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ASSESSMENT OF CLIMATE-FRIENDLY PRACTICES ADOPTION IN DAIRY CATTLE FARMING IN BAGAMATI PROVINCE

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ABSTRACT

The dairy sector plays a central role in rural livelihoods, but it is increasingly exposed to climate related risks. The adoption of climate-friendly practices (CFPs) may help improve farm resilience while reducing emission intensity from dairy production. This study assessed the adoption of CFPs among 198 dairy cattle farmers selected from Chitwan, Dhading, and Makwanpur districts of Bagamati Province, Nepal. The study found that 59.60% of farmers reported familiarity with the term climate change, whereas 92.42% perceived climate related impacts on dairy farming after the concept was explained. Adoption was high for improved breeds (100.00%) and artificial insemination (96.46%), but low for silage making (14.65%), biogas use (24.24%), and manure composting (8.59%). Based on the adoption score, 55.35% of farmers were categorized as medium adopters, followed by low adopters (24.75%) and high adopters (19.70%). These findings suggest that farmers more readily adopt practices with immediate production or herd health benefits, whereas technically demanding or capital-intensive practices remain less common. The results indicate the need for stronger extension support, practical training, and clearer promotion of underused CFPs. Because the analysis is descriptive and cross sectional, the findings should be interpreted as patterns of adoption rather than casual relationships.

Keywords: Climate-smart agriculture, Greenhouse gas emission, Low emission strategy, Heat stress

1. INTRODUCTION

Climate change is causing a negative impact to global agricultural systems, affecting food security and livelihoods of people (IPCC, 2022). Nepal is vulnerable to climate change induced natural disasters, making adaptation strategies crucial to attain agricultural sustainability (UNDP, 2023). However, agricultural sector contributes significantly to greenhouse gas (GHG) emissions through various production activities (FAO, 2021). The livestock sector contributes about 14.50% of global human-induced greenhouse gas emissions and 32% of anthropogenic methane emissions, with cattle accounting for roughly two-third of these emissions, primarily

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through enteric fermentation and manure decomposition (FAO, 2023; Li et al., 2024). As the global demand for dairy products continues to rise, there is an urgent need to balance production growth with environmental sustainability (Steinfeld et al., 2006). In developing nations like Nepal, the dairy is a key sub-sector of the agricultural economy. (Gautam et al., 2017). Despite its importance, dairy farming in Nepal is highly vulnerable to the adverse impacts of climate change, such as rising temperatures, altered rainfall patterns, and an increased frequency of extreme weather events (Shrestha et al., 2019). These climatic shifts exert a direct threat to cattle health through heat stress, uprisal of cattle disease incidence, and disruption of feed and water resources (Sejian et al., 2015).

Climate-Smart Agriculture (CSA) serve as an integrated approach to manage agricultural landscapes to address the interlinked challenges of food security and climate change (World Bank, 2023). CSA is a set of agricultural practices and technologies which simultaneously boost productivity, enhance resilience and reduce GHG emissions (World Bank, 2024). Climate-friendly practices (CFPs) are sector-specific measures and technologies that reduces greenhouse gas emission and enhances resilience to climate impacts (Wreford et al. 2017). In the context of dairy farming, the objectives of CFP are achieved through adoption of adaptation and mitigation measures that simultaneously improve farm productivity (Rojas-Downing et al., 2017). Common CFPs include the use of improved and high-yielding cattle breeds, balanced and nutrient-rich feeding strategies, cultivation of improved fodder species, feed conservation techniques, efficient manure management through composting and biogas production, provision of improved housing and ventilation, and efficient water management practices (Rosa et al., 2025). Adoption of these practices can improve feed conversion efficiency, reduce enteric methane emissions, enhance animal health and productivity, and strengthen farmers' adaptive capacity to climate variability (Oduor et al., 2025; Zenda, 2025; Zuwarimwe & Tada, 2026). The perception of climate change and its impact on dairy farming plays a crucial role in the adoption of CFPs (Mekonnen et al., 2023). Socioeconomic characteristics, access to institutional services, and awareness about impact of climate change significantly influences the adaptation decisions (Ahmad et al., 2022). Understanding farmers' awareness and adoption patterns of CFPs is essential for developing effective policies and interventions to promote sustainable dairy farming (Aryal et al., 2020).

Although national policies in Nepal encourage the climate-resilient agriculture, empirical evidence on the farm level adoption of specific CFPs in the dairy system remains limited, particularly in relation to how adoption is distributed across practices and farmers (Aryal et al., 2018). This gap constrains the design of targeted extension and policy intervention. Therefore, this study aimed to assess the level of adoption of CFPs among dairy cattle farmers in Bagamati Province, Nepal. Specifically, the study sought to: (i) describe the socio-economic characteristics of sampled dairy cattle farmers; (ii) assess farmers' awareness and perceptions of climate change; (iii) estimate the adoption rates of selected CFPs; and (iv) classify farmers according to their overall adoption score. By focusing on these objectives, the study provided descriptive evidence on the current pattern of CFP uptake in the study area.

2. METHODOLOGY

This section describes the study design, study area, sampling procedure, survey instruments, adoption design, scoring procedure, and analytical techniques used in the study

2.1 STUDY SITES AND SAMPLING TECHNIQUES

The study was conducted in Bagamati Province, Nepal in three districts: Chitwan, Dhading, and Makwanpur from 2 March to 4 April, 2025. These sites were selected purposively because of their importance in dairy production and to capture variation in agroecological and socio-economic conditions. However, the findings should be interpreted within the context of the selected study sites rather than generalized automatically to all dairy farmers in Nepal.

A multistage sampling procedure was applied. First, Chitwan, Dhading and Makwanpur districts were selected purposively based on their contribution to dairy production. Second, one local unit was selected from each district: Khairahani Municipality in Chitwan, Dhunibesi Municipality in Dhading, and Makwanpurgadi Rural Municipality in Makwanpur. Third, one dairy cooperative was identified in each selected local unit on the basis of preliminary field visits and consultation with key informants from the livestock and dairy development sector. Finally, the study population was defined as active member households of the selected cooperatives, and respondents were selected using simple random sampling from the cooperative membership lists.

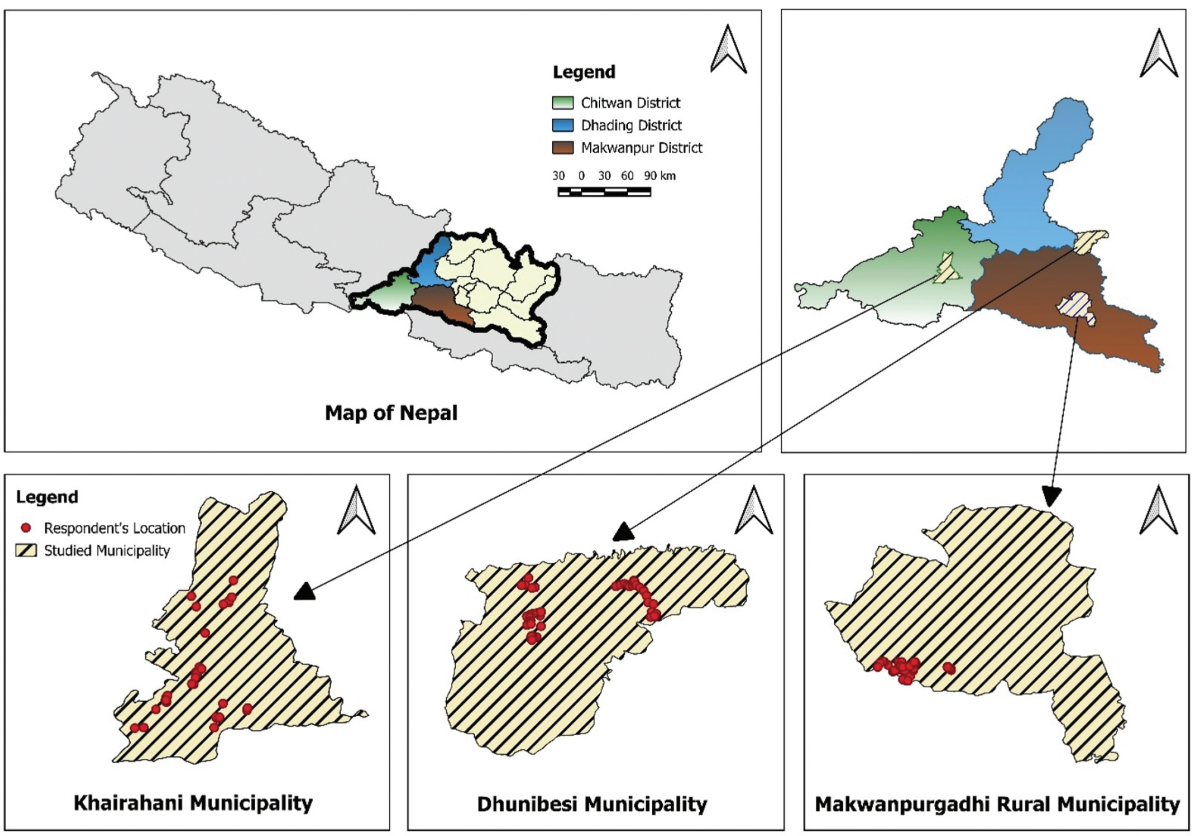

Figure 1. Map of Nepal showing study areas and respondent locations

Source: QGIS (version 3.34.10)

2.2 SURVEY DESIGN

Primary data were collected from dairy cattle farmers through face-to-face interviews using a structured questionnaire that included both closed-ended and open-ended questions. The questionnaire was designed and administered using the mWater Surveyor mobile application to facilitate digital data collection. Data collection was carried out by the principal author with the support of two enumerators. Before the main survey, the interview schedule was pretested to evaluate its clarity, relevance, and overall suitability. Feedback from the pretest was used to refine the questionnaire by addressing identified gaps and making the necessary revisions to improve its quality and effectiveness.

The sampling frame comprised 420 dairy farm households from dairy cooperatives in three municipalities. The sample size was determined using Yamane's formula (Yamane, 1967):

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

where, n = sample size, N = population size, and e = margin of error

Applying this formula, a sample size of 204 dairy cattle farmers was obtained at 5% margin of error. However, during the data cleaning process, six observations were removed because of incomplete sampling, resulting in a final sample size of 198 for the analysis. The specific ward location of respondents, along with corresponding municipalities and districts are presented below.

Table 1. Distribution of respondents across selected municipalities and districts

District	Municipality	Location	Sampling frame	Sample size
Chitwan	Khairahani	Khairahani 2, 5, 12	142	67
Dhading	Dhunibesi	Dhunibesi 3, 4, 5	140	65
Makwanpur	Makwanpurgadhi	Makwanpurgadhi 3, 6	138	66

2.3 SCORING SYSTEM

Climate friendly practices related to dairy production were identified from the literature and from recommendations of organizations such as the Food and Agriculture Organization of the United Nations (FAO), the Department of Livestock Services (DLS), and the National Dairy Development Board (NDDB). In total 20 practices were grouped into five management domains and assessed during the field survey. For transparency and replicability, the authors should ensure that the number of listed practices in Table 2 fully matches the number used in the adoption score and subsequent categorization.

Table 2. Description of CFPs used in dairy cattle farming

Variable	Description	Reference
Breed and reproduction management	-Use of high-yielding or improved breeds -Use of artificial insemination -Regular vaccination of cattle for disease prevention -Reduction of age of first calving	(Dall et al., 2019) (Gastelen et al., 2019) (Gerber et al., 2013) (Hawkins et al., 2022)
Feed management	- Provision of balanced feed to the cattle -Use of chopped fodder in the diet - Feeding silage in lean period -Use of mineral and supplements in diet	(Balehegn et al., 2020) (Bhusal et al., 2020) (Kataria, 2016) (Van Middelaar et al., 2014)
Cattle shed management	-Presence of proper ventilation and air circulation -Presence of insulated roofing -Comfortable bedding for cattle -Biosecurity measures followed	(Rotz, 2018)
Manure management	-Frequent removal of manure -Use of cover materials to cover the manure -Composting manure -Collection of urine for fertigation -Use of bio-gas plant	(Afotey & Sarpong, 2023) (Bhusal et al., 2020.)
Milking management	-Maintain consistent milking schedule and frequency -Use of proper milking techniques -Use of low emission or eco-friendly method for milk transportation	(D'Urso & Arcidiacono, 2021) (Mech et al., 2023)

A binary scoring method was used for each identified CFP, assigning a score of 1 if adopted and 0 otherwise. Individual scores were summed to generate gross adoption score (AS), for each household. This score represented the total number of CFPs adopted by a respondent. Assuming the adoption scores are roughly normally distributed, the method ensures that the medium category encompasses the central M ± SD of the sample, while the low and high categories capture the respective tails. This distribution aligns with the theoretical expectations in Rogers (2003) diffusion of innovations framework, where early adopters and laggards each represent relatively small proportions of the overall population.

Table 3. Methods of estimation of adoption score and adoption category

Category	Estimate Threshold
A (Low adoption)	AS ≤ M – SD
B (Medium adoption)	M – SD < AS ≤ M +SD
C (High adoption)	M+SD<AS ≤ Max

Notes: AS= Adoption score; SD= Standard deviation; M= Mean; Max= Maximum

2.4 ANALYTICAL TECHNIQUES

Socio-demographic characteristics such as age, sex, family size. education level, ethnicity, cattle size, and land allocated to cattle farming were included in the analysis. The study also examined farmers' awareness of climate change and their perceptions of its effects on dairy farming. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize the data. Data analysis was performed using Microsoft Excel Spreadsheet 2024 and IBM SPSS version 26 for tabulation and graphical presentation.

3. RESULTS AND DISCUSSION

This section presents the socio-demographic characteristics of the respondents. It also discusses farmers' awareness of climate change and their perceptions of its impacts on dairy farming. Finally, it highlights the adoption status of climate-friendly practices (CFPs) among dairy cattle farmers.

3.1 SOCIO-ECONOMIC PROFILE OF RESPONDENT

The socio-economic assessment of the respondents is illustrated in Table 1. The average age of respondents was 45.11 years, with a minimum of 18 years and a maximum of 78 years, indicating that both young and older farmers were engaged in dairy farming. The mean farming experience of households was 8.70 years, suggesting that most families had moderate experience in cattle rearing. The average household size was 5.31 members, ranging from 3 to 15, which is comparable to the national average family size reported in rural Nepal. On average, respondents owned 6.01 cattle, of which 4.02 were lactating, showing a considerable focus on milk production. Landholding patterns indicated that farmers allocated on average 0.30 ha of land specifically for cattle rearing, while the total mean landholding was 0.84 ha, highlighting small-scale land ownership.

In terms of categorical characteristics, the majority of respondents were male (69.70%), while females accounted for 30.30%. Regarding ethnicity, Hill Brahmin/Chhetri households dominated the sample (87.88%), followed by Hill Janajati (10.10%), Hill Dalit (1.52%), and Terai Janajati (0.50%). Educational status revealed that 19.10% of respondents were illiterate, while 22.72% had attained primary education. A larger share (43.43%) had completed secondary education, whereas only 14.64% had studied beyond secondary level. These findings indicate that while most respondents had at least some level of education, higher education was less common among dairy cattle farmers. Regarding institutional support, 39.90% of respondents reported having received training related to dairy cattle farming, indicating that a majority still lacked access to capacity-building opportunities. Similarly, 39.90% of households had benefited from subsidies for dairy operations, reflecting limited but important policy support for the sector. A very high proportion of farmers (96.46%) had insured their cattle, suggesting widespread recognition of insurance as a risk management tool against climate- and disease-related uncertainties. Meanwhile, only 34.34% of respondents had accessed credit specifically for dairy operations, highlighting the financial constraints faced by many farmers in scaling up or modernizing their production practices.

Table 4. Socioeconomic characteristics of respondent household

Continuous variable (n=198)

Variable	Description	Mean	Standard deviation	Maximum	Minimum
Age	Age of respondent	45.11	9.99	78	18
Farming experience	Number of years family had involved in cattle rearing	8.70	3.70	20	3
Family size	Total family members	5.31	2.01	15	3
Lactating cattle	Total number of lactating cattle	4.02	2.89	22	2
Cattle size	Total number of cattle	6.01	4.61	35	2
Land for cattle	Total land under cattle rearing in ha	0.30	0.32	2.33	0.01
Total land	Total land holding	0.84	0.78	8.66	0.13

Categorical variable

Variable	Description	n	Frequency	Percentage
Sex	Male	198	138	69.70
	Female		60	30.30
Ethnicity	Hill Brahmin/Chettri	198	174	87.88
	Hill Janajati		20	10.10
	Hill Dalit		3	1.52
	Terai Janajati		1	0.50
Education status	Illiterate	198	38	19.10
	Primary level		45	22.72
	Secondary level		86	43.43
	Higher level		29	14.64
Training	1= Yes	198	79	39.90

Variable	Description	n	Frequency	Percentage
Subsidy	1= Yes	198	79	39.90
Cattle insurance	1= Yes	198	191	96.46
Credit utilized for dairy operation	1=Yes	198	68	34.34

3.2 CLIMATE CHANGE PERCEPTION BY CATTLE FARMERS

A total of 59.60% of cattle farmers reported being aware of climate change, compared to 40.40% who were not. Regarding the impact of climate change, 92.42% of respondents perceived an effect, while 7.58% reported no effect. Responses on the impact of climate change were collected after explaining the concept to farmers, including examples of changes in agroclimatic variables such as temperature, rainfall, and humidity. These results indicate that, although 40.40% of farmers were not familiar with the term "climate change," a significant majority (92.42%) were able to perceive its impact on their livelihoods. (Figure 2).

The gender-disaggregated analysis revealed notable differences in farmers' awareness and perception of climate change. Among male respondents, 67.40% reported having heard of climate change, compared to 41.70% of female respondents. Similarly, a higher proportion of males (91.30%) perceived that climate change had an impact on their farming activities, while 95.00% of females also reported experiencing its effects. Despite lower awareness of the term climate change among women, the vast majority recognized its impacts, with only 5.00% reporting no perceived effect compared to 8.70% of men. These findings suggest that although female farmers were less familiar with the concept of climate change, they were equally, and even slightly more, likely than male farmers to perceive its effects on their livelihoods and farming systems (Figure 2).

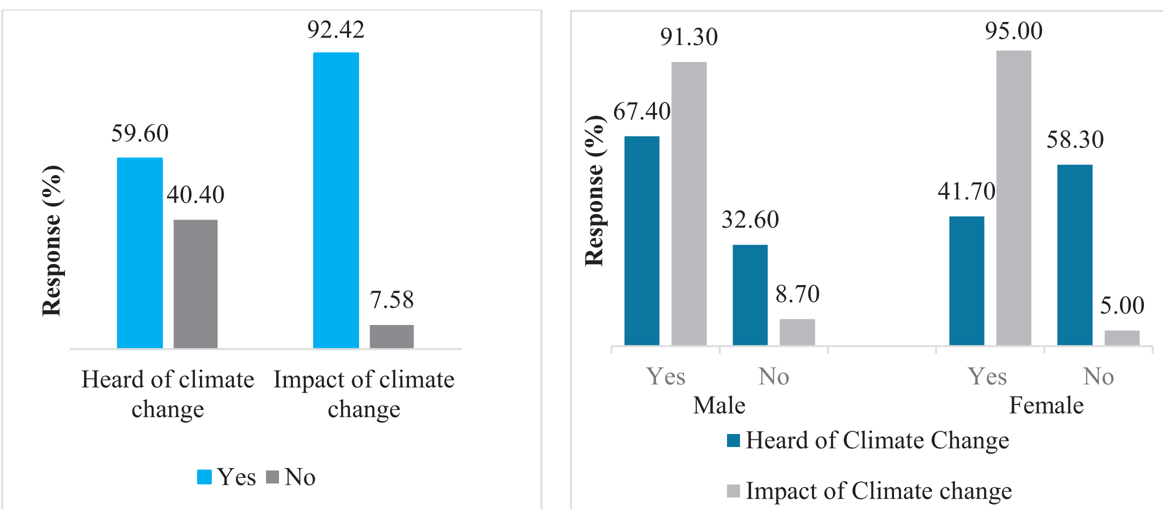

Figure 2. Farmers awareness on climate change and perceived experience of its impact (n=198, Male =138, Female = 60)

3.3 ADOPTION RATE OF CLIMATE-FRIENDLY PRACTICES

This section presents the observed adoption rates of 20 CFPs across five different management domains. The findings provide a descriptive overview of which practices were more commonly adopted in the samples households and which practices remained less common.

3.3.1 Breed and reproduction management

All households (100.00%) had adopted the improved or high-yielding breed in the study area. The cattle breeds on their farms were Holstein cross, Jersey cross, and Sahiwal cross. About 96.46% of farmers were using artificial insemination (AI) for the purpose of breeding. The success of improved breeds and AI is a result of decades of government and cooperative-led programs in Nepal that made superior genetics accessible and affordable (Gautam et al., 2017). Similarly, 94.45% of farmers provided vaccination to their cattle in regular interval. Likewise, 29.29% of households were involved in reducing age at first calving by providing enough dietary requirements to growing calves (Figure 4). The reduction of age at first calving requires sophisticated understanding of animal nutrition and requires long-term investment where economic return is delayed (Thorpe et al., 2010). These findings align with the findings of Montes de Oca Munguia et al. (2021) that farmers adopt technologies due to clear relative advantages.

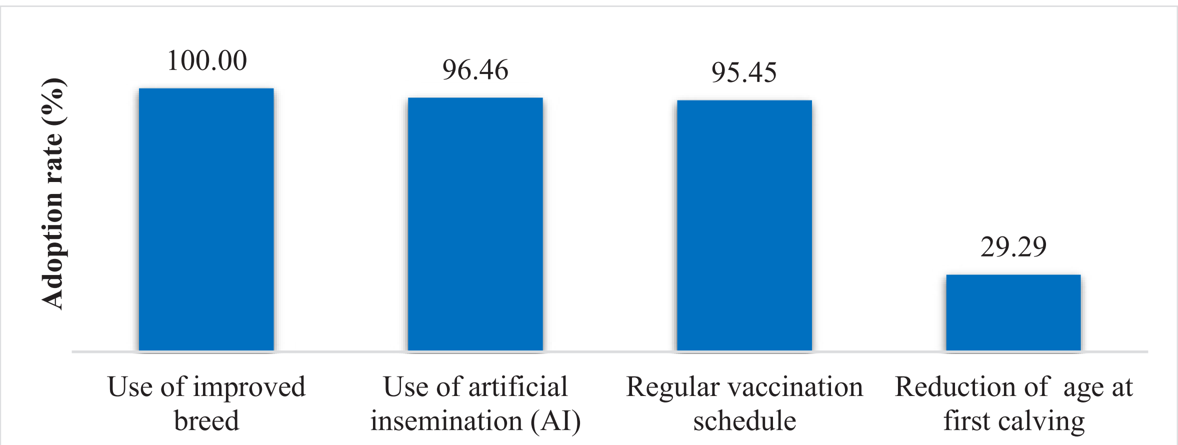

Figure 3. Adoption of breed and reproduction management practices among dairy cattle farmers (n=198)

3.3.2 Feed management

About 67.67% of household provided the balanced proportion of feeds to the cattle. This includes the provision of green roughage, dry roughage and concentrates in appropriate amount as recommended by the Department of Livestock Services. Similarly, 55.05% of sampled households provided chopped fodder to the cattle. Likewise, 31.31% used additional minerals and supplements in the cattle diet. The low uptake of mineral supplements is a persistent issue in smallholder dairy system across South Asia (Garg & Bhanderi, 2016). The use of silage for feeding the cattle in lean period was practices by only 14.65% of households (Figure 5). Farmers may have limited knowledge and skills to adopt technologies such as silage making (Kirimi et al., 2024).

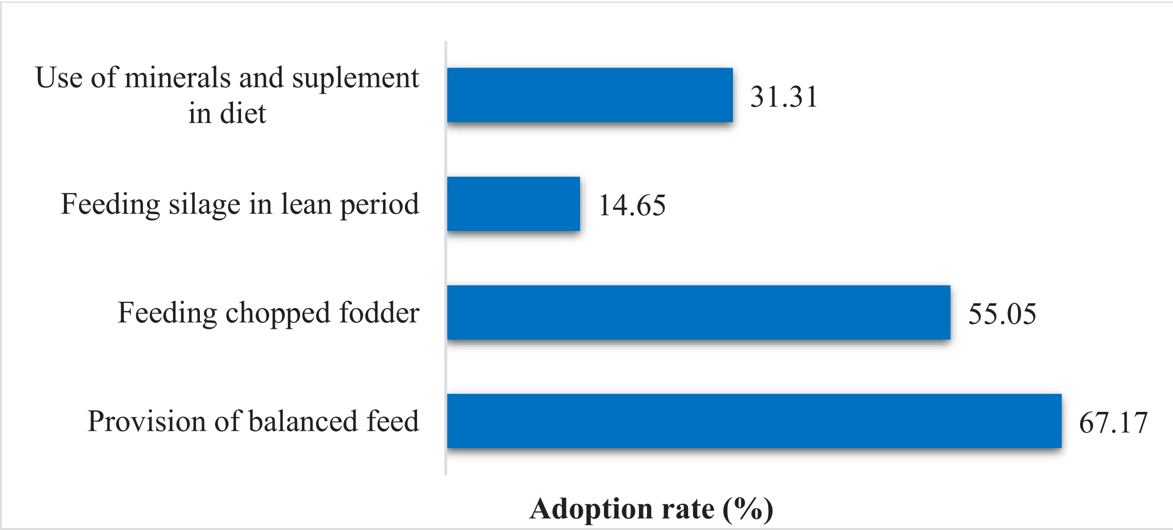

Figure 4. Adoption of feed management practices among dairy cattle farmers (n= 198)

3.3.3 Cattle shed management

Proper ventilation or air circulation in the farm was present in 50.51% of the households. Likewise, the presence of comfortable bedding was reported by 50.00% of the respondents. Practices like improved ventilation and bedding are crucial climate adaptation strategies to mitigate heat stress in dairy cattle under rising temperature (Sejian et al., 2015). Around 46.46% of households followed biosecurity measures to prevent disease transmission and to maintain cattle overall wellbeing. Similarly, 45.96% of cattle farms had insulated roofing to maintain the overall cattle shed temperature (Figure 6). The findings align with study by Shilpakar et al. (2021), who noted that the Nepalese farmer perceive high upfront cost of shed improvements as barrier to adopt these management practices. The partial adoption of biosecurity measures implies a more targeted training, as these practices are often low-cost but require a clear understanding of disease transmission pathways.

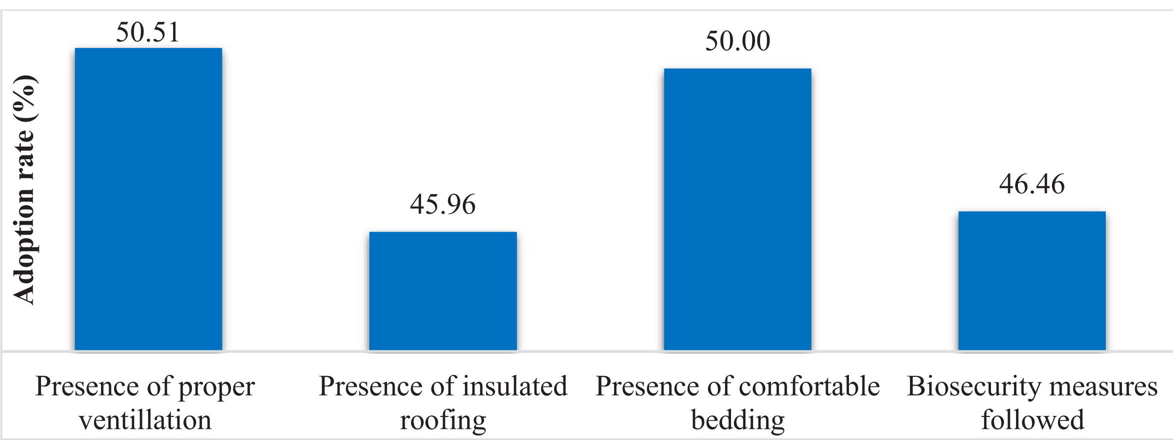

Figure 5. Adoption of cattle shed management practices among dairy cattle farmers (n= 198)

3.3.4 Manure management

All sampled households (100%) practiced the frequent removal manure from cattle shed. The 31.82% of households reported covering of manure to reduce the nutrient loss and odor. Similarly, 24.24% of farmers used biogas technology in their farm. The use of improved urine pits was reported by 18.18% of households. Likewise, 8.59% of the household was engaged in composting the manure (Figure 7). The climate-friendly practices like composting and biogas production reduces GHG emissions contributing to a circular farm economy (Sapkota et al., 2019). The barriers of adoption of these particular CFPs include high initial costs, as approaches like biogas technology is costly to set up (Munidasa et al., 2021).

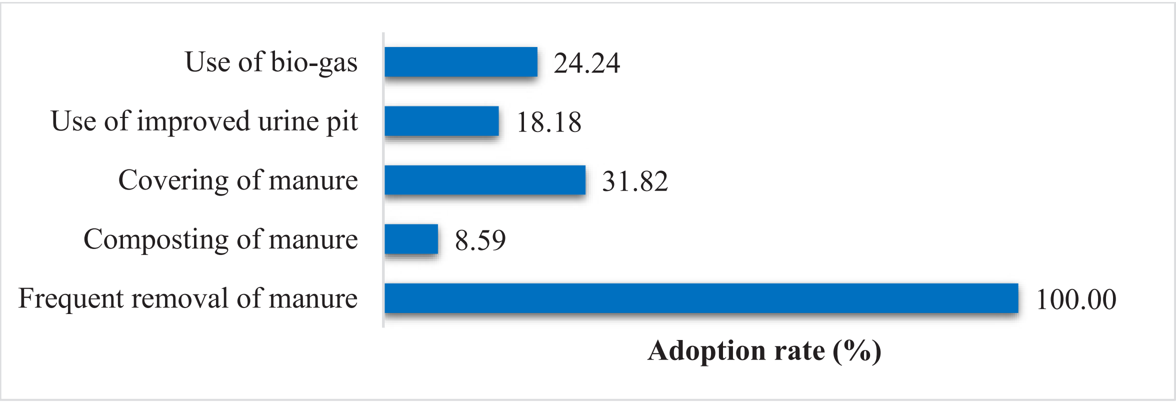

Figure 6. Adoption of manure management practices among dairy cattle farmers (n= 198)

3.3.5 Milk management

All sampled household (100.00%), maintained the consistent milking schedule. The 50.00% of household followed the clean milking practices. This finding is consistent with study of Adebe et al. (2013), which show that while farmers are aware about hygiene, limited technical knowledge and limited access to proper disinfectants hinder the uptake of this practice. Improving the adoption of clean milking is essential, as it not only enhances milk quality and safety but also reduces the incidence of costly diseases like mastitis. Similarly, 47.47% of household stated the use of low emission of eco-friendly mode for transportation of milk to the milk collection centers (Figure 8).

Figure 7. Adoption of milk management practices among dairy cattle farmers (n= 198)

3.4 CATEGORIZATION OF CATTLE FARMERS BASED ON ADOPTION OF CFPS

The classification of dairy farmers into low, medium, and high adoption categories provides a descriptive summary of the adoption status of CFPs in the study area. Of the 198 respondents, 110 were categorized as medium adopters, 49 as low adopters and 39 as high adopters. The observed distribution indicates that many farmers had adopted some CFPs, but the extent of adoption varied across households. These results may be useful for identifying groups that could benefit from the targeted technical support, but they should not be interpreted as evidence of adoption determinants because of no inferential analysis was conducted.

Table 5. Categorization of dairy cattle farmers based on their level of adoption of CFPs

Category	Description	Number of household (%)
Low adopter	Farmer adopting 1-7 CFPs	49 (24.75)
Medium adopter	Farmers adopting 8-14 CFPs	110 (55.35)
High adopter	Farmers adopting 15-20 CFPs	39 (19.70)

Note: Figures in parentheses indicate percentage.

LIMITATIONS OF THE STUDY

This study has several limitations that should be considered when interpreting its findings. First, the cross-sectional research design captures adoption status at a single point in time, which limits the ability to examine changes over time or establish causal relationships. Second, the sample was drawn from active members of dairy cooperatives in selected local units, which may restrict the generalizability of the findings to non-member farmers and to other regions of Nepal. Third, much of the information was based on self-reported responses, which may introduce recall bias or social desirability bias. Finally, the analysis was largely descriptive in nature and did not explore deeper explanatory relationships between adoption behavior and household or institutional factors. These constraints should be considered when interpreting the results and drawing policy or programmatic implication.

CONCLUSION

This study described the adoption of climate-friendly practices (CFPs) among sampled dairy cattle farmers in Bagamati Province, Nepal. Practices closely associated with herd productivity and animal health such as improved breeds, artificial insemination, and regular vaccination were widely adopted, whereas practices requiring greater technical knowledge, labor, or initial investment such as silage preparation, manure composting, and biogas use were less common. More than half of the respondents were categorized as medium adopters, suggesting partial uptake of the recommended practices. The findings indicate scope for extension support, practical training, and policy measures that address barriers to the adoption of less frequently used CFPs.

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ETHICAL STATEMENT

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of Agriculture and Forestry University (AFU) prior to data collection. Before the commencement of each interview, verbal informed consent was obtained from all respondents.

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