Factors affecting cattle herd size among smallholder farmers in Timor-Leste

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ABSTRACT: Smallholder farmers in Timor-Leste have been involved in raising cattle for a long time, but the cattle herd size per household has not increased significantly. The main objective of this study was to analyze the factors affecting the cattle herd size among smallholder farmers in Timor-Leste. In this study, a multi-stage random sampling technique was employed to select one hundred smallholder cattle farmers in Timor-Leste as respondents, and data were collected through a well-structured questionnaire. Descriptive statistics and an Ordinary Least Square (OLS) multiple regression analysis were employed to analyze the data. The results found that most smallholder cattle farmers in Timor-Leste were male, illiterate, and raised cattle for non-commercial purposes with limited land. The Bali breed was common, and natural mating with their own bull was practiced. The cattle were mainly fed with native grass, rice straws and plant leaves, including leucaena, turi, banana, and waru leaves. The smallholder cattle farmers had an average net farm income of 511.44 USD in 2017 and an average of 16 heads per farm. The OLS regression analysis indicated that the number of laborers working in cattle production had a significantly positive effect on the cattle herd size among smallholder farmers in Timor-Leste at P<0.01, while the number of lands for cattle rearing, education, and household total income had a significantly positive effect at P<0.05, but net farm income had a significantly negative effect at P<0.01. To increase cattle herd size among smallholder farmers in Timor-Leste, key policy recommendations include reinforcing the cattle rearing workforce, facilitating land access through redistribution and leasing, providing cattle husbandry education, and promoting the integrated farming, such as combining cattle rearing with crop cultivation or coffee production. These integrated strategies are poised to uplift both cattle production and farmers' livelihoods.

Keywords: Cattle farming system; cattle herd size; multiple regression analysis; smallholder cattle farmers; Timor-Leste

Introduction

Timor-Leste is a small country located at the eastern end of the Indonesian archipelago and to the north of Australia with a land size of about 15,000 square kilometers (Democratic Republic of Timor-Leste, 2011). Its topography is mountainous, with highlands in the central part of the island and more fertile lowland areas concentrated along the northern and southern coasts. The climate has two seasons: a rainy season with heavy rainfall, and a dry season when droughts are possible (United States Agency for International Development, 2013). Timor-Leste's climate is primarily influenced by the Intertropical Convergence Zone, which creates distinct climate patterns between the northern and southern coasts. This is due to Timor Island's geographical position, situated between the humid climate of Southeast Asia and the arid conditions of Central Australia (Da Costa et al., 2003).

Timor-Leste's strategic development plan for 2011-2030 aims to raise the country to middle-upper income status by 2030. A key strategy for economic growth is to establish a diversified economy, which involves creating new revenue streams beyond oil and gas. The agricultural sectors, including food and industrial crops, coffee, horticulture, livestock, and fisheries, are prioritized as potential drivers of economic diversification, enhancing national income and the livelihoods of the rural population (Democratic Republic of Timor-Leste, 2011; United States Agency for International Development, 2013). According to the 2019 Timor-Leste Agricultural Census, 141,141 households, or 66% of all households, were involved in agriculture. Additionally, 134,158 households, comprising 95% of the total agricultural households, engaged in livestock activities. Among these, cattle were the predominant livestock, with 57,637 households raising them, accounting for 43% of all livestock households (General Directorate of Statistics, Ministry of Finance, and the Ministry of Agriculture and Fisheries, 2020).

Cattle production plays important roles in Timor-Leste's economy, society, and culture. It contributes to family cash income, saving, food supply, social status, and traditional ritual ceremonies. Most cattle farms in Timor-Leste are smallholder operations with 2 to 6 cattle per household. This herd size is similar to neighboring countries such as Indonesia and Malaysia, raising 1 to 6 cattle per household (Ariff et al., 2015). As reported by General Directorate of Statistics, Ministry of Finance, and the Ministry of Agriculture and Fisheries (2020), there has been a modest growth in the average herd size of cattle per household in Timor-Leste, increasing from 3.36 cattle per household in 2004 to 4.96 cattle per household in 2019.

Bali cattle were introduced for raising in Timor-Leste in 1912 during the Dutch and Portuguese occupation, and they have since become a native breed raised throughout the country (Metzner, 1977). However, Copland et al. (2003) found that biological problems of the Bali breed cattle in Timor-Leste, such as a low reproduction rate with a long calving interval between 18 to 24 months and high cattle mortality rates of around 10% for adults and 20% for calves, have hindered an increase in cattle production and yield. In addition, Timor-Leste's cattle farmers have primarily raised cattle for social and ceremonial purposes rather than for commercial purposes. They have lacked knowledge and expertise in various aspects of cattle farming, including animal care, feeding, pasture management, disease control, and breeding (Australian Centre for International Agricultural Research, 2017). Moreover, cattle production in Timor-Leste has been characterized by a low input-low output system, meaning that a low level of inputs such as feed, labor, and capital is used, resulting in low cattle live weight (Waldron et al., 2016). These constraints are mostly related to inadequate animal husbandry and management techniques. Besides, issues such as restricted access to feed, poor-quality forage resource, cattle disease outbreaks, and difficulties in accessing credit and markets serve as barriers to expanding cattle production and productivity among small-scale farmers (Copland et al., 2003; Fan et al., 2013; Setiadi et al., 2016).

According to the Australian Centre for International Agricultural Research (2017), the average profit derived from cattle production by surveyed households in Timor-Leste amounted to USD 440 per year, with high variability across different regions. This suggests that despite the low productivity of Timor-Leste's cattle production system, there is potential for financial profitability in cattle production. Timor-Leste, with its semi-arid regional agroclimatic conditions and hilly topography, features communal grazing areas covering approximately 200,000 ha. These areas are abundant with native grasses and shrubs and sustain cattle throughout the 6 to 8 months of the wet season, utilizing a freely grass-grazing system. However, in the dry season, a shortage of pasture occurs, causing farmers to

tether their cattle near their homes and cut forage to feed them. Therefore, there is a pressing need to address and develop these rudimentary grazing areas to support future cattle production (Da Costa et al., 2003). In addition, the rapidly increasing demand for livestock products in Timor-Leste and Indonesia offers a significant opportunity for domestic cattle farmers. However, the government of Timor-Leste should provide support for the enhancement of cattle production and marketing systems. This can facilitate Timor-Leste's economic diversification and development goals, leading to increased rural incomes, improved living standards for farmers, and greater protein availability for domestic consumption (Australian Centre for International Agricultural Research, 2017).

Although farmers in Timor-Leste have been involved in cattle production for a long time and have dedicated time and effort to it, the size of their cattle herds has not increased significantly, and the growth rate of the country's cattle population has remained stable. It was necessary to investigate the causes of smallholder cattle herd size remaining unchanged for so long. The objectives of this research were to study the socio-economic characteristics and farming management of smallholder cattle farmers and to analyze the factors affecting the cattle herd size among smallholder farmers in Timor-Leste. The results of the study provided information on the socio-economic characteristics and farming management of smallholder cattle farmers, as well as policy recommendations for the expansion of cattle herd size for smallholder farmers in Timor-Leste.

Methodology

Area of study

Timor-Leste is a small Island State in Southeast Asia, between Indonesia and the Australian continent. The country is situated between 8.1° to 9.5° south longitude and 125.0° to 127.3° east longitude (Lopes and Nesbitt, 2012) and covers a land area of approximately 15,000 square kilometers (Democratic Republic of Timor-Leste, 2011). Its neighboring regions are the Indonesian archipelago to the north, west, and east, and the continent of Australia to the south. Timor-Leste is divided into three regional bases governmental administrative, and natural characteristics: western, central, and eastern regions. The municipality with the highest number of farmer households raising cattle in each region was selected as the study area representative. Specifically, Bobonaro municipality represented the western region, Ermera represented the central region, and Viqueque municipality represented the eastern region **(Figure 1)**.

Figure 1 Map of study areas

Source: Australia Timor-Leste Friendship Network (2018)

Data collection

        The study population was farmer households involved in cattle production in Timor-Leste, which totaled 57,637 households in 2019 (General Directorate of Statistics, Ministry of Finance, and the Ministry of Agriculture and Fisheries, 2020). A sample size of 100 cattle farmer households was deemed appropriate for the study, in accordance with the guideline proposed by Hair et al. (2014), which recommends a sample size of at least 10 times the number of predictors in a regression model. With 10 independent variables in this study, a sample size of 100 respondents was considered adequate.

        A multi-stage sampling technique was used to obtain the samples because the cattle farmer population in Timor-Leste was large and geographically dispersed. The three municipalities with the highest number of cattle farming households in each region, namely Bobonaro, Ermera, and Viqueque, were selected as the representatives (General Directorate of Statistics, Ministry of Finance, and the Ministry of Agriculture and Fisheries, 2020). The sample distribution was proportional to the population of cattle farming households in each municipality, and subdivided into sub-districts and villages to ensure comprehensive data collection **(Figure 2)**. The total samples consisted of 41 farmers from Bobonaro municipality in the western region, 34 farmers from Ermera municipality in the central region, and 25 farmers from Viqueque municipality in the eastern region **(Table 1)**. Data were collected by conducting face-to-face interviews with the selected farmers using a structured questionnaire which covered cattle production data in 2017.
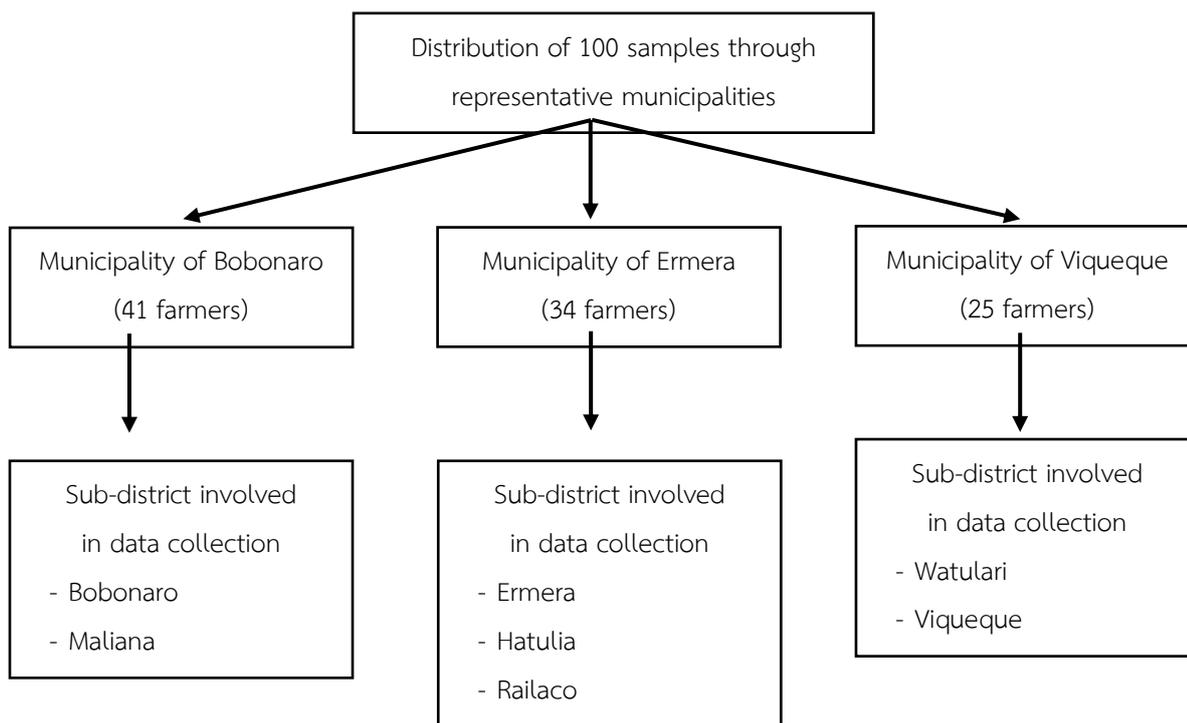
Figure 2 Diagram showing the sampling procedure by a multistage sampling technique

Table 1 Proportional distribution of population and sample size of cattle farmer households in each representative municipality

Region	Municipality	Number of cattle farming households*	Proportion	Distribution of sample size
Western	Bobonaro	8,889	0.41	41
Central	Ermera	7,469	0.34	34
Eastern	Viqueque	5,582	0.25	25
Total		21,940	1.00	100

Sources: * General Directorate of Statistics, Ministry of Finance, and the Ministry of Agriculture and Fisheries (2020)

Data analysis

      The OLS multiple regression model was used to analyze the factors affecting the cattle herd size among smallholder farmers in Timor-Leste. The dependent variable in the model was the cattle herd size. In contrast, the independent variables included socio-economic factors such as age, education, and household income, as well as farm management factors like rearing objective, rearing experience, farm labor, farm land, net farm income, training, and market information. The OLS multiple regression model was expressed in linear function as Equation 1.

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + e \quad (1)$$

Where:

Y = Cattle herd size in 2017 (heads)

b_0 = Intercept

b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10} = Estimated coefficients of independent variables

X_1 = Age (years)

X_2 = Education (0= illiterate, 1 = educated)

X_3 = Household total income in 2017 (USD)

X_4 = Cattle rearing objective (0= not for sale, 1 = for sale)

X_5 = Cattle rearing experience (years)

X_6 = Number of laborers working in cattle production in 2017 (persons)

X_7 = Number of lands for cattle rearing in 2017 (hectares)

X_8 = Net farm income in 2017 (USD)

X_9 = Attending the training in 2017 (0= no, 1 = yes)

X_{10} = Access to market information in 2017 (0= no, 1 = yes)

e = Error term

The OLS multiple regression analysis provided estimated regression coefficients, standard errors, t-values, F-value, and adjusted R^2 for presenting the model's goodness of fit. Furthermore, various assumptions, including normality, multicollinearity, homoscedasticity, and autocorrelation, were considered to ensure the model's validity (Gujarati, 2003).

The expected effects of each independent variable on the cattle herd size would vary. The expected effects of the independent variables on cattle herd size would be both positive and negative. The age of the farmer would have both a negative and positive relationship with the cattle herd size, as younger cattle farmers were typically more energetic and productive than their older counterparts, resulting in larger herds (Ogunkoya, 2014). While there are many reports such as Kambewa et al. (2011); Gichimu et al. (2018); Omonona et al. (2019) found that age had a significant positive correlation with cattle herd size.

The cattle herd size would have a positive relationship with education (Birhanu and Ambaye, 2017; Tadesse and Bahiru, 2017), household income (Gebreselassie and Gebremedhin, 2014; Kugonza et al., 2014; Coffie et al., 2015; Mudzielwana, 2015), farm objective for sales (Ogunkoya, 2014; Ghimire et al., 2017), production experience (Sagir and Dachung, 2014; Islam et al., 2016), number of farm laborers (Singh and Singh, 2014; Mgheni et al., 2015; Gichimu et al., 2020), number of farm land (Priyanti et al., 2012; Tibe Ouma and Jagwe, 2017; Ochieng et al., 2018; Getachew et al., 2020), net farm profits (Key et al., 2004; Feyera et al., 2014; Rueda and Lambais, 2018; Gichimu et al., 2020), attending to training (Akinwumi et al., 2015; Birhanu and Tadesse, 2016; Kamazima et al., 2019), and access to market information (Gebremedhin et al., 2004; Omiti et al., 2010; Zepeda et al., 2018).

Results and discussions

Socio-economic characteristics and farming management of smallholder cattle farmers in Timor-Leste

The socio-economic characteristics and farming management practices of smallholder cattle farmers in Timor-Leste in 2017 were presented in **Table 2**. The results showed that most farmers were male (96%), with only 4% female. The age range of the farmers was 40-68 years, with an average age of 50.78 years. More than half of the farmers were illiterate (58%). Most households had an income between 2,001-4,000 USD (44%), averaging at 3,200.20

USD, and 32% of farmers reported having debt, mostly from friends and neighbours (43.75%). The main purpose of cattle rearing among Timor-Leste's smallholder farmers was non-commercial purposes (90%), including for family consumption (7%), for asset saving (63%), and traditional celebrations (20%). Only a small percent of farmers (10%) reared cattle for sale.

Furthermore, the farmers' experience in cattle rearing ranged between 5-20 years, with an average experience of 10.29 years. Farmers had mostly less than 10 years of experience, which was relatively low compared to other countries. This was because the Government of Timor-Leste had recently started supporting cattle production and beef industry as an alternative country income (Democratic Republic of Timor-Leste, 2011). Most cattle farms had 1-2 household laborers working in cattle production (91%), with an average of 1.62 laborers. Regarding landholding, most cattle farmers had less than 0.20 hectares of land for cattle rearing (97%), with a mean of 0.10 hectares. Most farmers combined cattle rearing with corn farming (37%) and with coffee plantation (27%). The Bali breed was the most commonly raised cattle breed (99%), while only a few farmers raised Brahman (1%).

The study also revealed that most cattle farmers did not have cattle grazing or pasture fields (83%) and used native grass (37.17%), plant leaves (32.34%) and rice straw (25.65%) as roughage feed. During the dry season, plant leaves obtained from local sources and forestry such as leucaena, turi, banana, and waru leaves were widely used for feeding cattle. 33 cattle farmers who cultivated rice used their own rice straw for their cattle, while 36 cattle farmers who were not involved in rice farming purchased rice straw from local rice farmers. Natural mating by using their own bull was the common practice (98%). Due to the breed's native status and natural propagation, it tends to result in cattle with poor genetics and a low reproduction rate, consequently affecting their growth and the expansion of the herd, which aligns with the findings of Copland et al. (2003). This was consistent with Copland et al., 2003's (2003) finding. Most cattle farmers had a net farm income of 501 to 1,000 USD (66%), with an average income of 511.44 USD in 2017. Only one cattle farmers attended the training in 2017 (1%), while the remaining did not (99%). Most cattle farmers had access to market information such as market price, demand for cattle and beef (74%).

The number of cattle per farm and market prices classified by types of cattle in 2017 was presented in **Table 3**. The total number of cattle per farm ranged from 3 to 68 heads, with an average of 16 heads per farm. The majority of cattle raised by farmers in Timor-Leste were cows (32.31%) and bulls/oxen (22.56%), followed by young bulls (16.38%), heifers (14.31%), and calves (14.44%). On average, a farm had 3.61 bulls/oxen, 5.17 cows, 2.62 young bulls, 2.29 heifers, and 2.31 calves. It can be seen that there was a high proportion of bulls to cows in Timor-Leste's cattle farms because farmers commonly used their own bulls for natural mating.

Regarding market prices, the data showed that bull/oxen had the highest market price in 2017 at USD 771.3 per head, followed by cow at USD 658.2 per head. The market price for a young bull was USD 508.45 per head, while heifer and calf had lower market prices at USD 371.8 and USD 246.14 per head, respectively. It was important to note that the market prices were subject to change and could vary depending on supply and demand, seasonality, and location.

Table 2 Socio-economic characteristics and farming management of cattle farmers in Timor-Leste in 2017

Socio-economic characteristics and farming management	Frequency	Percentage (%)
Gender	**100.00**	**100.00**
- Male	96.00	96.00
- Female	4.00	4.00
Age	**100.00**	**100.00**
- 21 – 40 years old	2.00	2.00
- 41 – 60 years old	97.00	97.00
- More than 60 years old	1.00	1.00
Max = 68 years old, Min = 40 years old, Mean = 50.78 years old, S.D. = 4.48 years old		
Education	**100.00**	**100.00**
- Illiterate	58.00	58.00
- Educated	42.00	42.00
Household total income in 2017	**100.00**	**100.00**
- 1 – 2,000 USD	29.00	29.00
- 2,001 – 4,000 USD	44.00	44.00
- 4,001 – 6,000 USD	24.00	24.00
- 6,001 – 8,000 USD	2.00	2.00
- 8,001 – 10,000 USD	1.00	1.00
Max = 9,200 USD, Min = 80 USD, Mean = 3,200.20 USD, S.D. = 1,465.56 USD		
Debt in 2017	**100.00**	**100.00**
- No debt	68.00	68.00
- Having debt	32.00	32.00
Source of debt	**32.00**	**100.00**
- From relatives	6.00	18.75
- From friends/ neighbors	14.00	43.75
- From non-governmental organization (NGO)	12.00	37.50
Objectives of rearing cattle	**100.00**	**100.00**
- For family consumption	7.00	7.00
- For asset saving	63.00	63.00
- For traditional celebration (for dowry and funeral)	20.00	20.00
- For sale	10.00	10.00
Experience in rearing cattle	**100.00**	**100.00**
- Between 5-10 years	65.00	65.00
- More than 10 years	35.00	35.00
Max = 20 years, Min = 5 years, Mean = 10.29 years, S.D. = 2.88 years		
Number of household laborers working in cattle production in 2017	**100.00**	**100.00**
- 1 – 2 persons	91.00	91.00
- 3 – 4 persons	9.00	9.00
Max = 3 persons, Min = 1 person, Mean = 1.62 persons, S.D. = 0.65 person		

Table 2 Socio-economic characteristics and farming management of cattle farmers in Timor-Leste in 2017 (Continued)

Socio-economic characteristics and farming management	Frequency	Percentage (%)
Number of lands for cattle rearing in 2017	**100.00**	**100.00**
- 0.01 – 0.20 hectare	97.00	97.00
- 0.21 – 0.40 hectare	2.00	2.00
- 0.41 – 0.60 hectare	1.00	1.00
Max = 0.50 hectare, Min = 0.01 hectare, Mean = 0.10 hectare, S.D. = 0.07 hectare		
Farming system	**100.00**	**100.00**
- Only cattle rearing	3.00	3.00
- Cattle rearing combined with rice farming	9.00	9.00
- Cattle rearing combined with corn farming	37.00	37.00
- Cattle rearing combined with coffee plantation	27.00	27.00
- Cattle rearing combined with rice and corn farming	24.00	24.00
Species of cattle breed	**100.00**	**100.00**
- Native Bali	99.00	99.00
- Brahman	1.00	1.00
Cattle grazing or pasture field	**100.00**	**100.00**
- No cattle grazing or pasture field	83.00	83.00
- Have cattle grazing or pasture field	17.00	17.00
Type of roughage feed*	**269.00**	**100.00**
- Native grass	100.00	37.17
- Legume/ bush legume	13.00	4.84
- Rice straw	69.00	25.65
- Plant leaves	87.00	32.34
Mating	**100.00**	**100.00**
- Natural mating by own bull	98.00	98.00
- Natural mating by another farm's bull	2.00	2.00
Net farm income in 2017	**100.00**	**100.00**
- Less than 0 USD	17.00	17.00
- 1 – 500 USD	7.00	7.00
- 501 – 1,000 USD	66.00	66.00
- 1,001 – 1,500 USD	9.00	9.00
- 1,501 – 2,000 USD	1.00	1.00
Max = 1,962.63 USD, Min = -1,987.71 USD, Mean = 511.44 USD, S.D. = 655.28 USD		
Attending the training in 2017	**100.00**	**100.00**
- No	99.00	99.00
- Yes	1.00	1.00
Access to market information in 2017	**100.00**	**100.00**
- No	26.00	26.00
- Yes	74.00	74.00

Noted: * is multiple responses

Table 3 Number of cattle per farm and market prices classified by types of cattle in Timor-Leste in 2017

Type of cattle	Number of cattle per farm				Market price
	Minimum (head)	Maximum (head)	Mean (head)	Percentage of total cattle (%)	(USD per head)
Bull/ Oxen	1.00	15.00	3.61	22.56	771.30
Cow	1.00	22.00	5.17	32.31	658.20
Young bull	1.00	10.00	2.62	16.38	508.45
Heifer	1.00	14.00	2.29	14.31	371.80
Calf	1.00	10.00	2.31	14.44	246.14
Total cattle	3.00	68.00	16.00	100.00	558.71

Factors affecting cattle herd size among smallholder farmers in Timor-Leste

The OLS regression analysis results of the factors influencing cattle herd size among smallholder farmers in Timor-Leste was shown in **Table 4**. The adjusted R^2 value of 0.789 indicated that 78.9% of the variation in cattle herd size could be explained by the independent variables in the model. The F-value of 38.075 was significant at $P<0.01$, indicating that the model was a good fit for the data. The Durbin-Watson statistic of 1.747 fell within the range of 1.5 to 2.5, suggesting that there was no significant autocorrelation in the residuals of the model (Gujarati, 2003; Field, 2009; Wooldridge, 2015; Hill et al., 2018). The independent variables had correlation coefficients ranging from -0.616 to 0.435 and VIF values ranging from 1.077 to 1.991. These values indicated no multicollinearity in the regression model, as the correlation coefficients were below 0.80 and the VIF values were below 10 (Hair et al., 2010). The Breusch-Pagan-Godfrey (BPG) value of 21.40 for the model's heteroscedasticity was lower than the critical value at $P<0.01$ of 23.21, indicating no significant evidence of heteroscedasticity (Gujarati, 2003; Wooldridge, 2015).

The results revealed that five out of ten independent variables had a statistically significant effect on cattle herd size among smallholder farmers in Timor-Leste, namely the number of laborers working in cattle production, net farm income, number of lands for cattle rearing, education, and household total income. While age, cattle rearing objective, cattle rearing experience, attendance of training, and access to market information had no significant effect.

The number of laborers working in cattle production was found to have a significantly positive effect on cattle herd size at $P<0.01$. The coefficient for the number of laborers was 6.866, representing that an increase of one laborer resulted in an increase in cattle herd size by 6.866 heads. This relationship finding was consistent with previous studies (Mgheni et al., 2015; Gichimu et al., 2020), indicating a positive impact of labor on livestock or agricultural production. In addition, a research conducted in India found that labor scarcity was a key constraint to the expansion of farm size, as farmers were unable to find enough labor to manage larger operations (Singh and Singh, 2014). Labor was the second most critical resource in smallholder beef cattle operations, primarily involving tasks such as cutting and carrying grasses and forages, feeding, watering, cleaning barns, and providing medical care (Kalangia et al., 2016). Therefore, an increase in the labor force led to an increase in cattle herd size due to more efficient management and care.

Net farm income had a negative effect on cattle herd size at a significance level of P<0.01, with a coefficient of -0.007. This implied that a decrease in net farm income by one USD resulted in an increase in cattle herd size by 0.007 heads. This finding contradicted prior studies that showed a positive relationship between profit and livestock farm size (Key et al., 2004; Feyera et al., 2014; Rueda and Lambais, 2018; Gichimu et al., 2020). However, a study in Ethiopia found a negative relationship between farm profits and cattle farm size, with smaller farms achieving higher net incomes due to their efficient resource use and innovative farming practices (Adugna and Teshome, 2018). Similarly, Kaguongo et al. (2010) found that the relationship between farm profits and dairy farm size was not always straightforward. Farmers faced diminishing returns to scale as they increased their herd size, leading to lower profits per animal and ultimately limiting operations growth.

The number of lands for cattle rearing had a positive effect on cattle herd size at a significance level of P<0.05, with a coefficient of 21.597. This suggested that an increase in one hectare of land resulted in an increase in cattle herd size by 21.597 heads. This finding was in line with previous studies indicating that an increase in land area led to a growth in cattle herd size (Tibe Ouma and Jagwe, 2017; Ochieng et al., 2018; Getachew et al., 2020). Moreover, Priyanti et al. (2012) found that land was one of the primary factors affecting cattle herd size in smallholder beef operations in Indonesia.

Farmer's education positively affected cattle herd size at a significance level of P<0.05, with a coefficient of 2.736. Farmers who were educated tended to increase their herd size by 2.736 heads. This was consistent with Tadesse and Bahiru's (2017) finding that higher education levels were associated with larger livestock holdings. This was attributed to the fact that farmers with higher levels of education were more likely to have the financial literacy and knowledge required to access credit and invest in their farms. Similarly, Birhanu and Ambaye (2017) found that farmers with higher levels of education were more likely to have the financial literacy and knowledge required to access credit and manage their finances effectively, which could enable them to expand their farms.

Lastly, the farmer's household total income was found to have a significantly positive effect on cattle herd size at P<0.05. The coefficient for the farmer's household total income was 0.001, indicating that for an increase of one USD of income, there was an increase in cattle herd size by 0.001. This finding is consistent with previous studies which found that households with higher incomes tended to have larger cattle herds (Gebreselassie and Gebremedhin, 2014; Kugonza et al., 2014; Coffie et al., 2015; Mudzielwana, 2015). In addition, this study revealed that most Timor-Leste cattle farmers practiced mixed farming, combining cattle rearing with crop cultivation or coffee production. This complementary agricultural system offers the potential to reduce cattle feed costs and increase household income.

Table 4 Ordinary Least Square regression analysis of the factors affecting cattle herd size among smallholder farmers in Timor-Leste

Variables	Estimated coefficients	Std. Error	t-value	p-value
Constant	6.951	7.445	0.934	0.353
Age (x_1)	-0.161	0.135	-1.192	0.237
Education (x_2)	2.736	1.182	2.314	0.023*
Household total income (x_3)	0.001	0.000	2.234	0.028*
Cattle rearing objective (x_4)	-2.092	1.821	-1.149	0.254
Cattle rearing experience (x_5)	0.377	0.200	1.889	0.062
Number of laborers working in cattle production (x_6)	6.866	1.097	6.258	0.001**
Number of lands for cattle rearing (x_7)	21.597	8.434	2.561	0.012*
Net farm income (x_8)	-0.007	0.001	-7.249	0.001**
Attend the training (x_9)	1.309	5.227	0.250	0.803
Access to market information (x_{10})	1.696	1.429	1.187	0.238

Adjusted R^2 = 0.789

Standard error of the estimate = 5.012

F-value = 38.075**

Durbin-Watson = 1.747

N = 100

Source: Author's calculation (2022)

Noted: ** is statistical significance at P<0.01, * is statistical significance at P<0.05

Conclusion

The study found that most smallholder cattle farmers in Timor-Leste were male, illiterate, and relied on cattle raising for non-commercial purposes, including for family consumption, asset saving, and traditional celebrations. Only a small percent of farmers (10%) reared cattle for sale. Most farmers had limited land for cattle rearing with less than 0.20 hectares of land, combined cattle rearing with corn farming and coffee plantation, and fed their cattle with native grass, rice straw and plant leaves. The Bali breed was the most commonly raised cattle breed, and natural mating by using their own bull was the common practice. The cattle farmers had an average net farm income of 511.44 USD and an average of 16 heads per farm. These findings indicate that the cattle production management in Timor-Leste has traditionally been characterized by low inputs, low technologies, and low productivity. Natural propagation inevitably results in cattle with poor genetics, low reproduction, and slow growth. As a subsistence cattle production system, Timor-Leste's cattle farmers lack knowledge in animal care and nutrition, breeding practices, reproductive management, pasture management, disease and health management, and market information.

The OLS regression analysis results found that four factors had a statistically significant positive effect on cattle herd size among smallholder farmers in Timor-Leste: the number of laborers working in cattle production, the number of lands for cattle rearing, education, and household total income. In comparison, the net farm income had a statistically significant negative effect on cattle herd size.

The study's findings suggest policies to promote an increase in cattle herd size among smallholder farmers in Timor-Leste. These policies include increasing the cattle rearing workforce, providing access to more land for cattle rearing through land redistribution or leasing programs, supporting education and training programs to improve cattle rearing practices, and promoting the integrated farming, such as combining cattle rearing with crop cultivation or coffee production, to reduce feed costs and increase household income. By implementing these policies, smallholder cattle farmers' livelihoods can be improved by increasing cattle herd size.

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