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Exploring relationships and predictive models based on populations of cattle and farmers in upper northern Thailand

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ABSTRACT

The study was conducted to explore relationships and predictive models using quantitative information based on populations of beef, dairy cattle, and farmers in upper northern Thailand from 2008 to 2023, aiming to describe the strength and relationship of variables to create a basic predictive model that may benefit planning and decision-making in entrepreneurship. Quantitative data were provided by the Information and Statistics Group, Information and Communication Technology Center, Department of Livestock Development, Thailand, including the numbers of beef and dairy cattle populations, and farmers who raised beef and dairy cattle. Data for beef cattle were classified into four categories, while dairy cattle were classified into three. The results indicated highly significant relationships between all beef categories and household farmers ($p<0.01$), and four effective predictive models were generated. Simultaneously, significant relationships were found among all categories of dairy cattle and household farmers ($p<0.05$), and three predictive models were initiated. In comparison, the population of the beef herd was superior to the dairy herd ($p<0.01$) at a ratio of approximately 8.74:1. Likewise, the population of beef farmers was greater than the dairy farmers ($p<0.01$) at a ratio of about 36.04:1. In conclusion, there is clear statistical evidence that shows strengthen relationship between animal numbers and farmers that may able to be simple tools for prediction related to agricultural production and entrepreneurship in upper northern Thailand. Further research should be conducted to determine more criteria that may deal with simultaneous influence, maximum likelihood estimation of parameters.

Keywords: Relationship, Predictive model, Beef, Dairy, Upper northern Thailand

INTRODUCTION

Beef and dairy production are large-scale operations that are crucial in supporting rural livelihoods, ensuring food security, and driving the economy of an upper-middle-income country like Thailand. Both sectors are primarily operated by smallholder farmers, who differ in terms of geographical distribution, animal population, and market dynamics (Bunmee et al., 2018; Buaban et al., 2020). In the past two decades, the agricultural sector, together with forestry and fishing sectors, contributed approximately 8.8% added value to Thailand's GDP in 2022. Based on market values, beef production is estimated to be approximately 0.1 to 0.2% of Thailand's GDP (Seankamsorn and Cherdthong, 2020), where dairy production is likely to contribute about 0.3 to 0.5% of Thailand's GDP (Alvarez Aranguiz and Spoelstra, 2025). Beef production in Thailand mainly operates by smallholder farmers for domestic consumption. Beef cattle are mostly raised in the northeastern region (55.99%), with 16.82% in the central region, 15.37% in the northern region, and 11.82% in the southern region (Bunmee et al., 2018; Chaisrisawasdsuk et al., 2025). Likewise, the dairy population is dominant in the central region of Thailand (32.65%), the northeastern region (27.80%), the western region (20.93%), the northern region (13.29%), and other (5.33%) (DLD, 2025); about 360,000 to 400,000 lactating dairy cows produced approximately 1.2 to1.3 million tons of raw milk nationwide (Alvarez Aranguiz and Spoelstra, 2025; Buaban et al., 2020).

Upper northern Thailand is a region well-known for its scenic and culturally elegant landscapes due to its mountainous landscapes, cool climate, particularly during the cool season, distinctive Lanna culture, and diverse ethnic communities. It refers to eight provinces, including Chiang Mai, Chiang Rai, Lampang, Lamphun, Mae Hong Son, Nan, Phayao, and Phrae, where the combined area is approximately 93,690 km², which accounts for about 18% of Thailand's total land area, with a population of approximately 6.2 million people. According to DLD data, there are about sixty-five thousand heads of beef cattle currently in this region, mainly crowded in Lampang, Chiang Mai, Phrae, Chiang Rai, and Phayao, respectively (Office of Regional Livestock 5, 2020a). Likewise, dairy cattle are more than thirty thousand head of milking cows; more than half population has raised in Chiang Mai, and Lamphun (Office of Regional Livestock 5, 2020b; Punyapornwithaya et al., 2021; Boonyayatra et al., 2022). In the past two decades, the number of cattle population and farmers has fluctuated quite a bit in response to changes in geographical distribution, market dynamics, and some disease outbreaks, such as Covid-19 for Thai people, which began in 2020, and Lumpy Skin for ruminant animals, which began in 2021 (Chaisrisawasdsuk et al., 2025). Moreover, information that serves as a basic tool for drawing inferences about the relationship between qualitative data based on large ruminant animals and farmers in this region is limited. One simple tool that has received attention, perhaps the most used of all data analysis tools, which can efficiently describe those relationships, is regression analysis. It is a type of approach with the potential to be used as predictive models, designed to shed light on certain aspects of the mechanism that relate to them. Moreover, it can build predictive models from real data sets into an algebraic form to detect the degree of importance of each variable from sets of data involving measurements on the variables (Myers, 1990).

The objective of this study was to identify the simple predictive models and the relationship between either beef or dairy cattle population versus farmer population using simple linear regression as a basic tool. These would help understand the strength and relationship between variables in each category, which may be useful in prediction for planning or decision-making related to beef and dairy cattle production in upper northern Thailand.

MATERIALS AND METHODS

Area and scope

Data were collected using online livestock data as the secondary data source provided by the Department of Livestock Development, Ministry of Agriculture and Cooperatives, Thailand, for fifteen consecutive years between 2008 and 2023: except 2016, no available data: covering eight provinces of the Thai upper northern regions, including Chiang Mai, Lampang, Lamphun, Chiang Rai, Mae Hong Son, Phrae, Phayao, and Nan (Figure 1). Data covered the main criteria of the beef and dairy cattle population. Categories for beef cattle data were: total, native, mixed purebred and crossbred, and fattened cattle populations. On the other hand, three data categories —total, female, and milking cows — were collected for the dairy cattle population.

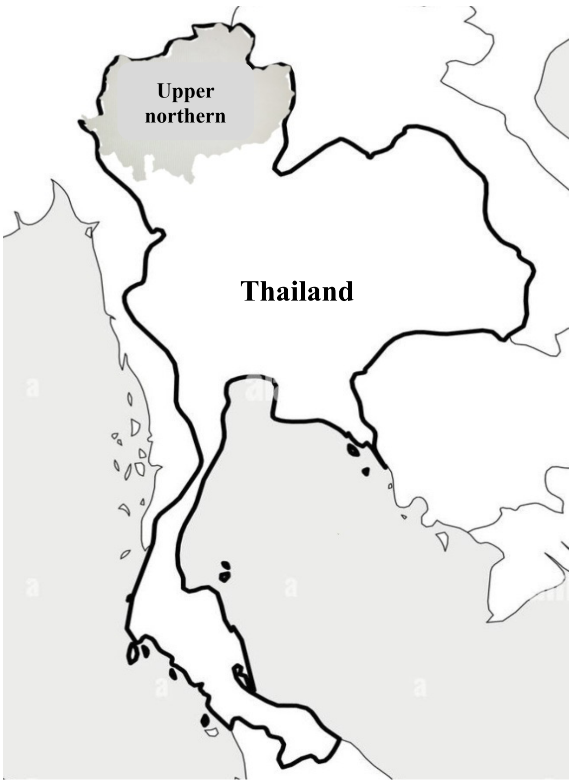

Figure 1. Upper northern Thailand.

Statistical protocols

After data exploration and collection, they were recorded into Microsoft Excel spreadsheets and then analyzed for descriptive statistics and simple regression analysis. According to Myers (1990), predictive models were built to describe the relationship between a dependent variable (Y) and a single independent variable (X) using a linear equation. The model is represented as:

$$Y = \beta_0 + \beta_1 X + \varepsilon,$$

where β_0 is the y-intercept or the predicted value of Y when X is zero; β_1 is the slope of the predicted value of Y changes if X increases by 1 unit; and ε is the error term.

The fitness of predictive models was evaluated using R-squared, Pearson correlation, and F-statistic. Overall, beef and dairy production scales were compared using an independent sample t-test (Steel and Torrie, 1980). Significance was declared for correlation, Pearson correlation coefficients, and F-statistic when the P-value <0.05. All statistical protocols were performed using IBM SPSS Version 27 (IBM Corp, 2020).

RESULTS AND DISCUSSION

Beef cattle

Total beef cattle

Descriptive statistics relating to the total beef population and farmer data set in upper northern Thailand are presented in Figure 2 and Table 1. The total beef cattle population averaged 590,281.66 heads, with a range between a minimum of 397,390 and a maximum of 897,705, while beef farmers averaged 63,241.26 households with a range between a minimum of 44,460 and a maximum of 93,450. In the past decade, the total number of beef cattle in upper northern Thailand accounted for 6.11% of the country's total beef cattle population, which was approximately 9.65 million, while beef farmers made up only 4.51% of the 1.4 million national farm households (DLD, 2023). Major beef breeds include Brahman crossbreds, while other breeds are Bos taurus crossbreds, such as Charolais crossbreds and Angus crossbreds (Thannithi et al., 2025).

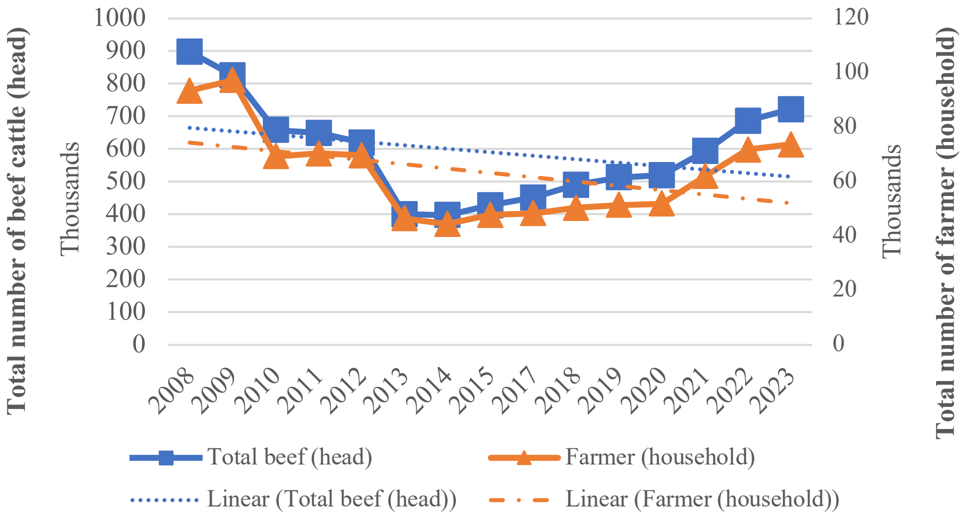

Figure 2. Total beef cattle and farmer populations.

Table 1. Descriptive statistics and predictive model of total beef population and beef farmers

Items	Mean	SD	Min	Max
Total beef population (heads)	590,281.66	152,489.22	397,390	897,705
Beef farmers (households)	63,241.26	16,715.97	44,460	93,450
Predictive model	**P-value**	**R^2**	**Pearson Correlation**	**P-value**
Model 1	<0.001	0.957	0.978	<0.001

The relationship between these two variables can be built into a simple predictive model with a P-value <0.001, suggesting that a relationship between the total beef population and the total beef farmer population exists. The relationship between the total beef cattle population and the total number of beef cattle farmers can be expressed using a simple linear regression model as Model 1:

$Y_1 = 25,894.371 + 8.924X_1$ ………..……….. [1]

where Y_1 is the total number of beef cattle population (heads), and X_1 is the number of farmers (households).

In this model, the intercept or β_0 is positive, which implies that the model predicts that Y is greater than zero when the intercept is zero. The coefficient of determination (R^2) was 0.957, suggesting that about 95.7% of the variability of the total beef population can be explained by the relationship with the total beef farmer population. R^2 indicates the proportion of variance in Y explained by X, where R^2 is greater than 0.7 or 70%, indicating a strong fit of the predictive model (Myers, 1990; Gupta et al., 2024). Simultaneously, the Pearson correlation (r) at 0.978, indicating a very strong correlation between the total beef population and the population of beef farmers, with the strength and direction of a linear relationship, with a P-value <0.001(Dancey and Reidy, 2004; Dancey and Reidy, 2011). In general, R^2 ranges from 0 to 1, while r ranges from – 1 to + 1 (Myers, 1990; Patrick et al., 2018).

Native beef cattle

The number of native beef cattle and farmers is shown in Figure 3 and Table 2. The native beef cattle population in the upper northern region had an average of 438,368.86 head, with a range between a minimum of 310,984 and a maximum of 674,970, or calculated as a percentage of 4.51, compared to the total country beef population with an average of 47,071.93 households or 3.36 % of country beef farm households that raised beef cattle (DLD, 2023).

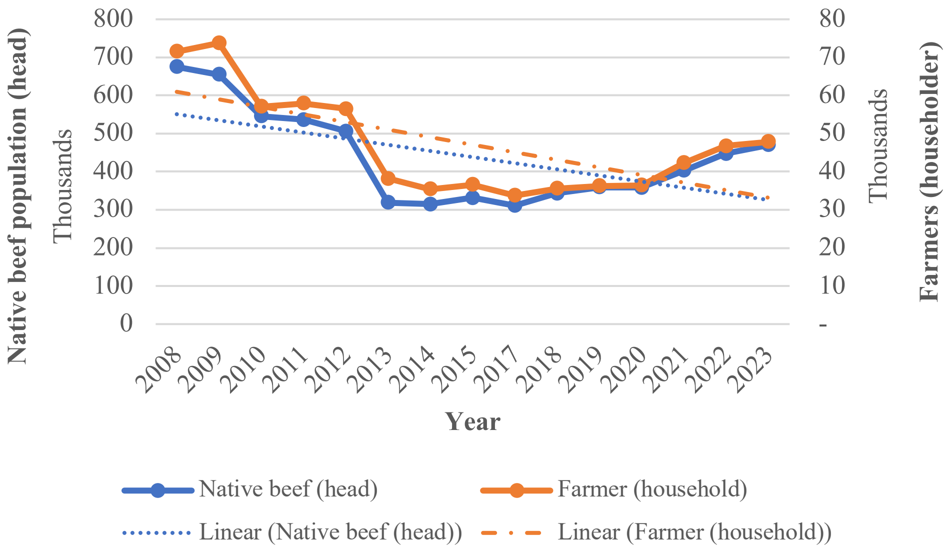

Figure 3. Native beef and farmer populations.

Table 2. Descriptive statistics and predictive model of native beef population and farmers.

Items	**Mean**	**SD**	**Min**	**Max**
Native beef population (heads)	438,368.86	122,431.01	310,984	674,970
Native beef farmers (households)	47,071.93	13,388.55	33,738	73,769
Predictive model	**P-value**	**R^2**	**Pearson Correlation**	**P-value**
Model 2	<0.001	0.976	0.988	<0.001

The relationship between the native beef cattle population and the number of beef cattle farmers can be described as a simple linear regression as a predictive model ($p < 0.05$), as Model 2:

$$Y_2 = 13{,}094.127 + 9.035X_2 \quad \text{[2]}$$

where Y_2 is the number of native beef population (heads), and X_2 is the number of native beef farmers (households).

The coefficient of determination was 0.976, suggesting that about 97.6 % of the variability of the native beef population can be explained by the relationship with the number of native beef farmers (Table 2), with strong fit of the model (Myers, 1990; Gupta et al., 2024); likewise, the Pearson correlation at 0.988 implied the strength and direction of a linear relationship ($p<0.01$) with a very strong correlation (Dancey and Reidy, 2004; Dancey and Reidy, 2011).

Purebred and crossbred beef cattle

The number of pure- and crossbred beef cattle, and farmers is shown in Figure 4 and Table 3. According to those records between 2008 and 2023, it was found that the population of purebred plus crossbred cattle in the upper northern region had an average number of 148,922.73 heads or 1.54 % of the national beef population, with 18,223.46 farm households or 1.30 % of the country (Table 3).

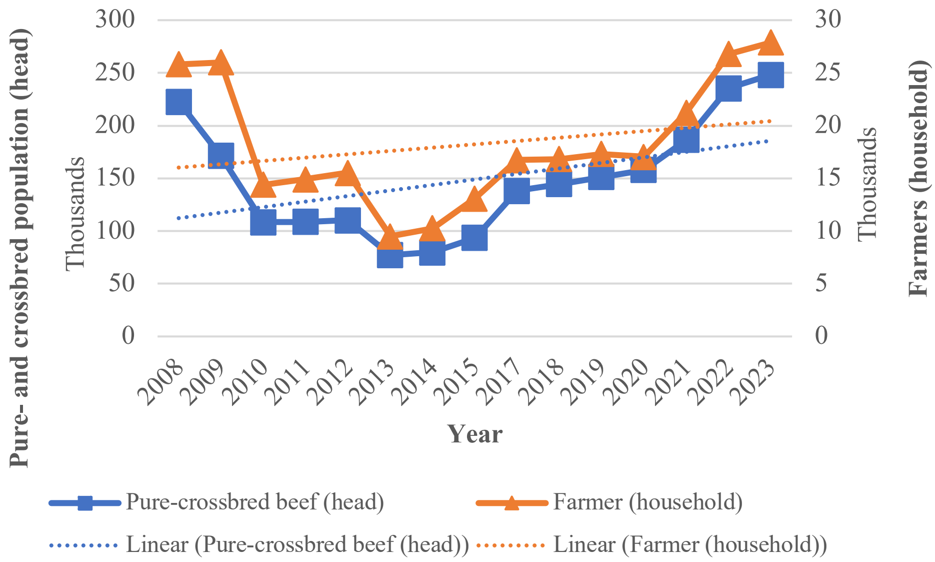

Figure 4. Pure- and crossbred beef cattle and farmer populations.

Table 3. Descriptive statistics and predictive model of purebred and crossbred beef population and farmers

Items	**Mean**	**SD**	**Min**	**Max**
Pure and crossbred beef population (heads)	148,922.73	55,208.12	77,128	248,241
Farmers (households)	18,223.46	5,969.13	9,510	27,878
Predictive model	**P-value**	**R^2**	**Pearson Correlation**	**P-value**
Model 3	<0.001	0.913	0.956	<0.001

The relationship between the population of purebred and crossbred cattle and the total number of raisers can be shown by a simple linear regression equation as a predictive model ($p < 0.05$) as follows:

$$Y_3 = -12131.338 + 8.838X_3 \quad \text{......................[3]}$$

where Y_3 is the number of purebred and crossbred beef cattle population (heads), while X_3 is the number of farmers (households).

In this model, the intercept or β_0 is negative, so the model's starting point is below zero, which may not be realistic, but the slope (β_1) may still capture a useful trend. The coefficient of determination was 0.913, suggesting that about 91.3 % of the variability of purebred and crossbred beef cattle population can be explained by the relationship with beef farmers, with a very strong fit for the predictive model (Table 3). (Myers, 1990; Gupta et al., 2024). Simultaneously, the Pearson correlation at 0.956 ($P<0.01$) indicated the strength and direction of a linear relationship ($p<0.01$) with a very strong correlation for the model. (Dancey and Reidy, 2004; Dancey and Reidy, 2011).

Fattened beef cattle

The number of fattened beef cattle and farmers is shown in Figure 5 and Table 4. The number of fattened beef cattle was relatively low compared to other categories. According to data between 2010 and 2023, it was found that the fattening cattle population of the upper northern region had an average of 3,405.46 heads with 559.76 households raising them (Table 4).

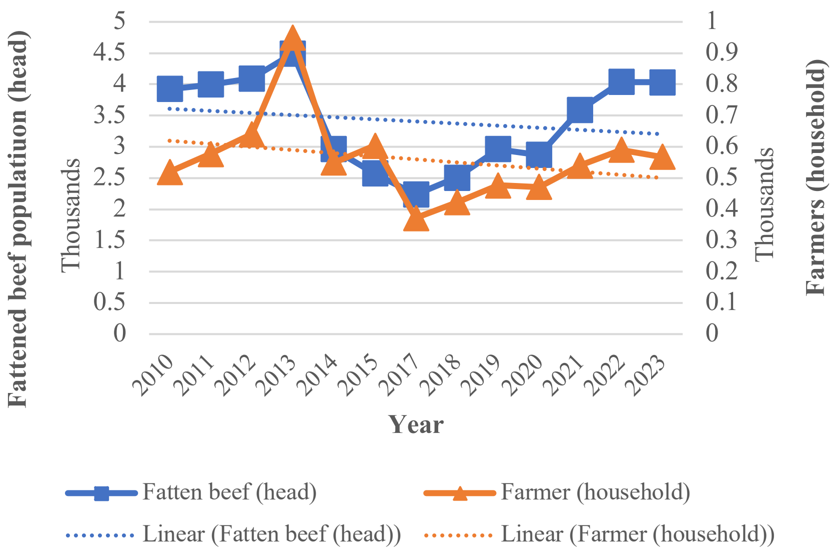

Figure 5. Fattened beef cattle and farmer populations.

Table 4. Descriptive statistics and predictive model of fattened beef population and farmers.

Items	**Mean**	**SD**	**Min**	**Max**
Fattened beef population (heads)	3,405.46	745.01	2,235	4,494
Farmers (households)	559.76	139.39	372	950
Predictive model	**P-value**	$\mathbf{R^2}$	**Pearson Correlation**	**P-value**
Model 4	<0.001	0.507	0.712	0.003

The relationship between the population of purebred cattle and crossbred cattle and the total number of raisers can be shown as a simple linear regression equation as a predictive model ($p< 0.01$) as follows:

$$Y_4 = 1275.919 + 3.804X_4 \quad \text{……………………..[4]}$$

where Y_4 is the number of fattened beef population (heads), and X_4 is the number of farmers (households).

However, the coefficient of determination was quite low at 0.507, suggesting that only 50.7 % of the variability of fattened beef cattle population can be explained by the relationship with beef farmers, or a moderate fit, which the model can explain only half the variation (Myers, 1990; Gupta et al., 2024). In contrast, the Pearson correlation still showed a very strong correlation at 0.712 ($p<0.01$) (Dancey and Reidy, 2004; Dancey and Reidy, 2011).

Dairy cattle

Total population

Between 2008 and 2023, the total dairy cattle population in the upper northern region averaged 67,468.86 heads, with 1,754.53 dairy farmer households (Figure 6 and Table 5).

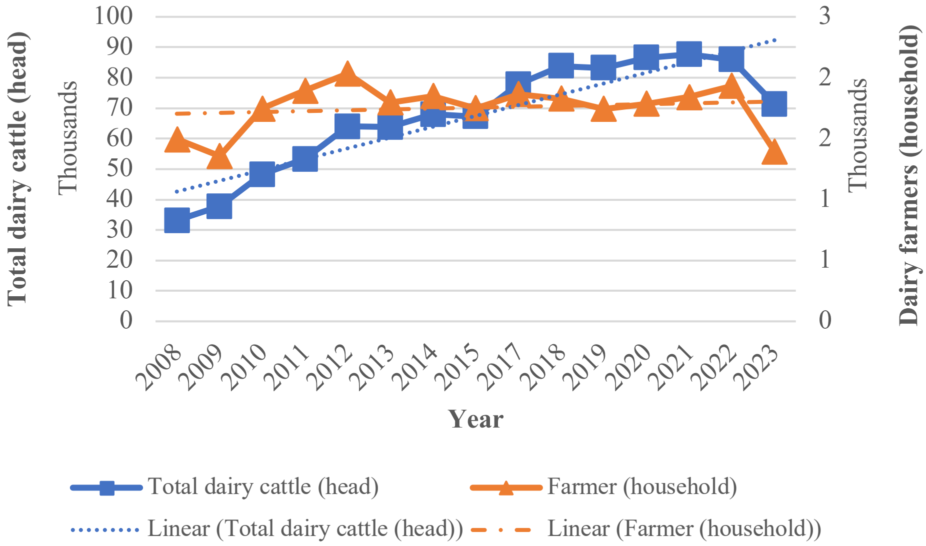

Figure 6. Total dairy cattle and farmer populations.

Table 5. Descriptive statistics and predictive model of total dairy population and farmers

Items	**Mean**	**SD**	Min	Max
Total dairy cattle population (heads)	67,468.86	17,740.71	33,159	87,684
Farmers (households)	1,754.53	193.03	1,357	2,034
Predictive model	**P-value**	**R^2**	**Pearson Correlation**	**P-value**
Model 5	0.055	0.255	0.505	0.027

The total dairy population and dairy farm population can be shown as a simple linear regression equation as follows:

$Y_5 = -14011.665 + 8.924X_5$……………………..[5]

where Y_5 is the total dairy cattle population (heads), and X_5 is the number of farmers (households).

However, this simple linear regression equation was not considered an effective predictive model ($p>0.05$). Moreover, the intercept or β_0 is negative in this model, indicating the model's starting point is below zero, which may not be realistic. However, the slope (β_1) may still capture the useful trend for the model. At the same time, the coefficient of determination is 0.255, indicating weak or modest explanatory power of the variation (Myers, 1990; Gupta et al., 2024). Concurrently, the Pearson correlation is 0.505, but still indicates a strong correlation ($p<0.05$) (Dancey and Reidy, 2004; Dancey and Reidy, 2011). This may result from outlier data caused by some large farms with a huge number of dairy cattle, which adversely affects the linear relationship.

Female dairy cattle

According to data from 2008 to 2023, the population of female dairy cattle in the upper northern region averaged 65,948.46 heads and 1,754.53 households (Figure 7 and Table 6).

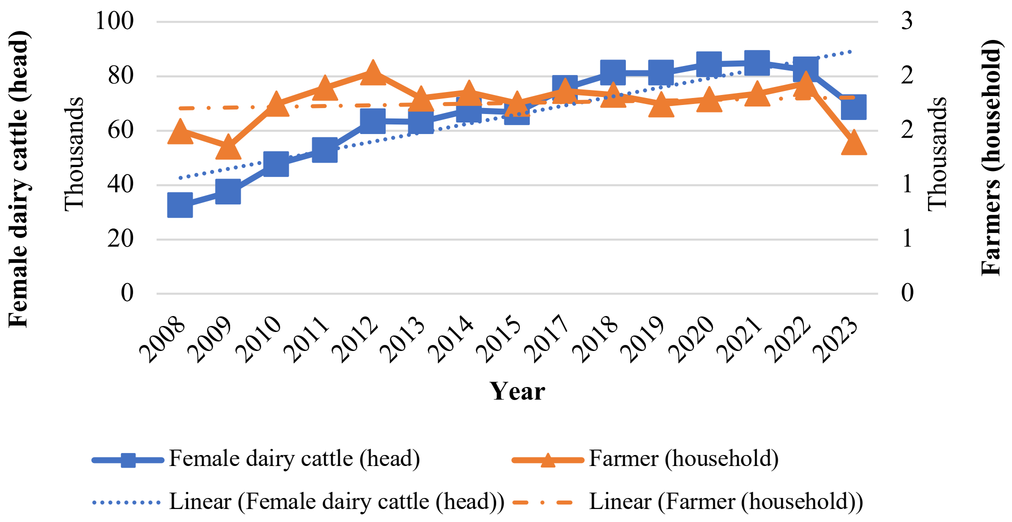

Figure 7. Female dairy cattle and farmer populations.

Table 6. Descriptive statistics and predictive model of female dairy cattle and farmers.

Items	**Mean**	**SD**	**Min**	**Max**
Female dairy cattle (heads)	65,948.46	16,904.55	32,402	84,862
Farmers (households)	1,754.53	193.03	1,357	2,034
Predictive model	**P-value**	**R^2**	**Pearson Correlation**	**P-value**
Model 6	0.045	0.274	0.523	0.023

The relationship between the total dairy cow population and the total number of dairy farmers can be shown by a simple linear regression equation as follows:

$Y_6 = -14{,}446.461 + 45.821X_6$…………………..[6]

where Y_6 is the number of female cattle population (heads), and X_6 is the number of farmers (households).

In this model, the intercept or β_0 is also negative, which may not be realistic, but the slope (β_1) may still benefit from capturing the useful trend, and the predictive model is efficient ($p<0.05$). Although the predictive models, coefficient of determination, and the Pearson correlation were significant ($p<0.05$). R^2 at 0.274 indicates that the predictive model is considered a poor approach and can explain almost none of the variation (Myers, 1990; Gupta et al., 2024). However, the Pearson correlation at 0.523 still indicated a strong correlation between the two parameters ($p<0.05$) (Dancey and Reidy, 2004; Dancey and Reidy, 2011). This may be influenced by some outlier data from some provinces that contain big farms with a huge number of dairy cattle.

Milking cow

The number of milking cows averaged 29,588.40 heads with 1,754.53 households (Figure 8 and Table 7).

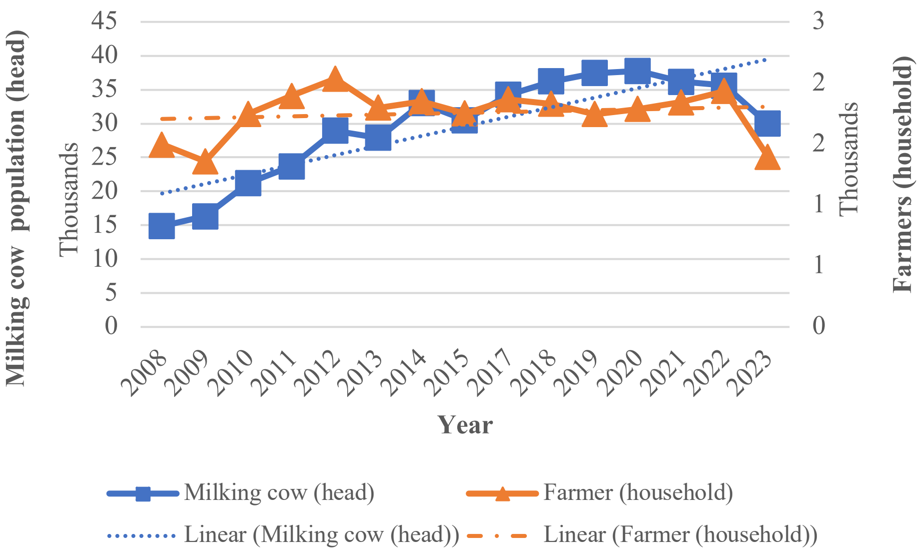

Figure 8. Milking cow and farmer populations.

Table 7. Descriptive statistics and predictive model of milking cow population and farmers.

Items	Mean	SD	Min	Max
Milking dairy cow (heads)	29,588.40	7,496.27	14,877	37,760
Farmers (households)	1,754.53	193.03	1,357	2,034
Predictive model	**P-value**	**R^2**	**Pearson Correlation**	**P-value**
Model 7	0.035	0.300	0.548	0.017

The relationship between the milking cow population and dairy farmers can be shown as a predictive model ($p< 0.05$) as follows:

$Y_7 = -7729.455 + 21.269X_7$……………………..[7]

where Y_7 is the number of milking cow population (heads), and X_7 is the number of farmers (households).

Similar to the total population and female population, the predictive model had a negative coefficient of β_0, meaning the intercept is negative, so the model's starting point is below zero, which may not be realistic, but the slope (β_1) may be full to capture the useful trend for the predictive model ($p<0.05$). The coefficient of determination at 0.300 indicates weak or modest explanatory power in explaining the variation (Myers, 1990; Gupta et al., 2024). However, the Pearson correlation at 0.548 indicates a strong correlation between X and Y ($p<0.05$) (Dancey and Reidy, 2004; Dancey and Reidy, 2011).

Beef vs. dairy

The beef population is approximately 8.74 times greater than the dairy population ($p<0.01$) (Figure 9 and Table 8). Meanwhile, the number of beef farmers is also greater than that of dairy farmers ($p<0.01$), approximately 36.04 times (Figure 10 and Table 8).

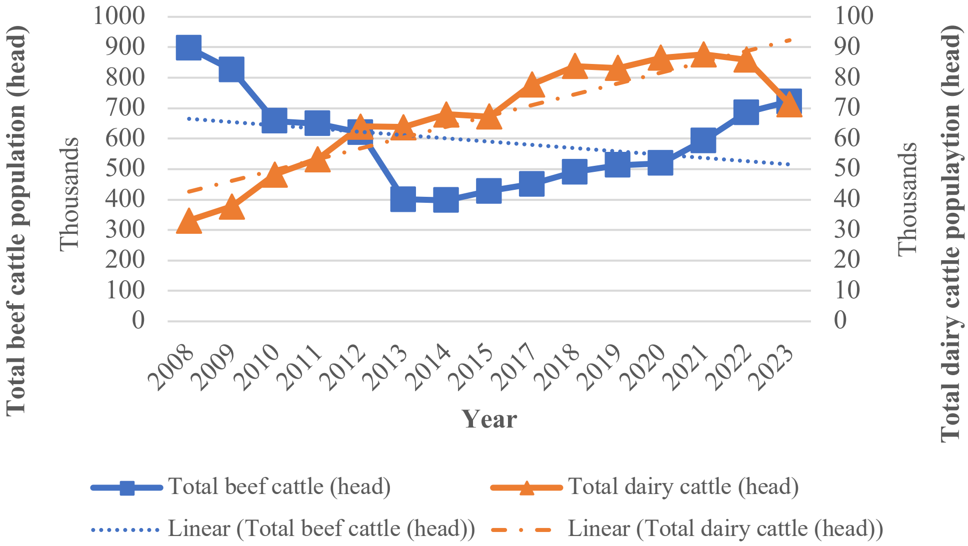

Figure 9. Total beef vs total dairy cattle populations.

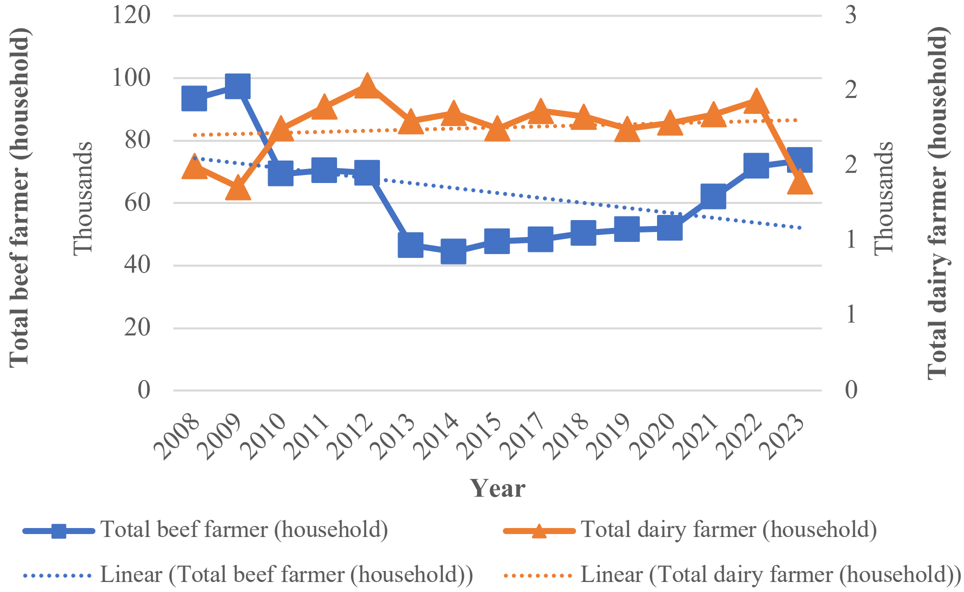

Figure 10. Total beef farmer vs. dairy farmer populations.

Table 8. Descriptive statistics and t-test for beef vs. dairy

Items	Beef	SD	Dairy	SD	t-test	P-value
Animal (head)	590,281.66	152,489.22	67,468.86	17,740.71	13.19	<0.001
Farmer (household)	63,241.26	16,715.97	1,754.53	193.03	14.24	<0.001

In the upper northern region, dairy production and farms are normally condensed into hubs around some big provinces, such as Chiang Mai, while beef production and farms are more scattered and distributed across the upper northern region and are mostly operated by smallholder farms, with native and crossbred types being dominant. (Boonyayatra et al., 2022).

CONCLUSIONS

Relationships and predictive models using quantitative information based on populations between either beef or dairy cattle and farmers in upper northern Thailand from 2008 to 2023 were explored. Significant relationships in categories of either beef or dairy cattle population with household farmers were observed, and predictive models for different animal populations were developed by using household farmers as independent variables. According to the results, there is clear statistical evidence of a strengthened relationship between animal numbers and farmers. This finding may be useful as one of the simple tools for prediction in the agricultural production of upper northern Thailand. Further study should be conducted to determine more criteria that may deal with the simultaneous influence and maximum likelihood estimation of either beef or dairy cattle population.

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