Nepal Agriculture Research Journal
Vol. 16, No 1, pp. 12-25, 2025
DOI: https://doi.org/10.3126/narj.v16i1.80430

Typology and Characterization of Dairy Cattle Farms in Nepal

Jyoti Dhungana[1*], Devendra Gauchan[1], Hari Krishna Panta[1] and Krishna Prasad Timsina[2]

[1]Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Kirtipur, Kathmandu, Nepal
[2]Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, Nepal
[*]Corresponding author's email: jyoti.hohen@gmail.com
[*]ORCID: https://orcid.org/0000-0002-6165-0942

ARTICLE INFO

Research Paper

Received: December 25, 2024
Revised: February 5, 2025
Accepted: February 17, 2025
Published: June 25, 2025

Contents available at
http://www/sasnepal.org.np

ABSTRACT

The dairy sector plays a key role in generating income for smallholder farmers in Nepal. However, dairy cattle farms have variations in production practices and farm types, and very few studies have been conducted to understand their diversities. Therefore, this study aims to assess the typologies and characteristics of dairy cattle farms. Surveys were conducted across 407 dairy cattle farms in *Ilam* (86), *Morang* (114), *Kavre* (91), and *Chitwan* (116) between February and October 2024, representing the Hill and *Terai* regions of Nepal. Data was validated through 30 Key Informant Interviews (KIIs) and 10 Focus Group Discussions (FGDs). The Principal Component Analysis (PCA) and Cluster Analysis (CA) were used for data analysis, along with one-way ANOVA and Chi-square test for characterization. The PCA result indicated that farm area, forage area, technology, dairy cattle, and daily milk sales influenced the first component (42.38%), land holdings and feed rate affected the second component (11.39%), and lactation period, experience in dairy farming, and milk yield consisted third component (10.45%), collectively explaining 64.22% of the total variation. CA identified three distinct farm typologies. Cluster 1 (24.8%) included large-sized, specialized, and commercialized dairy farms, cluster 2 (36.6%) consisted of medium-sized, market-oriented farms, and Cluster 3 (38.6%) featured small-sized farms with limited resources and lower production. A variation among the respondent farms was attributed to milk yield, scale of production, intensity of production, degree of commercialization, and management practices. Therefore, the extension strategies need to be tailored based on the size, type, and characteristics of each cattle farm.

Keywords: Cluster Analysis, Dairy Cattle Farms, Milk Production, Principal Components Analysis

Cited as: Dhungana J, D Gauchan, HK Panta and KP Timsina. 2025. Typology and characterization of dairy cattle farms in Nepal. Nepal Agriculture Research Journal 16(1): 12-25. DOI: https://doi.org/10.3126/narj.v16i1.80430

INTRODUCTION

The dairy sector in Nepal offers nutritional benefits and economic opportunities, contributing 63% to Livestock Gross Domestic Product (GDP) and 9% to Agriculture GDP (MoF 2022). The dairy sector comprises 733 dairy producer groups, 1700 primary dairy cooperatives (NDDB 2023), and 500,000 milk-producing households, generating rural employment (CASA 2020). The Government of Nepal (GoN) has mandated the provision of services in the Agriculture Development Strategy (2015-2035), National Dairy Development Policy (2021), and 10 Year Dairy Development Plan (2018-2028) to provide essential extension services. Farmers benefit from various forms of support, including livestock insurance, breed improvement programs, health and nutrition services, as well as access to fodder and forage. However, dairy farms in Nepal show significant variability in productive and reproductive performance (Shingh et al 2020). The diversity of farm resources, capacity, and socio-economic contexts among dairy farmers influence dairy-related interventions.

Despite the variations in farming practices, existing intervention strategies in Nepal are applied same across all types of farms. This is primarily due to the absence of specifically designed policy provisions for different farming contexts in the country. Thus, the GoN has established a system to identify and categorize types of farmers (ADS 2015, NDDP 2021); however, this has yet to be implemented. Farm typology assesses the variability among farms, allowing them to separate into different homogeneous sub-groups (Azeze et al 2024). The farm category ensures efficient resource allocation, leading to improved overall performance of dairy farming (Fiorillo and Amico 2024). Farm typology is needed to design plans and priorities that align with the unique characteristics of each farm (Huber et al 2024, Khanal et al 2022, Zepeda et al 2023). It is essential to address the varied needs and challenges faced by farms. Farm typology studies have been conducted (Barnes et al 2022, Gobin and Herzele 2023, Innazent et al 2022, Thar et al 2021, Upadhaya et al 2021) to capture the varied characteristics and perceptions of farmers.

However, research on the typology of dairy farms in Nepal is lacking. The research gaps were identified to assess the farm dynamics (Tacconi et al 2022), and awareness of farm typology (Bartkowski et al 2022). It is crucial to develop types that examine the similarities and dissimilarities among farms based on their unique experiences (Hassall et al 2023, Stapley 2022). Thus, this paper aims to assess the typology and characterization of dairy cattle farms in Nepal. The expected outcome is to assist policy-makers and dairy stakeholders in developing effective policies and broader dissemination. This, in turn, can lead to improved overall performance of dairy cattle farms in Nepal. The study considered the following research question: What are the typologies and distinct characteristic features of dairy cattle farms in Nepal?

MATERIALS AND METHODS

Study Area and Sampling Frame

The multistage sampling procedure was applied to select the study area and sample size (Abbasi and Nawab 2021). The stages involved the selection of (i) provinces, (ii) districts, (iii) municipalities, and (iv) dairy farming households. In the first stage, *Koshi* and *Bagmati* provinces were chosen based on milk production quantity (MoALD 2023), number of Artificially Insemination (AI) used (MoICS 2023), and number of registered dairy cattle farms (NLBO 2021). In the second stage, four districts: *Ilam*, *Morang*, *Kavre*, and *Chitwan* were chosen using the same criteria, representing the *Terai* and hilly regions of Nepal. These districts have a high potential for milk production. In the third stage, the Veterinary Hospital and Livestock Service Expert Centers (VHLSECs) identified dairy pockets in each district.

The list of dairy cattle farms was taken from municipalities and used as a sampling frame. In the fourth stage, primary sampling units were taken from registered cattle-rearing households. A total of 407 households were randomly selected: 86 from *Ilam,* 114 from *Morang,* 91 from *Kavre,* and 116 from *Chitwan,* ensuring better representation.

Data Collection

The explanatory sequential method was applied, and quantitative and qualitative data were gathered in two phases. The data were collected from February 2024 to October 2024. In the first phase, household data were collected using the Kobo toolbox and a structured questionnaire covering various aspects such as socio-economic and farm characteristics, milk production, feeding, breeding, health practices, and herd management. The questionnaires were pre-tested at non-sampled households, adjusted, and administered to the sampled farms. Before each interview, respondents signed a consent form and were given the option of participating in the interview. In the second phase, a total of 10 Focus Group Discussions (FGDs) were conducted with milk producer groups and dairy cooperatives. We conducted 30 Key Informant Interviews (KIIs) with milk farmers, dairy processors, traders, and enablers. Qualitative data from FGDs and KIIs were compiled as written notes for triangulation and interpretation of survey data.

Data Analysis

The data were entered into an Excel sheet and analyzed using R (version 4.3.1). Descriptive statistics, including mean and standard deviation were calculated to describe the variables. To identify the farm types, the multivariate methods using Principal Component Analysis (PCA) and Cluster Analysis (CA) were used (Fanchone et al 2020, Tonet et al 2023, Zoma-Traoré et al 2020). PCA reduces the dataset by converting correlated variables into a set of uncorrelated variables that reflect the majority of variability present in the original data (Beattie et al 2021). The principal component extraction method with orthogonal varimax rotation and Kaiser Normalization was adopted to separate the components. The factors were interpreted using the rotated component matrix applied in PCA. A factor loading greater than 0.5 indicates a strong association, while less than 0.5 indicates a weaker relationship (Kamadi et al 2016). Thus, factor loading greater than 0.5 was taken as a reference point to show how strongly different variables were associated with underlying factors. A scree plot was generated to show the number of components with an eigenvalue greater than one (Kaise 1960). It helps to determine the optimal number of components to retain in the analysis. It was widely used in literature (Patel and Rank 2023, Reichenbach et al 2021). Sample adequacy was tested using the Kaiser–Meyer–Olkin (KMO), which required a value greater than 0.6. Bartlett's Sphericity test was used to evaluate whether the correlation matrix was an identity matrix (Shrestha 2021). Highly correlated variables were omitted, and 10 continuous variables were used for PCA (Table 1).

Table 1: Sample characteristics

Variable	Description of Variable	Variable	Description of Variable
Forage area	Area for forage (ha)	Land size	Land owned by family (ha)
Dairy farm area	Dairy farm area (ha)	Feed rate	Feed per cattle per day (kg)
Technology	Number of technology (no)	Lactation	No of lactation days (days)
Dairy cattle	Number of dairy cattle (no)	Experience	Dairy farming experience (years)
Milk sale	Milk sale per day (liter)	Yield	Milk yield (liter/cattle/day)

Similarly, CA categorizes the dataset into distinct clusters based on unique characteristics (Reddy et al 2020). The CA was used to measure clustering using the squared Euclidean distance, and Ward's method was used to fix the appropriate number of clusters. The clusters were compared using one-way ANOVA for continuous and Chi-square tests for categorical variables (Gautam and Khadka 2022). The data were validated with relevant literature and secondary data sources from reports and policy documents from the government and non-government sectors of Nepal.

RESULTS

Socio-economic Profile of Respondents

Table 2 presents the socio-economic and farm characteristics of four districts: *Ilam, Morang, Chitwan*, and *Kavre*. The average age of the respondents was 44 years. Among them, 67% were male, and only 22% of the households had female-headed. This percentage is lower than the national average of 31.6% (CBS 2021). The FGDs discussion stated that males mainly owned dairy farm operations. Most households belonged to the *Brahmin*, *Chhetri*, and *Thakuri* (BCT) communities, 85% in *Chitwan* and 88% in *Kavre*. In contrast, *Ilam* had the highest percentage of *Janajati* households at 37%, while 28% were from the *Madhesi* community in *Morang*. The average education level of household heads was nine years of schooling.

Table 2: Socio-economic characteristics from four districts

Variables	*Ilam*	*Morang*	*Chitwan*	*Kavre*	Overall
Age of respondent (years)	44	43	46	43	44
Education of HH head (years)	10	8.87	9.79	7.45	9
Forage area (ha)	0.19	0.15	0.16	0.13	0.16
Dairy cattle (no)	8.94	10.68	10.92	6.88	9.55
Milk Yield (Liter/cattle/day)	11.52	10.6	10.36	10.89	10.79
Membership (%)	73.6	38.6	94.9	58.4	66.4
Distance to selling point (km)	1.7	1	1	2.5	1.6

Source: Field Survey, 2024

Chitwan has the highest membership in the dairy cooperative at 96% and the lowest for *Morang* at 39%. The overall average distance to the milk selling point was 1.6 km. Regarding dairy cattle numbers, Chitwan had the largest number, 10.92 cattle, while the lowest average was found in Kavre, at 6.88 cattle. The daily milk yield per cattle is highest in Ilam, averaging 11.5 liters.

Principal Component Analysis

The KMO test of 0.849 exceeded the acceptable threshold of 0.6. Bartlett's Sphericity test was highly significant ($p<0.001$) with a Chi-square value of 2560.334 and 55 degrees of freedom, indicating that this method was appropriate for further analysis. A scree plot was generated to show the number of components with eigenvalues greater than one (Figure 1).

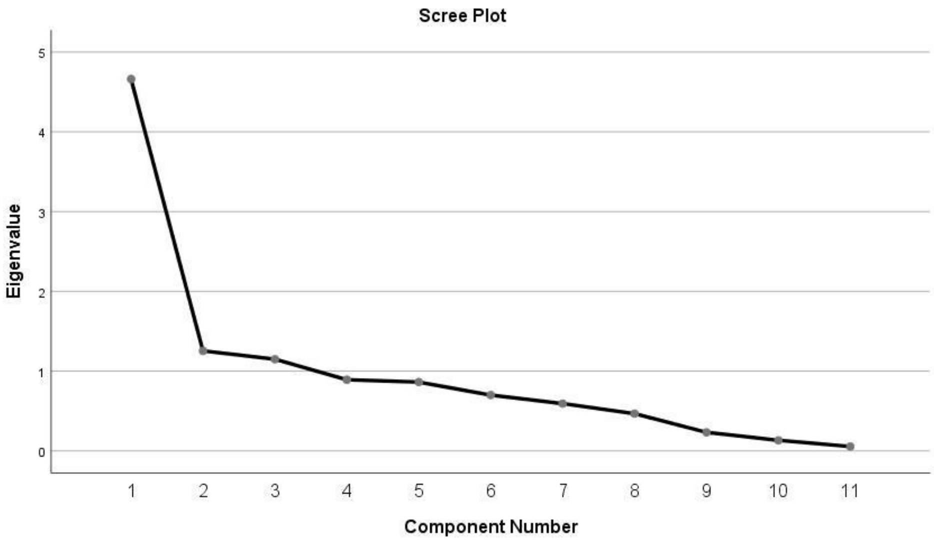

Figure 1: Scree plot showing the number of components that had Eigen value >1

The result from PCA with a rotated component matrix shows the key variables that defined the significant differences among groups. Table 3 presents that PC1 accounted for the largest percentage of variability (42.38%), which is positively correlated with the area allocated for dairy farms and forage, technology use, number of dairy cattle, and daily milk sales. This component consists of specialized, market-oriented dairy farms. The PC2 was explained for 11.39% and positively associated with farms with more land holdings and feed rates.

Table 3: Initial Eigen value and rotated component matrix

Variables	Components		
	PC1	**PC2**	**PC3**
Forage area	**0.887**	0.196	-0.017
Dairy farm area	**0.597**	0.476	-0.013
Technology	**0.739**	-0.141	0.007
Dairy cattle	**0.939**	-0.006	0.072
Milk sale	**0.922**	0.038	0.176
Land size	0.207	**0.711**	-0.144
Feed rate	0.348	**0.577**	-0.18
Lactation	0.275	-0.251	**0.554**
Experience	-0.295	-0.025	**0.608**
Yield	0.310	0.231	**0.674**
Eigenvalues	4.662	1.254	1.151
Variance (%)	42.38	11.39	10.45
Cumulative Variance (%)	42.38	53.77	64.22

Note: Bold numbers refer to loadings higher than 0.5, highly correlated variables (|r| > 0.5)

This component represents farms with greater land access and daily feed rates. The PC3 explained 10.45% of the variability and positive relationship to the lactation period, years spent in dairy farming, and milk yield. The component indicates the farms with more extended dairy farming periods, longer lactation days, and higher milk yield. The cumulative variance explained by these three components is 64.22%, indicating that they capture the majority of the variability in the dataset. A factor loading greater than 0.5 was used as a reference point to determine the variability of components.

Clusters of Dairy Cattle Farms

K-means clustering analysis identified three distinct clusters among the surveyed households; each was named according to its most distinguishing characteristics. The visual plots shown in Figure 2 separated the farms in each cluster. Cluster 1 consists of 101 farms (24.8%), Cluster 2 consists of 149 farms (36.6%), and Cluster 3 consists of 157 farms (38.6%). The sampled farms were differentiated using 14 key variables, including 10 continuous and four categorical variables. The primary variables influencing the cluster were forage area, dairy farm area, number of technologies used, number of dairy cattle, milk sales, land size, feed rate, years spent in dairy farming, milk yield, and lactation period.

Figure 2: Cluster plot showing the three clusters in K-means cluster analysis

To characterize the clusters identified from CA, a one-way ANOVA test for continuous variables (Table 4) and chi-square tests for categorical variables were applied (Table 5). The sum of squares and F-value was used to assess the variability between and within the groups. The p-value (<0.05) indicates that the three clusters differ significantly based on various characteristics. Post-hoc tests were conducted to compare the variability within each group. The following were the identified clusters:

Typology 1 (Cluster 1)

Cluster one comprises 101 farms, representing 24.8% of sample respondents. These farms averaged 18.9 dairy cattle with 96 liters of daily milk sales (Table 4). This cluster was characterized by households with better access to land, owning an average of 0.96 ha, of which 0.28 ha is allocated for forage production, using both owned and rented land. The feed rate was also higher, at 2.39 kg/day/cattle, compared to the average value. The farm owned 0.15 ha of dairy farm area with an average of 5.6 years of experience in cattle farming. The average number of technology adoptions was 10, and the lactation period was 313 days, higher than across the clusters. The household with 70% of farmers relied on hired labor, implying that hired labor increased as farm size grew.

A majority, 66%, of the farms had improved housing, while 33.7% still have traditional cattle sheds. More than half of the farms, 58.3%, maintained the farm records, and 60% had a business plan (Table 5). This indicates that the dairy cattle farms in this cluster were highly productive, intensive, and commercially focused. The post hoc test result described that the technology use, forage area, lactating cattle, years of dairy farming experience, and daily milk sales among the three clusters were significant at a 5% level. However, there was no significant difference between clusters one and two for the lactation period and milk yield.

Table 4: Continuous variables used for characterization of three clusters

Variable	Cluster 1 Large (n=101)	Cluster 2 Medium (n=149)	Cluster 3 Small (n=157)	Overall	F-value
Forage area (ha)	0.28[a]	0.13[b]	0.07[c]	0.16	233.503*
Dairy farm area (ha)	0.15[a]	0.08[b]	0.07[b]	0.09	54.812*
Technology (no)	10[a]	6[b]	3[c]	6.3	152.98*
Dairy cattle (no)	18.9[a]	8.9[b]	4[c]	9.55	326.830*
Milk sale (Liter/day)	96[a]	51[b]	14[c]	53.7	361.677*
Land owned (ha)	0.96[a]	0.60[b]	0.33[c]	0.63	47.574*
Feed rate (Kg/cattle/day)	2.39[a]	1.9[b]	1.76[b]	1.97	11.550*
Lactation (days)	313[a]	308[a]	282[b]	298.97	24.375*
Experience (Years)	5.6[a]	12[b]	7.3[c]	8.61	168.857*
Yield(Liter/cattle/day)	11.5[a]	11.8[b]	9.4[c]	10.79	60.286*

Note: * indicate significant at 5% level, [a,b,c] means with a different superscript in the same row differ ($p<0.05$)

Typology 2 (Cluster 2)

Cluster two comprises 149 farms, representing 36.6% of the sample respondents. The households had higher milk yield of 11.8 liters with an average of 8.9 dairy cattle, selling 51 liters daily (Table 4). These farms had an average of 12 years of experience in dairy farming, significantly longer than the overall average of 7.3 years. They have adopted six farming technologies and have a dairy farm area of 0.08 ha. The average land size was 0.60 ha, and the allocated forage area was 0.13 ha. The average lactation period was 308 days (Table 4). A relatively small percentage of these households (28.9%) employed hired labor, with the majority (71%) relying mainly on family labor (Table 5). The analysis revealed that nearly one-third (30%) had prepared a business plan. In 45.6% of these farms, improved housing existed, while the remaining had traditional sheds. The results indicated that these farms combine traditional and modern practices, are heavily dependent on family labor, and show a moderate level of milk production.

Table 5: Categorical variables used for characterization of three clusters

Variable		Cluster 1 Large (n=101)	Cluster 2 Medium (n=149)	Cluster 3 Small (n=157)	Overall	χ2
Hired labor	Yes	71(70.3)	43(28.9)	15 (9.6)	129 (31.7)	105.622a*
	No	30(29.7)	106(71.1)	142 (90.4)	278(68.3)	
Improved housing	Yes	67(66.3)	68(45.6)	35(22.3)	170(41.8)	50.465a*
	No	34(33.7)	81(54.4)	122(77.7)	237(58.2)	
Farm record	Fully	59(58.4)	26(17.4)	10(6.4)	95(23)	121.04a*
	Partially	36(35.6)	83(55.7)	40(25)	159(39)	
	Never	6(5.9)	40(26.8)	107 (68)	153(38)	
Business plan	Yes	60(60)	44(30)	12(7.7)	116(29)	23.297a*
	No	41(40)	105(70)	145 (92.3)	291(71)	

Note: Figures in parentheses indicate percentage, * indicate significant at 5% level

Typology 3 (Cluster 3)

Cluster three consisted of 157 dairy cattle farms, representing 38.6% of sample respondents. This cluster was characterized by an average of 4 dairy cattle, with a minimal quantity of feed per cattle per day (1.76) (Table 4). The daily milk sale was found to be 14 liters, and milk yield of 9.4 liters was significantly below the overall average. The allocated forage area was 0.07 ha, and the dairy farm area was 0.07 ha. These farms had an average lactation period of 282 days, and farmers had 7.3 years of experience. However, the number of used technology was three. The households have used family labor by 90% and 78% having the traditional shed (Table 5). There was little practice of business planning or record-keeping of their farms. The farmers of this cluster followed the conventional method of cattle rearing, with low use of inputs and technology.

DISCUSSION

The cluster analysis identified three typologies of dairy cattle farms: 24.8% large-sized farms, 36.6% medium-sized farms, and 38.6% small-sized farms (Figure 2). These cattle farms vary in terms of milk yield, scale of production (land owned, dairy farm area, number of dairy cattle), intensity of production (forage area, feeding rate, labor use, technology), commercialization (daily milk sales), and management aspects (Table 4). A similar study in Kenya by Otieno et al (2021) categorized dairy farms into low, moderate, and high ranks based on resource endowment and market orientation. The key variables were the land size, years of dairy farming, labor involvement, family income, household assets, and dairy outputs. Conversely, Zoma Traore et al (2020) in Burkina Faso identified four cattle production systems: sedentary lobi, sedentary crossbreed, semi-transhumant Fulani zebu, and transhumant Fulani zebu farms, primarily based on different ethnic groups. Nyambo et al (2019) classified farms into deterministic, probabilistic, participatory, and expert-based clusters. Nutritional, technical, and milking practices influenced the type of farm (Tramontini et al 2021). Based on the above insights, discussions on differences and suggestions for each cluster with farm sizes are provided below:

Commercialized with Large-Scale of Production

The study found that 24.8% of dairy cattle farms fall into cluster 1, which was characterized by large-sized commercial dairy farming focusing on specialized milk production (Figure 2). The daily milk sales are nearly double than the average (Table 4). The lactation period was 313 days, which aligns closely with the national average of 314 days in Nepal (Poudel et al 2023). According to interviews with farm owners, large farms are more likely to adopt modern practices such as high-yielding breeds, use of AI, milking machines, chaff cutters, medicine stockpiles, and concrete floors with mats, fencing, and stainless steel containers. There was a positive correlation between technology adoption and farm investment (Erdem and Ağır 2024). Focus group discussions with milk producer groups revealed that most farmers in this cluster employ regular veterinary technicians, lease land for forage and dairy farms, and provide adequate concentrated feed for each animal, supplemented with fodder and forage. Similar findings in Congo indicate that large land size influences herd size (Mugumaarhahama et al 2021). Large-sized dairy farms have greater economic sustainability than small-sized farms (Bánkuti et al 2020). This is due to the large-sized farms that can meet market and institutional demands for milk quality and volume.

However, Paul et al (2020) found that farms with larger herds often have more local breeds, lower feed rates, and reduced yield. Akhtar et al (2020) reported that demographics, economic and social factors, and financial support impact farm performance. The discussion in FGDs with farmers revealed the high production cost due to high use of imported feed and intensive hired labor use, disease prevalence, delay in milk payment, and low competitiveness of milk products. This is aligned with previous research highlighting disease prevalence (Dhakal 2022) and the impact of diseases and parasites (Kaur et al 2021). Most dairy farms in this cluster were located in semi-urban and urban areas, providing easy access to road, milk collection centers, and markets. The availability of basic services and inputs stimulates market-oriented production (Reichenbach et al 2021). Access to resources and facilities can motivate dairy farmers toward commercial production.

Semi-commercialized with Medium-Scale of Production

Cluster 2 includes 36.6% of the sampled dairy cattle farms with mixed crop and livestock production systems (Figure 2). These farms showed moderate average number of cattle and milk sales, but they demonstrate higher milk yield compared to other clusters (Table 4). This was validated by FGDs with milk producers confirming that the owners of medium-sized farms are directly involved in farming with intensive care and management by using a partial labor workforce. The farmers have had better day to day management regarding feeding and veterinary services. Although the primary focus was milk production, some farms within this cluster also produce value-added products like cheese and yogurt. A study by Otieno et al (2021) reported minimal variation between medium and small-sized dairy farms in terms of production scale and land access. They noted that farmers rely on family labor, tend to have smaller herd sizes, and typically have 12 to 14 years of dairy farming experience. Farmers in cluster two were located around the cities of *Terai* and accessible hilly regions. Facilities like road and collection centers also encouraged market-oriented production (Habanabakize et al 2022, Pinto et al 2020). Nevertheless, farmers face constraints such as insufficient information on modern technologies, poor hygiene, inadequate veterinary services, low-quality feed, and limited networks among the dairy value chain actors.

Low Commercialized with Small-Scale of Production

Cluster 3 consists of 38.6% of respondent dairy cattle farms with fewer cattle and the lowest milk yield (Figure 2). This finding aligns with a study conducted in Senegal by Habanabakize et al (2022), which reported that agro-pastoralist small-sized farms experienced lower milk production per farm, less market access, and higher rates of animal diseases than other clusters. Ahikiriza (2021) found that 57.3% of subsistence small-sized farmers in Sub-Saharan tend to have small plots of land with few dairy cattle and minimal use of modern tools, rating only 3.6 out of 7. Interestingly, these farmers allow their cattle to graze in enclosed paddocks without additional feed. Mednonca et al (2020) reported that Brazilian family farms struggled to meet market and institutional milk production standards.

The findings revealed that small-sized farmers in cluster three rely on family or exchange labor and have traditional sheds. These farms adopted diverse production systems, integrating livestock such as cattle, pigs, goats, poultry, cereals, and vegetables. This finding aligns with Fanchone et al (2020), who reported that family farms are more likely to adopt agro-ecological practices and maintain diverse operations than specialized farms. The farmers primarily use low-nutrition feed, such as rice straw, crop residues, and locally available feeds for animal husbandry. Similar findings were reported by Bendahan et al (2018), who found that small-sized farming is labor-intensive and depends heavily on local knowledge. Further, the feed supply for dairy animals in Nepal is inadequate, with a deficit of 42% in metabolizable energy, 38% in crude protein, and 33% in dry matter (Osti 2020). The majority of farmers, 77%, use rice straw as their primary animal feed (NDDB 2020). The poor quality of feed, combined with insufficient green fodder and limited access to advanced technology, significantly reduces milk production in Nepal (Paudel et al 2021, Sah et al 2020). However, small-sized farmers could benefit from regular extension services and collective marketing efforts (Tonet et al 2023). It is essential to enhance dairy extension services, improve access to local inputs, and implement fodder and forage programs to increase the overall milk yield of dairy farms. These farmers rely heavily on dairy cooperatives to receive extension services as well as assistance in production and marketing activities.

CONCLUSION

This study examined the typology of dairy cattle farms in Nepal, categorizing them into large-size, medium-size, and small-size cattle farms. The characteristics of these clusters vary in terms of milk yield, intensity and scale of production, commercialization, and management practices. Large-size farms tend to be highly specialized and commercially focused, with large number of dairy cattle, high volume of milk production and sales per day, more technologies used, and greater access to resources. Medium-size farms have a moderate production level, combining traditional and modern practices relying mainly on family labor. Small-size dairy cattle farms follow traditional practices using low inputs and having limited access to resources, technology, and services.

This study emphasizes the need for tailored interventions for each farm cluster. Large-size farms can improve their efficiency by adopting modern technologies and good husbandry practices, which can be facilitated through training programs. These farms often face high operational cost, including feed, labor, and machinery expenses. The farms can reduce production costs by using machine milking, enhanced feeding practices, and promoting local fodder and forage options. It is crucial to provide access to credit through soft loan in investments for farm expansion and innovation in dairy farms. Medium-sized farms need support for infrastructure development by using modern tools and equipment and providing accessible animal healthcare services. These farms would benefit from enhanced information dissemination, improved quality and hygiene practices, and support for product diversification. The opportunities for collective forage production in marginal land could address the land constraints. Small-sized farms need better input supplies, extension services, and opportunities for integration into cooperatives. Regular dairy extension services are crucial for these farms to adopt modern practices, access necessary inputs, and receive technical training in dairy farming. The subsidy to enable the purchase of high-yielding breeds and quality feed and upgrade the farm through infrastructure support can motivate farmers to expand their farms. Similarly, these farmers heavily rely on dairy cooperatives for milk production and marketing services. Therefore, it is essential to strengthen the connection between farmers and dairy cooperatives to ensure mutual benefits for both parties. Further, this study suggests that future research on location-based typology can support region-specific policy adjustments.

Acknowledgements

We would like to thank all dairy farmers and stakeholders for their contributions in data collection process.

Authors' Contributions

Jyoti Dhungana: Conceptualization, data collection, data analysis, methodology and write up of original draft, Devendra Gauchan: writing, review and editing, methodology, Krishna Prasad Timsina: review and editing, conceptualization. Hari Krishna Panta: conceptualization, writing, and editing.

Conflicts of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Publisher's Note

All claims made in this article are those of the authors alone; they do not necessarily reflect the views of any affiliated organizations, the publisher, the editors, or the reviewers.

REFERENCES

Abbasi S and K Nawab. 2021. Determinants of the dairy technology adoption by the rural milk producers in district muzaffarabad, azad Jammu and Kashmir. Sarhad Journal of Agriculture **37**(3): 921-929. https://dx.doi.org/10.17582/journal.sja/2021/37.3.921.929

ADS. 2015. Agriculture Development Strategy. The Ministry of Agriculture and Livestock Development, Singha Durbar Kathmandu Nepal.

Ahikiriza E. 2021. Typology and characterization of dairy cattle farmers in Sub-Saharan Africa. In 21st PhD Symposium of the Belgian Association of Agricultural Economists (BAAE): Agricultural and Natural Resource Economics. https://biblio.ugent.be/publication/8729189/file/8729192 (accessed on 15 May 2024)

Aktar MF, AR Abdullah, AH Jantan and D Hossan. 2020. Factors influencing entrepreneurial success among the rural women entrepreneurs in Bangladesh. International Journal of Business and Economy **2**(3): 42-58. https://myjms.mohe.gov.my/index.php/ijbec/article/download/11221/5398 (accessed on 22 May 2024)

Azeze T, M Eshetu, Z Yilma and T Berhe. 2024. Typification and differentiation of smallholder dairy production systems in smallholder mixed farming in the highlands of southern Ethiopia. PLoS ONE **19**(8): e0307685. https://doi.org/10.1371/journal.pone.0307685.

Bánkuti FI, RC Prizon, JC Damasceno, MM De Brito, MSS Pozza and PGL Lima. 2020. Farmers' actions toward sustainability: A typology of dairy farms according to sustainability indicators. Animal **14**(2): s417-s423. https://dx.doi.org/10.1017/S1751731120000750

Barnes AP, B Thompson and L Toma. 2022. Finding the ecological farmer: A farmer typology to understand ecological practice adoption within Europe. Current Research in Environmental Sustainability **4**: 100125. https://doi.org/10.1016/j.crsust.2022.100125.

Bartkowski B, C Schüßler and B Müller. 2022. Typologies of European farmers: approaches, methods and research gaps. Regional Environmental Change **22**(2):43. https://doi.org/10.1007/s10113-022-01899-y.

Beattie JR and FW Esmonde-White. 2021. Exploration of principal component analysis: deriving principal component analysis visually using spectra. Applied Spectroscopy **75**(4): 361-375. https://dx.doi.org/10.1177/0003702820987847.

Bendahan AB, R Poccard-Chapuis, RD de Medeiros, ND Costa and JF Tourrand. 2018. Management and labour in an integrated crop-livestock-forestry system in Roraima. Brazilian Amazonia. Cahiers Agricultures 27. https://doi.org/10.1051/ cagri/2018014.

CASA. 2020. Dairy Sector Strategy–Nepal. Commercial Agriculture for Smallholders and Agribusiness Nepal. Available at: https://www.casaprogramme.com/wp-content/uploads/CASA-Nepal-DairySector-analysis-report.pdf (accessed on 20 October 2024).

CBS. 2021. National Population and Housing Census, 2021 Observation Report: Century Printing & Publishing Nepal, Pvt. Ltd, KTM. Kathmandu: Central Bureau of Statistics. https://censusnepal.cbs.gov.np/results/downloads/census-dataset

Dhakal SC. 2022. Determinants of technical efficiency among dairy farms in Chitwan, Nepal. Journal of Agriculture and Forestry University 5:149-156. https://old.afu.edu.np/sites/default/files/Determinants_of_technical_efficiency_among_dairy_farms_in_Chitwan_Nepal.pdf ((accessed on 20 June 2024).

Erdem M and HB Ağır. 2024. Enhancing Dairy Farm Welfare: A Holistic Examination of Technology Adoption and Economic Performance in Kahramanmaraş Province, Turkey. Sustainability **16**(7): 2989. https://doi.org/10.3390/su16072989, Fanchone A, G Alexandre, E Chia, JL Diman, H Ozier-Lafontaine and V Angeon. 2020. A typology to understand the diversity of strategies of implementation of agroecological practices in the French West Indies. European Journal of Agronomy **117**:126058. https://doi.org/10.1016/j.eja.2020.126058

Fiorillo V and BM Amico. 2024. Milk quality and economic sustainability in dairy farming: A systematic review of performance indicators. Dairy **5**(3), 384-402. https://doi.org/10.3390/dairy5030031.

Gautam G and U Khadka. 2022. Reproductive and Productive performance of crossbred and Terai Cattle in Bardiya District of Nepal. Journal of Nepal Agricultural Research Council **8**:64-71. https://doi.org/10.3126/jnarc.v8i.44862.

Gobin A and AV Herzele 2023. A Data-Driven Farm Typology as a Basis for Agricultural Land Use Decisions. Land **12**(11):2032. https://doi.org/10.3390/land12112032

Habanabakize E, K Ba, C Corniaux, P Cortbaoui and E Vasseur. 2022. A typology of smallholder livestock production systems reflecting the impact of the development of a local milk collection industry: Case study of Fatick region, Senegal. Pastoralism **12**(1):22. https://doi.org/10.1186/s13570-022-00234-8

Hassall KL, F Baudron, C MacLaren, JE Cairns, T Ndhlela, SP McGrath and SM Haefele. 2023. Construction of a generalised farm typology to aid selection, targeting and scaling of on farm research. Computers and Electronics in Agriculture **212**:108074.https://doi.org/10.1016/j.compag.2023.108074.

Huber R, B Bartkowski, C Brown, N El Benni, JH Feil, P Grohmann and B Müller. 2024. Farm typologies for understanding farm systems and improving agricultural policy. Agricultural System **213**:103800. https://doi.org/10.1016/j.agsy.2023.103800.

Innazent A, D Jacob, JS Bindhu, B Joseph, KN Anith, N Ravisankar and AS Panwar. 2022. Farm typology of smallholders integrated farming systems in Southern Coastal Plains of Kerala, India. Scientific Reports **12**(1):333. https://doi.org/10.1038/s41598-021-04148- 0

Kaiser HF. 1960. The application of electronic computers to factor analysis. Educational and psychological measurement **20**(1):141-151. https://doi.org/10.1177/001316446002000116.

Kamadi VSRPV, AA Rao and TS Mahalakshmi. 2016. A computational intelligence technique for the effective diagnosis of diabetic patients using principal component analysis (PCA) and modified fuzzy SLIQ decision tree approach. Applied Soft Computing **49**:137-145. http://dx.doi.org/10.1016/j.asoc.2016.05.010.

Kaur J, AK Prusty, N Ravisankar, AS Panwar, M Shamim, SS Walia and P Kashyap. 2021. Farm typology for planning targeted farming systems interventions for smallholders in Indo-Gangetic Plains of India. Scientific reports **11**(1): 20978. https://doi.org/10.1038/s41598-021-00372-w

Khanal P, R Dhakal, T Khanal, D Pandey, NR Devkota and MO Nielsen. 2022. Sustainable livestock production in Nepal: A focus on animal nutrition strategies. Agriculture **12**(5): 679. https://doi.org/10.3390/books978-3-0365-5530-0.

Mendonça BSD, FI Bánkuti, MSDS Pozza, HL Perez and TTDS Siqueira. 2020. A typology of corporate and family dairy farms in eastern Goiás, Brazil. Ciência Rural. **50**(10) https://doi.org/10.1590/0103-8478cr20190285.

MoALD. 2023. Statistical information on Nepalese agriculture 2021/2022. Ministry of Agriculture and Livestock Development, Singhadurbar, Kathmandu

MoF. 2022. Economic Survey 2021/22. Ministry of Finance, Government of Nepal. https://giwmscdnone.gov.np/media/pdf_upload/1674635120_Economic_Survey_2022_piyux3h.pdf.

MoICS. 2023. Micro, small and cottage industry report 2022/23. Ministry of Industry, Commerce and Supplies, the Government of Nepal Singh Durbar Kathmandu Nepal.

Mugumaarhahama Y, RBB Ayagirwe, VB Mutwedu, NC Cirezi, DS Wasso, PC Azine and K Karume. 2021. Characterization of smallholder cattle production systems in South-Kivu province, eastern Democratic Republic of Congo. Pastoralism **11**:1-15. https://doi.org/10.1186/s13570-020-00187-w.

NDDB. 2020. Five-year Dairy Development Plan. Study on Cost of Milk Production, Dairy Development Board, Government of Nepal.

NDDB. 2023. Study of the present tax system on the import of raw and prepared goods used in the dairy sector, Harihar Bhawan Lalitpur Nepal. https://giwmscdnone.gov.np/media/app/public/329/posts/1718254391_56.pdf ((accessed on July 2024).

NDDP. 2021. National Livestock Breeding Policy 2021. The Ministry of Agriculture and Livestock Development, Department of Livestock Development, Harihar Bhawan Lalitpur Nepal.

NLBO. 2021. Annual Technical Report. Government of Nepal, Ministry of Agriculture and Livestock Development, Department of Livestock Services, National Livestock Breeding Office, Pokhara- 14, Lampatan, Kaski, Nepal. http://nlbo.gov.np/downloadfile/NLBO_POKHARA_Annual_Book_NLBO 2076_16 1 1801190.pdf (accessed on 12 May 2024).

Nyambo DG, ET Luhanga and ZQ Yonah. 2019. A review of characterization approaches for smallholder farmers: Towards predictive farm typologies. The Scientific World Journal **6**:1-9. https://doi.org/10.1155/2019/6121467.

Osti NP. 2020. Animal feed resources and their management in Nepal. Acta Scientific Agriculture. **4**(1): 02-14. https://actascientific.com/ASAG/pdf/ASAG-04-0737.pdf ((accessed on 10 July 2024).

Otieno GO, K Muendo and R Mbeche. 2021. Smallholder dairy farming characterisation, typologies and determinants in Nakuru and Nyandarua counties, Kenya. Journal of Agriculture, Science and Technology **20**(1): 1-23. https://www.ajol.info/index.php/jagst/article/view/219226 (accessed on 14 July 2024).

Patel A. J, DN Rank. 2023. Principal Component Analysis of Biometric Traits Explain the Body Weight of HF Crossbred Cattle. Indian Journal of Veterinary Sciences and Biotechnology **19**(2): 34-39. https://doi.org/10.48165/ijvsbt.19.2.07.

Paudel S, SH Ghimire and YR Pandey. 2021. Cattle research in Nepal: current status, challenges and way forward. In Proceedings of 12th national workshop on livestock and fisheries research in Nepal. Nepal Agric. Res. Counc (pp. 14-21).

Paul BK, JC Groot, CA Birnholz, B Nzogela, A Notenbaert, K Woyessa and P Tittonell. 2020. Reducing agro-environmental trade-offs through sustainable livestock intensification across smallholder systems in Northern Tanzania. International Journal of Agricultural Sustainability **18**(1): 35-54. https://doi.org/10.1080/14735903.2019.1695348.

Pinto A, T Yin, M Reichenbach, R Bhatta, E Schlecht and S König. 2020. Phenotypic dairy cattle trait expressions in dependency of social-ecological characteristics along rural–urban gradients Sustainability **12**(21):9021. https://doi.org/10.3390/su12219021.

Poudel S, D Chhetri and SR Barsila. 2023. Productive and Reproductive Performance of Farmers Managed Dairy Cattle in Western Chitwan, Nepal. Journal of the Institute of Agriculture and Animal Science **37**(2023): 160-172. https://doi.org/10.3126/jiaas.v37i1.57003

Reddy GT, MPK Reddy, K Lakshmanna, R Kaluri, DS Rajput, G Srivastava and T Baker. 2020. Analysis of dimensionality reduction techniques on big data. IEEE Access **8**: 54776-54788. https://doi.org/10.1109/ACCESS.2020.2980942.

Reichenbach M, A Pinto, S König, R Bhatta and E Schlecht. 2021. Dairy production in an urbanizing environment—Typology and linkages in the megacity of Bengaluru, India. PLoS One. **16**(8). https://doi.org/10.1371/journal.pone.0255791report.pdf.

Sah K, P Karki, RD Shrestha, A Sigdel, AT Adesogan and GE Dahl. 2020. MILK Symposium review: Improving control of mastitis in dairy animals in Nepal. Journal of dairy science **103**(11): 9740-9747. https://doi.org/10.3168/jds.2020-18314.

Shingh S, CS Kalwar, S Poudel, P Tiwari and S Jha. 2020. A study on growth and performance of dairy sector in Nepal. International Journal of Environment, Agriculture and Biotechnology **5**(4): 2456-1878. https://dx.doi.org/10.22161/ijeab.54.36.

Shrestha N. 2021. Factor analysis as a tool for survey analysis. American journal of Applied Mathematics and statistics **9**(1): 4-11.

Stapley E, EO Keeffe and N Midgley. 2022. Developing typologies in qualitative research: The use of ideal-type analysis. International Journal of Qualitative Methods. **21**:16094069221100633. https://doi.org/10.1177/16094069221100633.

Tacconi F, K Waha, JJ Ojeda and P Leith. 2022. Drivers and constraints of on-farm diversity. A review. Agronomy for Sustainable Development **42**(1):2. https://doi.org/10.1007/s13593-021-00736-6.

Thar SP, T Ramilan, RJ Farquharson and D Chen. 2021. Identifying potential for decision support tools through farm systems typology analysis coupled with participatory research: A case for smallholder farmers in Myanmar. Agriculture **11**(6):516. https://doi.org/10.3390/agriculture11060516.

Tonet RM, FI Bánkuti, JC Damasceno, TT da Silva Siqueira, MDM Bouroullec and MM Loddi. 2023. Typology of Brazilian dairy farms based on vulnerability characteristics. Animal-Open Space **2**: 100040. https://doi.org/10.1016/j.anopes.2023.100040.

Tramontini RDCM, FI Bánkuti, MSS Pozza, EM Massuda, JC Damasceno, AM Dias and GT Santos. 2021. Typology of dairy production systems based on management strategies in Paraná State, Brazil. Tropical Animal Science Journal **44**(1):123-130. https://doi.org/10.5398/tasj.2021.44.1.123.

Upadhaya S, JG Arbuckle and LA Schulte. 2021. Developing farmer typologies to inform conservation outreach in agricultural landscapes. Land use policy **101**:105157. https://doi.org/10.1016/j.landusepol.2020.105157.

Zepeda A, S Cheesman, N Neupane, N Shrestha, RN Shrestha, TS Amjath-Babu and S Lopez-Ridaura. 2023. Characterizing farm households in Khotang, Eastern Nepal, through a quantitative farming systems typology. International Maize and Wheat Improvement Center. https://cgspace.cgiar.org/server/api/core/bitstreams/9a43d9fd-6e52-44b8-8dc6-4691bf53d53d/content

Zoma-Traoré B, A Soudré, S Ouédraogo-Koné, N Khayatzadeh, L Probst, J Sölkner and M Wurzinger. 2020. From farmers to livestock keepers: a typology of cattle production systems in south-western Burkina Faso. Tropical Animal Health and Production **52**:2179-2189. https://doi.org/10.1007/s11250-020-02241-6