain optimal soil moisture levels and reduces the risk of soil saturation and slope failure. Infiltration, facilitated by plants and their residues, maintains soil porosity and permeability, delaying the onset of runoff (ICIMOD, 2012). Furthermore, plants engage in evapotranspiration, a process where they absorb water through their roots and release it into the air, contributing to a balanced moisture level in the ecosystem (ICIMOD, 2012). Further research is needed to evaluate the long-term sustainability and maintenance requirements of these bioengineering methods in various Nepalese ecosystems. Considering these roles, future research should also assess the long-term sustainability and maintenance requirements of vegetation in bioengineering, ensuring that these natural systems continue to support soil health over time.

PLANT REQUIREMENTS FOR BIOENGINEERING

The importance of plants and vegetation and their roles in soil bioengineering is categorically summarized below.

Sturdy, numerous, and flexible stems for structural robustness and resilience.
Possessing the capability to recover from damage, ensuring long-term effectiveness.
Demonstrating a dense vegetation cover that bolsters protection against erosive forces.
Maintaining a low canopy and small leaves to optimize erosion control efficiency.
Displaying strong, fibrous roots that contribute significantly to erosion resistance.
Cultivating deep roots, characterized by strength and vertical orientation, enhances overall stability.
Possessing an extensive, deep, and wide-reaching root system that further fortifies erosion control capabilities.

(Source: ADB, Bioengineering for Green Infrastructure, 2020)

It is vital to integrate these bioengineering strategies with traditional agricultural practices, aligning modern techniques with the rich local knowledge of Nepal's farming communities. Integrating these plant characteristics with Nepal's traditional agricultural practices can create a synergy between modern bioengineering and time-tested local knowledge, leading to more sustainable land management solutions.

SELECTION OF PLANT HABITS AND SPECIES FOR BIOENGINEERING

Employing indigenous plant species in bioengineering is advisable due to their inherent adaptation to local growing conditions, increased resistance to regional diseases, greater availability, and potential cost-effectiveness (ICIMOD, 2012). Additionally, selecting species that serve different purposes as bearing fruit, and providing firewood, fuel, and timber can enhance the benefits (ICIMOD, 2012).

An economic analysis is essential to understand the cost-effectiveness of these bioengineering practices and their potential impact on Nepal's agricultural economy. To fully realize the potential of these species, a detailed economic analysis is necessary to evaluate the cost-effectiveness and potential economic benefits of employing indigenous plant species in bioengineering, particularly in enhancing Nepal's agricultural productivity.

Some commonly used plants for bioengineering techniques in Nepal are given below:

Grasses	Vetiver grass (*Chrysopogon zizanioides*) Napier Grass (*Pennisetum purpureum*) Buffel Grass (*Cenchrus ciliaris*) Amliso (*Thysanolaena maxima*) Dubo (*Cynodon dactylon*) Kans (*Saccharum spontaneum*) Setaria (*Setaria anceps*) Molasses (*Melinis minutiflora*) Stylo (*Stylosanthes guianensis*) Nigalo Bans (*Drepanostachyum intermedium*) Phurke (*Arundela nepalensis*) Padang Bans (*Calamus hookerianus*) Khar (*Cymbopogon microtheca*) Narkat (*Arundo donax)* Babiyo (*Eulaliopsis binate*) Sito (*Neyraudia arundinacea*) Bluegrass (*Poa pratensis*)
(Source: Amatya and Shrestha, 2002 cited in Kafle et.al.,2005)	
Shrubs	Bains (*Salix tetrasperma*) Bhujetro (*Butea Minor*) Dhanyero (*Woodfordia fruticosa*) Namdi Phul (*Colquhounia coccinea*) Tilka (*Wendlandia puberula*)
Trees	Chilaune (*Schima wallichii*) Khayer (*Acacia catechu*) Lankuri (*Lagerstroemia parviflora*) Sisau (*Dalbergia sissoo*) Uttis (*Alnus nepalensis*) Bakaino (*Melia azedarach*)

(Source: Howell 1999b; Devkota and others, 2006, cited in Dhital et.al, 2012)

COMMON BIOENGINEERING TECHNIQUES

Soil bioengineering employs a variety of techniques utilizing living plant materials to address challenges such as soil erosion, slope instability, and ecological restoration. Key methods include:

- Brush Layering: This involves strategically placing live branches or cuttings along slopes. It's a method to promote root growth and enhance slope stabilization.
- Live Fascines: This technique involves bundling live or freshly cut branches to form barriers, crucial for slope stabilization and erosion prevention (Franti, 2013).
- Planted Pole Walls: In this approach, poles like larch are used to support the growth of deciduous trees, aiding in the gradual correction of soil movement.
- Live Slope Grids: Comprising vertical and horizontal logs nailed together and filled with live branches and soil, these grids create a dense vegetation cover for effective erosion control (Florineth and Christoph, 2023).
- Live Wooden Crib Walls: Constructed from logs and anchor logs, these structures provide immediate support for stabilizing slopes (Florineth and Christoph, 2023).
- Vegetated Stone Walls: Incorporating live plants into the joints of stone walls, this method is adaptable to various angles and is effective in stabilizing the lower parts of slopes (Florineth and Christoph, 2023).
- Vegetated Gabions: Consisting of wire mesh filled with plant materials, these structures offer flexible and efficient solutions for slope stabilization and drainage improvement.

Other techniques such as jute netting, bamboo fencing, and Sloping Agricultural Land Technology are also employed based on specific requirements. These diverse bioengineering techniques capitalize on the natural strength of plants to reinforce soil structures, combat erosion, and support sustainable environmental stewardship. The selection of a particular technique is guided by factors including the characteristics of the slope, soil composition, and overall project goals. Further studies should examine the impact of these bioengineering techniques on local biodiversity, ensuring ecological balance is maintained. Given the diverse range of techniques available, further studies are needed to assess their impacts on local biodiversity and ecological balance. This will ensure that bioengineering practices contribute positively to the environment while achieving their intended goals.

Figure 1. Bamboo Fencing (Source: Anil Gautam) 2. Jute Netting (Source: Sandbag) 3. Brush Layering (Source: LaRiMiT)

NOTEWORTHY SOIL BIOENGINEERING INITIATIVES IN NEPAL

Several noteworthy soil bioengineering initiatives in Nepal have demonstrated the effectiveness of using vegetation for soil stabilization and erosion control:

Siwalik Hills Initiative: A study in the Siwalik region of Nepal revealed significant stabilization of ephemeral stream banks within three growing seasons. The use of vegetative check dams led to a natural coverage of shrubs and grasses over previously bare ground, showcasing their superiority in controlling soil erosion and managing floods compared to traditional mechanical stream bank stabilization methods (Dhital and Tang, 2015).

Lalitpur Landslide Management: In a landslide-prone area of Lalitpur, the implementation of vegetated bamboo crib walls was observed to be highly effective. Within two monsoon cycles, these structures not only remained intact but also supported the vigorous growth of vegetation, resulting in minimal soil erosion over three years. This case study underlines the success of soil bioengineering in managing shallow slope instabilities in Nepal's Middle Mountains (Acharya, 2020; Lammeranner, Rauch, and Laaha, 2005).

Dipayal Mallekh Road Project: This project in Nepal is notable for its efficient application of soil bioengineering techniques to strengthen roadside slopes and mitigate erosion while preserving the local environment. Utilizing indigenous plants and simple bio-structural measures offers a viable and practical solution for sustainable roadside soil management (Ojha and Shrestha, 2008).

Krishnaveer Soil Bioengineering Program in Dhading: This program stands out for its efforts in curbing soil erosion and environmental degradation. By integrating native vegetation and modest bio-structural interventions, it has successfully stabilized slopes, controlled erosion, and fostered biodiversity. The program exemplifies a harmonious combination of traditional practices with basic bioengineering, serving as an exemplary model for small-scale soil management endeavors. The success of these initiatives also depends on addressing policy and implementation challenges, including community acceptance and governmental support. These initiatives highlight the need for policies that support bioengineering methods and their acceptance by local communities. Understanding and addressing these policy and implementation challenges will be crucial for the broader adoption of soil bioengineering practices in Nepal.

LIMITATIONS OF SOIL BIOENGINEERING

While soil bioengineering has made significant strides in habitat restoration and damage recovery, it is important to acknowledge its limitations:

- **Data Gaps**: There is often a lack of comprehensive data regarding soil characteristics, climatic conditions, and vegetation types. This gap poses challenges in designing and implementing effective soil bioengineering solutions that are tailored to specific environmental needs (Simon and Steinemann, 2000).
- **Limitations of Conventional Methods:** The effectiveness of soil bioengineering can be constrained by the limitations inherent in traditional erosion control methods. This restricts the scope of these solutions in complex environmental scenarios (Simon and Steinemann, 2000).
- **Applicability Concerns**: Soil bioengineering may not be universally suitable, especially in areas facing severe erosion or landslide risks. In such extreme cases, the effectiveness of bioengineering approaches can be limited (Lewis, 2000).
- **Structural Challenges**: Bioengineering projects can face short-term challenges, such as the potential for damage or failure of the structures soon after installation. This can undermine the immediate effectiveness of these interventions (Simon and Steinemann, 2000).

- **Soil Saturation Issues:** The growth of roots in deep soil layers can be hindered by anaerobic conditions in consistently saturated soils. Therefore, implementing proper drainage measures is crucial for the success of these bioengineering projects (Bischetti et al., 2021).
- **Monitoring Deficiencies:** A lack of adequate long-term monitoring can adversely impact the performance and effectiveness of soil bioengineering projects. Continuous oversight is essential to ensure the long-term success of these interventions (Mickovski and Slobodan, 2021).
- **Strategic Framework Shortcomings**: The absence of a comprehensive strategic framework for soil bioengineering hampers its broader adoption as a sustainable solution to combat climate change and other environmental challenges (Mickovski and Slobodan, 2021).

Soil bioengineering projects, exemplified by initiatives such as the Krishnaveer Soil Bioengineering Program, demonstrate the success of employing vegetation-based techniques for ecological restoration, particularly in stabilizing stream banks and landslide-prone areas. However, this field faces certain gaps and challenges. Notably, there is a need for more comprehensive data regarding the interaction between soil physics and vegetation, which is critical for tailoring bioengineering solutions to specific environmental contexts. Additionally, the absence of a well-defined strategic framework for implementing these practices limits their broader application and effectiveness, particularly in addressing the impacts of climate change.

These limitations highlight the need for enhanced research, better data collection, and the development of more robust frameworks to maximize the potential of soil bioengineering in diverse ecological contexts. There is a need to adapt these bioengineering practices to the emerging challenges posed by climate change, ensuring their effectiveness in a changing environment. To overcome these limitations, it is imperative to adapt bioengineering practices to the challenges posed by climate change. Developing a strategic framework that encompasses these adaptations will be crucial for the future success of bioengineering in Nepal.

CONCLUSION

In conclusion, the application of vegetation in soil bioengineering stands out as a pivotal element in addressing various environmental and infrastructural challenges, including habitat destruction, land degradation, civil engineering problems, and associated economic impacts. The ability of plant roots to anchor soil effectively combats erosion, while the overall vegetation cover plays a crucial role in reducing surface runoff. The strategic selection of indigenous plants, particularly those with multiple functions, is vital for adapting to local environments and reducing the introduction of invasive species.

Moreover, sustained success in soil bioengineering requires continuous monitoring and assessment of projects to ensure long-term viability and adaptability. The integration of local plant species and the incorporation of traditional land management practices with contemporary bioengineering methods offer practical solutions, especially for small-scale soil management endeavors.

Looking ahead, adopting a holistic and strategic approach to vegetation-based soil bioengineering is imperative. Such an approach should not only focus on immediate ecological benefits but also consider the long-term resilience of Nepal's diverse and fragile landscapes against the increasing threats posed by climate change and other environmental challenges. This comprehensive strategy would better equip Nepal to protect and sustain its natural resources, ensuring environmental stability and the well-being of its communities. Future research should also include a comparative analysis with alternative soil conservation methods to assess the relative effectiveness of bioengineering techniques. The implementation of these techniques should be accompanied by robust training and capacity-building programs for local communities and practitioners. Future publications should aim to include quantitative metrics or case studies to demonstrate the tangible impacts of bioengineering on soil stabilization and agricultural productivity in Nepal. The future of soil bioengineering in Nepal also hinges on comparative analyses with other soil conservation methods, offering insights into the most effective practices for different environments. Moreover, establishing robust training and capacity-building programs for local communities and practitioners will be essential. Such efforts, combined with quantitative assessments of bioengineering's impact on soil stabilization and agricultural productivity, will provide a clearer picture of the effectiveness of these techniques in Nepal's unique landscapes.

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