Profitability of Livestock Farming in Kazakhstan: The Impact of Farm Size and Feeding Strategy

Master Thesis

December 2024

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Summary

This study explores the profitability of livestock farming in Kazakhstan, focusing on the impact of farm size and feeding strategies on economic outcomes. Kazakhstan's livestock industry is a significant contributor to the national economy, yet the detailed economic analysis at the farm level remains underexplored. To address this gap, the research assesses the financial performance of 250 farms using gross margin analysis, a method that calculates the difference between revenue and variable costs, providing a clear picture of profitability across different farming systems.

The analysis begins with an evaluation of gross margins across various farm sizes and feeding strategies. Larger farms, defined by their higher livestock holdings, tend to benefit from cost efficiencies, particularly in areas such as bulk feed purchasing and optimized resource use. These cost efficiencies contribute to higher total gross margins, making large-scale farming operations generally more profitable in absolute terms. However, when profitability is measured on a per-head basis, smaller farms demonstrate higher profitability. This is largely attributed to more intensive management practices, which allow smaller farms to achieve better outcomes in terms of gross margin per head of livestock.

To gain deeper insights into the factors influencing profitability, the gross margin results are further analysed using ANOVA and regression models. These statistical tools help quantify the impact of various income and cost components on overall profitability, as well as the specific effects of farm size and feeding strategies. The ANOVA results reveal significant differences in profitability across different farm sizes and feeding strategies, while the regression models provide a more nuanced understanding of how these factors interact.

One of the key findings of the study is the effectiveness of natural grazing strategies in enhancing profitability. Natural grazing, which relies on the use of available pastures rather than purchased feed, significantly reduces variable costs for farmers. This strategy is particularly advantageous in Kazakhstan, where vast tracts of grazing land are available. Farms that employ natural grazing not only lower their operational costs but also achieve higher gross margins compared to those that rely heavily on purchased fodder.

The study also highlights the complexity of scaling up livestock operations. While larger farms benefit from economies of scale, such as lower per-unit costs for feed and other inputs, they also face challenges related to the management and efficiency of larger herds. The findings suggest that simply increasing herd size does not automatically lead to higher profitability on a per-head basis. In fact, the marginal benefits of increasing herd size may diminish as the farm grows, making it crucial for farmers to balance scale with efficient management practices.

Overall, the thesis shows that both farm size and feeding strategies play critical roles in determining profitability. While larger farms generally achieve higher total gross margins due to cost efficiencies, smaller farms excel in maximizing per-head profitability. Additionally, natural grazing emerges as a highly effective strategy for reducing costs and enhancing overall profitability.

1 Introduction

The livestock industry is a cornerstone of Kazakhstan's economy, contributing approximately 42% to the nation's gross agricultural product volume (FAOSTAT, 2023a; Tazhibaev et al., 2014; World Bank, 2023a). Despite its significance, detailed understanding of the economic returns from livestock at the household and farm level remains limited (Anagol et al., 2013). This gap is notable in a context where global meat demand is rising and Kazakhstan, an upper-middle-income country, seeks more balanced economic development beyond its reliance on raw material extraction. With a global rise in meat demand and Kazakhstan positioned as an upper-middle-income country reliant on extraction of raw materials with volatile prices, an exploration of other sectors becomes crucial for more homogeneous economic development (Jumabayeva, 2010; World Bank, 2023b). Notably, Kazakhstan's abundant pastures position the country competitively on a global scale in terms of feeding costs for livestock, provided improved animal production practices are adopted (Jumabayeva, 2010).

This thesis aims to quantitively assess the profitability of various farm types and feeding strategies in Kazakhstan, exploring economic barriers to efficient livestock production. By focusing on production and supply, this study investigates the impact of farm size and feeding strategies on profitability, a critical factor for the long-term viability of rural communities. The focus of this thesis is the financial returns generated by different livestock farming systems in Kazakhstan and variable costs and their influence on decision-making, this research explores the influence of farm size (livestock holdings) and feeding strategy on profitability. The feeding strategy, in this context, is defined by the extent to which animals are pasture-fed or fodder-fed. Specifically, the research aims to understand the differences in profitability between intensive (fodder-based) and mobile strategies, providing insights into the decision-making processes of farmers and their implications for resource use. In the domain of livestock farming's economic sustainability, profitability is an important determinant in the strategic optimisation of the economic prosperity of rural communities. Profitability not only helps to assess the immediate economic success of livestock farming activities but functions also as a critical factor in ensuring their long-term viability and contribution to broader socio-economic development objectives. This study further aids in identifying major economic barriers to the adoption of specific production strategies. Literature including recent findings by Robinson and Petrick (2024) suggest that larger farms in Kazakhstan benefit from increasing their cattle numbers, as this allows them to better utilize the nearly unlimited resource of grazing land. But they also underscore that access to pastures poses a significant constraint on herd growth, leading producers with larger herds to primarily adopt remote pasturing as their main feeding strategy.

After a literature review that examines the challenges and developments within Kazakhstan's livestock industry, focusing on factors like farm size, profitability, pastures, mobility, and fodder, the thesis also explores various cost concepts and economic performance measures such as farm profit, gross margin, and return on investment. It outlines the research questions and hypotheses, and describes the methodology, including survey data collection and gross margin analysis, alongside methods for addressing the research questions through descriptive statistics and multiple regression analysis. The structure aims to systematically investigate the impact of farm size and feeding strategies on profitability in Kazakhstan's livestock farming, offering insights to inform stakeholders in the agricultural sector.

2 Literature review

2.1 Challenges and Developments in Kazakhstan's Livestock Industry

The livestock industry in Kazakhstan heavily relies on rangeland resources, with pastures making up over 184.3 million hectares, or 68%, of the country's agricultural land (FAOSTAT, 2023). Seasonal livestock mobility, as practiced by Kazakhstani pastoralists, exploits the natural variability of pastures. This practice, which dates back well before the Soviet era and continued through it, has been an integral part of Kazakhstani pastoralism (Kerven et al., 2021; Robinson et al., 2003). Three fundamental agricultural structure types exist in Kazakhstan (Robinson, 2020). Households, as the smallest farm category, have the smallest mean holding size. These structures continue to be the primary producers of all types of meat, with households owning about 50 percent of Kazakhstan's cattle and small ruminants (QAZSTAT, 2023). Individual farms, legally registered entities usually based on a single household or family, display varying grazing practices, and have experienced rapid expansion since the average livestock holding is limited to 26 animals per unit (QAZSTAT, 2023). Large enterprises, corporate successor organizations to Soviet state farms, vary in grazing practices and can facilitate extensive migrations over greater distances (Robinson & Petrick, 2024).They have a mean number of livestock of 58. There are less than 20,000 livestock producing enterprises in Kazakhstan and they only have a share of 8% of the overall Livestock ownership, so they are way less represented in the country (QAZSTAT, 2023).

Development of the Kazakhstani Livestock Sector

The historical development of Kazakhstan's livestock sector provides crucial context for understanding the evolving economic landscape of farms in the region. Significant changes in holding sizes, feeding strategies, and overall profitability over the past century have shaped the trajectory of Kazakhstani pastoralism.

The process began with Soviet collectivization in the 1930s, which disrupted traditional nomadic practices and led to a collapse of social structures, severely impacting livestock mobility (Kerven et al., 2021). This period marked the start of profound alterations in the pastoral life and the management of livestock, setting the stage for the challenges and transformations that followed. During the mid-20th century, nomadism experienced a revival under state management, transitioning into a form that might be described as industrialized nomadism. This shift was notably driven by the Virgin Lands campaign of the 1960s, a Soviet endeavour that promoted the migration of Russian farmers into northern Kazakhstan. This movement marked an important shift from traditional rangeland grazing to farmed fodder, fundamentally changing the landscape of livestock management (Kerven et al., 2021).

Following the dissolution of the Soviet Union, the period between 1992 and 1999 presented new challenges, resulting in a loss of 70% of the national livestock. This dramatic decline, driven by the dissolution of collective farms, was accompanied by a fragmentation of livestock inventories between large numbers of rural household and family farms (Kerven et al., 2006). From 2000 onwards, livestock inventories began to recover , with the new private farmers increasingly utilizing pasture heterogeneity to enhance forage intake (Robinson et al., 2021). The recent trends indicate a further evolution toward feedlot-based systems fed by crops, driven by financial inducements such as subsidies for growing feed crops. This shift, while offering increased productivity, raises questions about the sustainability of such systems and their potential environmental impact (Kerven et al., 2021).

The contemporary landscape of livestock farms in the post-Soviet period is marked by a diversity of producers with varying strategies. While financial inducements have led some large-scale producers to shift towards intensified production, a majority of larger and medium farms are increasingly adopting pasture-based strategies to feed their animals (Kerven et al., 2021; Robinson & Petrick, 2024). This shift aligns with the transition towards smaller family units operating independently of state support, in contrast to a minority of large-scale pastoralists who, with concentrated capital and resources, continue to adopt mobility and selective intensification practices. Together, these diverse approaches contribute to a range of farm sizes and operational scales across the sector.

2.2 Farm Size and Profitability

Building on the historical evolution of Kazakhstan's livestock sector, it becomes imperative to delve into the microeconomic foundations underpinning the sector's current state, particularly the dynamics of farm size and profitability. These changes and challenges faced by the sector set the stage for a closer examination of how macro-level trends translate into economic realities at the farm level.

The findings of Chavas and Aliber (1993) indicate that farm size plays a significant role in determining the presence and magnitude of economies of scale in agriculture. An economy of scale refers to the cost advantage that arises with increased output of a product. As the scale of production grows, the average cost per unit of output decreases. This is because fixed costs, such as machinery and management expenses, are spread over a larger number of units produced, resulting in the ability to produce each unit of output at a lower cost compared to smaller businesses (Makeham & Malcolm, 1986). This phenomenon underscores the importance of operating a farm at a sufficient scale to distribute fixed costs across a larger operation. Within the context of farm operations, costs are typically categorized into fixed and variable costs. Fixed costs are expenses that do not change with the level of output and include investments in buildings, land, and equipment. Variable costs, however, vary directly with the level of production and encompass expenses like seeds, fertilizers, pesticides, and labour. The size of a farm significantly influences its ability to achieve economies of scale. Larger farms can distribute their fixed costs over a greater volume of production, potentially lowering the average cost per unit. This advantage allows them to invest in more efficient technologies and negotiate better terms with suppliers, resulting in lower input costs and higher selling prices (Tomich et al., 1995).

Conversely, the relationship between farm size and variable costs is nuanced. While larger operations may benefit from economies of scale with variable costs, due to factors such as bulk purchasing discounts, they also face the challenge of efficiently managing increased input needs (Barnard & Nix, 1979). However, there are disadvantages to large farms. They can offer less individual care and attention, a crucial aspect given their high reliance on nature and the ever-changing circumstances that necessitate frequent and rapid decisions. Controlling a workforce spread over a larger area is more challenging, and while supervisors may provide necessary oversight, it often comes at a higher cost per unit of production compared to smaller-scale farmers who work alongside their employees for much of the time. Consequently, managerial, and administrative overhead costs are likely to be higher on large farms. Furthermore, expansion for farmers often entails acquiring land scattered across a wide area (Barnard & Nix, 1979). Fixed resources place a limit on the maximum level of production from individual enterprises (Barnard & Nix, 1979).

Smaller farms can offset higher labour costs by focusing on land productivity, adopting labour-saving technologies, adapting to local conditions, diversifying agricultural activities, and exploring cooperative arrangements. These strategies can help smaller farms improve efficiency, reduce labour expenses, and remain competitive in the agricultural sector (Tomich et al., 1995). Family labour makes a farm resilient against changes in input prices, a crucial factor as wages increase in other emerging sectors, threatening the low family labour costs characteristic of Kazakhstan's agricultural landscape (Jumabayeva, 2010; World Bank, 2023).

In some cases, larger farms can take advantage of economies of scale with variable costs, resulting in a reduction in the per-unit variable cost. This might be attributed to factors such as bulk purchasing discounts, more efficient resource utilization, or lower transportation costs. However, it's important to note that variable costs may increase with farm size due to the need for more inputs or resources to sustain larger production volumes, but the variable cost per unit of output can decrease. Understanding how these variable costs change with scale is essential for a comprehensive assessment of farm profitability, particularly when focusing on gross margin, as it directly impacts the net returns from agricultural activities.

2.3 Pastures, Mobility, and Fodder: Key Factors in Farm Profitability

Given its vast pastures and surplus of grain, Kazakhstan is well-positioned to emerge as a significant force within the worldwide meat industry. The country's status as a significant grain producer, coupled with competitive prices—especially in comparison to the Russian Federation—underscores its advantage in low fodder costs, a crucial element in the economics of livestock farming (Jumabayeva, 2010). However, challenges such as the risk of drought due to arid conditions pose threats to grain production and, by extension, livestock feed availability. Despite these challenges, Kazakhstan's ability to achieve self-sufficiency in grain for both human and livestock consumption, leveraging its vast pastural resources, remains robust (Fileccia et al., 2010; Statista, 2024).

The choice of whether to purchase or produce fodder depends significantly on the size of the farm. Larger farms often have the resources and capacity to produce their own fodder, reducing the need for outsourcing (Gillespie et al., 2010). This self-sufficiency in fodder production is less feasible for farms with significant livestock holdings but limited arable land. Conversely, farms with limited land availability often find outsourcing to be a more cost-effective option. The profitability of this choice depends on factors such as the cost and quality of outsourced fodder and how efficiently the farm utilizes it. Therefore, the extent of arable land a farm operates on plays a crucial role in determining fodder purchasing behaviour, which, in turn, significantly affects profitability.

In Kazakhstan, the interplay between herd size and mobility plays an important in determining the economic viability and sustainability of livestock farming. Studies in Australia have highlighted the critical importance of pasture-based forage for farm profitability, where both economic and biological processes are intricately linked (Tozer & Huffaker, 1999). The exploitation of pasture resources in Kazakhstan is notably uneven, ranging from overgrazed to entirely unused areas, with natural productivity varying significantly (Fileccia et al., 2010). This variability, along with environmental factors and human decisions, influences the availability of forage and consequently, livestock condition (Milner-Gulland et al., 2006).

Fodder, particularly for cattle and sheep, emerges as a crucial factor in this dynamic. While sheep primarily graze on pastures, they require additional fodder during snowfall, underscoring the seasonal challenges to feeding livestock (Fileccia et al., 2010). The quality of hay, a primary fodder source, varies, affecting its utility as sole feed (Fileccia et al., 2010). Larger operations, capable of producing or accessing better-quality forage, may have an advantage in maintaining livestock health and productivity.

The relationship between herd size and mobility further complicates this scenario. Large herds benefit from the ability to migrate to areas with available pasture, reducing the reliance on supplementary fodder. This seasonal mobility, essential for maintaining herd condition and controlling feed costs, represents an economy of scale that smaller farms, with limited resources for migration, struggle to achieve (Kerven et al., 2006; Mirzabaev et al., 2016). Kerven et al. (2006) illustrate how sheep on distant pastures gain weight during winter, while those confined and fed fodder lose weight, impacting spring lambing rates. This highlights the economic and biological benefits of mobility, where the costs of transportation must be balanced against the advantages of natural grazing.

However, it's essential to recognize the unique challenges within Kazakhstan's context. Smaller flock owners face resource limitations that make independent seasonal migrations difficult, often requiring collaboration with larger herd owners or the hiring of shepherds to transport animals to far-off pastures (Kerven et al., 2006). This cooperative approach, while addressing the limitations of smallholders, underscores the broader economic strategies within the sector that prioritize mobility and efficient forage utilization to enhance farm profitability.

In the Kazakhstani cattle farming industry, literature identifies two distinct economic approaches. Some households engage in labour-intensive farming that incurs high feeding costs but potentially yields higher income per head. This method, characterized by intensive husbandry, is limited by the availability of family labour and arable land near the village, both of which face the risk of depletion and are not scalable indefinitely (Jumabayeva, 2010). Conversely, other farms opt for a more extensive approach, allowing cattle to graze on pastures outside the village. While this method reduces feeding costs, it results in lower weight gain per animal and, consequently, less income per head, necessitating larger herds to maintain profitability. The choice between these strategies hinges on several factors, including farm size, rangeland conditions, and the logistical costs of moving livestock, which collectively influence farm profitability. Robinson and Petrick (2024) highlight that large herds necessitate pasture access due to the insufficiency of self-produced fodder to meet their needs. As Kerven et al. (2006) observe, small flock owners, due to the absence of capital assets like land and labour, are often compelled to collaborate with larger herd owners or hire shepherds for transporting animals to distant pastures, underscoring the interdependence within the sector. Economic decisions around pasture use, herd mobility, and feed production are critical to achieving sustainable profitability.

2.4 Different Concepts of Costs

Makeham and Malcolm (1986) describe in their textbook different kinds of costs, that must be paid by a farmer. Table 1 systematically categorises costs as variable or fixed, providing a clear distinction between costs that vary with production levels and those that remain constant regardless of short-term changes in output.

Table 2 broadens the scope by introducing concepts such as average production costs, opportunity costs, sunk costs, marginal costs and whole costs. This table enriches the discussion by addressing cost considerations that go beyond the simple binary of variable versus fixed and provides insights into the strategic financial planning necessary for farm management. Capital costs are funds spent on capital items should but not always increase the productive potential and asset value of the farm. Most capital items lose value, or depreciate over time, and a depreciation allowance should be deducted from gross income each year so that the item can be replaced at the end of its useful life (Makeham & Malcolm, 1986).

Table 1 Variable and Fixed Costs in Farm Economics: Key Concepts

Cost Classification in Agricultural Operations: Variable vs. Fixed/Variable and Fixed Costs in Farm Economics: Key Concepts	
Variable costs:	Costs, that vary size and/or level of output if an activity varies (Makeham & Malcolm, 1986). They will increase when production increases and will not be incurred unless production takes place. Examples are feed, fuel, livestock health expenses, that are directly associated with the volume of livestock, hired labour or a interest on operating loans (Olson, 2004). They are also called operating costs (Kay et al., 2020). Direct costs are most often also variable costs (Olson, 2004).
Fixed costs:	Costs, that do not change as the level of production changes in the short run but can change in the long run. They cannot be controlled by the farmer in the short run. They, within limits, do not change when the level of activities changes and are not directly related to the amount of livestock produced on the resources (Makeham & Malcolm, 1986). Besides fixed inputs like property and land, depreciation, insurance, taxes (not income taxes) on land and buildings as well as interest are fixed costs (Kay et al., 2020). Capital invested in a fixed input has an opportunity cost, so interest on that investment is also included as part of the fixed cost. **Overhead costs** are costs associated with owning a fixed input and are hard to assign directly to a particular enterprise and are a type of fixed costs (Kay et al., 2020; Olson, 2004). While labour costs associated with tasks that directly vary with the scale of production are most often referred to as variable costs, certain labour activities on a livestock farm may be considered fixed costs like the costs of permanent workers. This is further discussed in the generation of outcome variables.
Total costs:	Sum of total fixed costs and total variable costs(Kay et al., 2020; Makeham & Malcolm, 1986).

** Depreciation can be calculated as* $depreciation = \frac{purchase\ price - salvagevalue}{useful\ life}$ *to determine the average annual depreciation,*

***Interest can be calculated as* $average\ asset\ value = \frac{purchase\ price + salvage\ price}{2}$ *and then* $Interest = average\ asset\ value * interest\ rate$

Table 2 Other Key Concepts of Costs in Farm Economics

Other key concepts of costs in farm economics	
Average cost of production	Average costs of production refer to the total costs incurred in the process of raising an animal or conducting a specific activity, divided by the quantity of output produced. It represents the per-unit cost and provides insight into the efficiency and economic viability of the production process (Makeham & Malcolm, 1986).
Opportunity costs	The most hidden cost might be the opportunity cost. This is a cost which is incurred because money is used to provide equipment, hired labour and other resources to raising an animal. Other opportunities are thus given up. The opportunity cost of a resource is the income that could be received from the best alternative use of this resource (Olson, 2004).
Sunk costs	Costs, that have already been committed to or paid and cannot be altered are often referred to as sunken costs. Variable costs can in this case transform to fixed costs. For example, once a labour contract is signed, the farmer is bound by the agreed-upon salary amount, making it a fixed cost for the entire contract duration(Kay et al., 2020).
Marginal costs	Change in total cost divided by the change in output (Kay et al., 2020). Marginal costs are used to choose the optimal level of production(Olson, 2004).
Integer costs	Costs, that will vary (in comparison to general overhead costs, which will remain the same whatever enterprises are selected and whatever their size) but not constantly but only in steps (Barnard & Nix, 1979).

2.5 Measures of Farm Economic Performance

One effective way to assess economic performance is by looking at profitability. While economic performance considers a wide range of financial indicators beyond costs and revenue and includes assessments of utilisation, efficiency in managing resources, return on investment, and debt management, profitability is a critically important factor for a farm's sustainability and success. The upcoming exploration of measures of profitability in the following sections is important to choose a method that will provide as much information as possible with the data given.

In agricultural science, profitability is a crucial concept that measures the economic success and efficiency of agricultural operations. According to Alarussi and Alhaderi (2018), profitability is generally understood to be a company's earnings from revenue after all costs incurred over a specific time period have been subtracted. In agricultural economics, profitability is often assessed through various financial metrics and ratios that analyse the relationship between revenue and costs associated with agricultural production. This is consistent with common definitions of profit such as that of Mankiw (2014), who defines profit as the firm’s total revenue minus its total costs. Profit is also often referred to as some surplus or excess of income over costs (Makeham & Malcolm, 1986). Kay et al. (2020) define profitability as the degree or extent to which the value of the income derived from a set of resources exceeds their cost. Olson (2004) also characterizes profitability as the ability to produce a profit over a period of time. Farmers typically prioritize profitability as their primary objective, which is why it's given priority in the analysis process. When examining profitability, the focus is not solely on the exact profit figure, but also on how it compares in relation to other factors (Olson, 2004). This assessment also indirectly reflects the farmer's managerial skills. Specifically, attention is drawn to two aspects: (1) whether the current net income from the farm sufficiently covers living expenses and other obligations, and (2) whether this net income is satisfactory when compared to factors such as the farmer's invested capital, the labour provided by the farmer and family labour, and the value of the farmer's management expertise (Olson, 2004).

There are different ways to calculate indicators of profitability (Jayathilaka, 2020). The most basic yet crucial calculations made in businesses where profit serves as a driving force is gross margin calculation.

2.5.1 Annual Farm Profit

Annual farm profit, which represents the amount of money earned from farming activities over the course of a year after deducting expenses, is a fundamental metric used to evaluate profitability.

$$Annual\ Farm\ Profit = Gross\ Income - Total\ Costs$$

Solely looking at annual farm profit might not provide a comprehensive understanding of profitability. It's essential to consider this profit in relation to other financial factors (Olson, 2004). Some farms might generate high annual profits due to a high volume of sales, but while total costs are essential for understanding long-term financial health and sustainability, short-term decision-making often requires a focus on variable costs. This focus allows managers to adjust production levels, control immediate expenses, and make pricing decisions that ensure the business remains profitable in the near term.

2.5.2 Gross Margin

Gross margin analysis is a critical tool for assessing the profitability of farm activities, primarily because it focuses on the difference between gross income and variable costs without accounting for capital and other fixed costs (Makeham & Malcolm, 1986). This distinction is fundamental to understanding the financial health of a farm, especially in smallholder agricultural production systems where simplicity and minimal data requirements are crucial (Dalie et al., 2015; Mafimisebi et al., 2013). Gross Margin is calculated as:

$$Gross\ Margin = Gross\ Income - Variable\ Costs$$

By excluding fixed costs such as taxes, interest, and depreciation of capital assets, the gross margin provides an immediate insight into the operational profitability of a production process (Dalie et al., 2015). However, it's important to note that this method may overstate short-term profitability by not accounting for depreciation, a key factor in the long-term financial sustainability of assets (Barnard & Nix, 1979) as shown in Table 3. The farm's total gross margin, after variable costs are subtracted, offers a straightforward indicator of potential profitability. Yet, it's crucial to understand that to calculate net profit, one must consider all operating and non-operating expenses and incomes beyond the gross margin. The use of gross margin as a proxy for profit helps estimate returns with ease, but for a detailed financial analysis, further assessment is necessary. Many examples of the use of this analysis in arable farming can be found in literature (Dalie et al., 2015; Mafimisebi et al., 2013; Nasiru et al., 2012; Nkadimeng et al., 2021). But this can also be applied to livestock farms (Jobirov et al., 2022).

2.5.3 Net Farm Income

Net farm income (NFI) is a direct indicator of farm profitability. It includes earnings from unpaid labour, management, and owner investment (Kay et al., 2020; Olson, 2004). The calculation accounts for risk compensation, usually linked with management, equity, and labour. Net farm income is computed by subtracting cash expenses and depreciation from Gross Cash Farm Income and adjusting for inventory changes. Inventory change is determined by comparing ending and starting inventory, except for accounts payable changes, which are the opposite (Olson, 2004).

$$NFI = Net\ Cash\ Farm\ Income + inventory\ change - depreciation$$

Net Farm Income, as on the income statement, is surplus when revenue surpasses expenses, plus capital asset gains and losses. It compensates for operator labour, management and equity. Net farm income gives a dollar value and is a useful measure of farm profitability, but it has several limitations.

It overlooks opportunity costs, cash flow issues, and market risks, among other factors. It's a starting point for analysis (Kay et al., 2020).

2.5.4 Return on Investment

One indicator of how well the farm's resources are managed is the annual profit after interest and taxes, expressed as a percentage of the capital (Makeham & Malcolm, 1986). Return on investment (ROI) is a key measure of profitability. It reflects the interest earned on all investments in the farm business. ROI compares net income to capital invested (Kay et al., 2020). It can show the cost of farming compared to other investments. If assets are valued at cost, the return on investment mirrors the actual return on invested dollars in the farm. Return on Investment is the annual operating profit expressed as a percentage of total capital. Interest, loan repayments, living expenses, purchases of new capital, and tax obligations are not included in this amount (Makeham & Malcolm, 1986). It's also termed return to capital or rate of return on farm assets (ROA) (Kay et al., 2020).

ROI can be calculated as:

$$ROI = \left(\frac{Net\ Income}{Capital\ invested}\right) x\ 100$$

A higher ROI means better resource use and profitability (Uddin et al., 2010). Researchers suggest intensive livestock farming has high ROI due to scale economies and efficient management. ROI = (Net Profit / Cost of Investment) x 100 (Uddin et al., 2010).

For those in charge of using the capital (which could be an individual, a cooperative, or a government department), return on capital serves as a guide. It also makes it possible to compare the performance of this capital's current investment to other possible ones. The market value of all the resources the farm enterprise owns is added, and the sum of all the debts it owes is deducted from that figure to determine the farmer's capital (Anagol et al., 2013). ROI is useful for comparing investment profitability but doesn't consider time value of money or investment duration, providing a simple measure for relative evaluation (Olson, 2004).

2.5.5 Operating Profit Margin Ratio

The operating profit margin ratio (OPM) is another measure of profitability. It determines operating efficiency. When expenses align with output value, a positive net profit margin results. Low margin can arise from low prices, high expenses, or inefficiency (Kay et al., 2020).

$$Operating\ Profit\ Margin = \frac{Net\ farm\ income}{Gross\ Income} \times 100\%$$

OPM measures the portion of gross income remaining after expenses. It's calculated by dividing adjusted net farm income by gross income. Farms with high fixed asset investment and fewer operating costs have higher OPM. Conversely, more rented assets yield a lower OPM and higher ROI. Owned and rented assets are interchangeable. Their mix influences the ratios. Both measures should be analysed together, as low ratios indicate profitability issues (Olson, 2004).

2.5.6 Rate of Return on Farm Equity

Rate of Return on Farm Equity (ROE) is a crucial profitability measure. It assesses the percentage return on the owner's equity. When no debts are involved, ROE aligns with ROA. In debt scenarios, interest impacts ROE. It considers net farm income minus labour/management value before calculation (Kay et al., 2020).

$$ROE = \frac{Net\ Farm\ Income - \frac{Labor}{Management\ Value}}{Average\ Farm\ Equity} \times 100\%$$

ROE quantifies the interest rate earned on the farm's average net worth, based on starting and ending year net worth. Market value comparisons or cost-based valuation are relevant. FFSC's NFI from operations is ideal for ROE computation (Olson, 2004).

Comparing ROE with alternative investment returns and considering equity cost is crucial. ROE mirrors general business ROI, using owner's equity investment (Olson, 2004). Operator labour/management value covers unpaid family labour and operator's worth. For partnerships/corporations with wages, use owner's withdrawals. For sole proprietorships, local non-farm labour rates estimate it. Value could be fixed across farms (Olson, 2004).

2.6 Comparing Profitability Metrics

The above-mentioned different indicators provide a comprehensive view of the economic condition and profitability of agricultural enterprises. They help farmers and agricultural businesses make informed decisions, identify areas for improvement, and develop strategies to enhance the overall profitability and sustainability of agricultural operations. Table 3 offers an in-depth look at how various profitability metrics are calculated and what costs they entail, specifically within the context of livestock production. Each analysis has a different focus and calculates different values. The dataset used in this thesis was collected to answer questions about animal feeding and not to perform holistic economic profitability analyses. When choosing a suitable analysis tool in this thesis, some of the methods are therefore omitted, as they require data for their calculation that are not available.

Table 3 Different Measurements of Profitability of Livestock Production and Their Calculation

Measurement and abbreviation		Calculation	Costs included
Annual farm profit	AP	AP = GI - TC	feed costs, husbandry costs, veterinary expenses, seasonal labour, breeding and reproduction costs, marketing and sales costs+ Depreciation, interest on loans, taxes, insurance, building and equipment (maintenance). labour cost, lease or rent
Gross Margin	GM	GM = GI – TVC	feed costs+ veterinary expenses+ husbandry costs+ seasonal labour+ breeding and reproduction costs+ marketing and sales costs
Net Farm Income	NFI	NFI = GM – TFC	feed costs, veterinary expenses, husbandry costs, seasonal labour, breeding and reproduction cost, marketing and sales costs+ Depreciation, interest on loans, taxes, insurance, building and equipment (maintenance), labour costs, lease or rent
Return on Investment	ROI	ROI = (AP / Cost of Investment) * 100= ((GI-TC)/Cost of Investment) *100 Cost of Investment = Initial Purchase Price + Transaction Fees + Other Costs	feed costs, veterinary expenses, husbandry costs, seasonal labour, breeding and reproduction costs, marketing and sales costs+ Depreciation, interest on loans, taxes, insurance, building and equipment (maintenance), labour costs, lease or rent + costs of investment
Operating profit margin ratio	OPM	OPM = (Operating Profit /GI) * 100 Operating Profit = NFI - Interest Expenses= (GM-TFC) – Interest Expenses	feed costs, veterinary expenses, husbandry costs, seasonal labour, breeding and reproduction costs, marketing and sales costs+ Depreciation, interest on loans, taxes, insurance, building and equipment (maintenance), labour costs, lease or rent + interest expenses

Rate of return on farm equity	ROE	ROE= (NFI – value of operator's labour and management) /average farm net worth= ((GM-TFC) – value of operator's labour and management) /average farm net worth	feed costs, veterinary expenses, husbandry costs, seasonal labour, breeding and reproduction costs, marketing and sales costs+ Depreciation, interest on loans, taxes, insurance, building and equipment(maintenance), labour costs, lease or rent + value of operators labour and management

Where:

GI =*gross income*

TVC =*total variable costs*

TFC =*total fixed costs*

TC =*Total costs (TC=TVC+TFC)*

The fundamental principles of production economics are grounded on the premise that the primary goal in resource allocation planning is to optimize profit (Barnard & Nix, 1979). Nonetheless, it is evident that farmers frequently have additional objectives that must also be considered in practical planning to ensure the viability of solutions. Often, the focus of farm planning is on maximising gross margin rather than profit, as profit is calculated by subtracting fixed costs. In many instances, maximising gross margin leads to the same outcome as maximising profit (Barnard & Nix, 1979).

Gross margins, calculated as the difference between gross income and variable expenses, serve as a tool for short-term analysis. When evaluated on a per-unit basis (e.g., per unit area or unit of money invested), gross margins aid in decisions related to product selection and production volume. However, this approach overlooks fixed and sunk costs in the short run. Allocation of direct and indirect expenses and revenue is a form of enterprise analysis, that encompasses both variable and fixed costs to estimate an enterprise's contribution to overall farm profit. Indirect expenses, also known as overhead costs, are costs that cannot be directly attributed to a specific product, service, or activity. They are necessary for the overall operation of the business but are spread across various activities. Allocating indirect expenses might involve a certain degree of subjectivity, yet for a comprehensive evaluation of enterprises over an extended timeframe, such allocation becomes necessary (Olson, 2004). Assignment of assets and liabilities to enterprises is another analytical level, that requires making informed decisions on how to apportion assets and liabilities to each individual enterprise (Olson, 2004).

For this thesis, the primary analysis tool will be Gross Margin, emphasising its role in assessing profitability. Gross Margin provides a valuable short-term perspective, guiding decisions on product selection and production volume. It is important to note that by using gross margin as an analytical tool, a crucial component of what creates economies of scale—fixed costs—is missed. On the other hand, gross margins will tell something about the different types of variable costs. It is therefore a great tool for comparing different economic performances in different types of farms divided in scale and feeding strategy.

3 Research Questions and Hypotheses

In exploring the economic viability of livestock as a significant asset class in developing nations, this study aims to dissect the intricacies of profitability across different scales of farming operations. Specifically, the first research question investigates the impact of holding size on the gross margin in both cattle farming and, more broadly, livestock farming, which in this context includes cattle, sheep, goats, and horses. This distinction allows for a nuanced analysis that accounts for the varied economic dynamics and efficiencies across different types of animal husbandry practices.

1. Which effect does scale (i.e. holding size) have on profit of (i) cattle farming and (ii) livestock farming?

- *Null Hypothesis (H0): There is no significant difference in profitability between large and small farms within Kazakhstan's cattle and livestock farming sectors.*
- *Alternative Hypothesis (H1a): Farms have a higher gross margin (GM) per herd than households.*
- *Alternative Hypothesis (H1b): Households have a higher gross margin (GM) than farms per head.*
- *Alternative Hypothesis (H1c): There is a positive relationship between farm holding size and the gross margin of (i) cattle farming and (ii) livestock farming.*
- *Alternative Hypothesis (H1d): There is a negative relationship between farm holding size and the gross margin per head of (i) cattle farming and (ii) livestock farming.*

One key factor affecting gross margin in cattle and livestock farming is the number of animals in a farm. If the gross margin per head of livestock is positive- which should be the case-, a higher count of animals can contribute to a higher gross margin for the farm. Therefore, a positive relationship is expected between the number of livestock and the gross margin per farm.

Several pieces of research provide empirical support for the notion that larger farms tend to have higher profitability. For instance, a study by Zweigbaum et al. (1989) demonstrated a positive correlation between increased herd size and enhanced profitability. This suggests that as cattle and livestock farms scale up, there is a likelihood of improved financial performance. Similarly, Gillespie et al. (2010) found a positive correlation between farm size measured by the number of dairy cows and profitability. This observation aligns with the concept of economies of scale, where larger operations may benefit from cost efficiencies and increased output. Additionally, in Kazakhstan, larger herds enable producers to access additional pasture resources, which supports overall profitability. This is supported by evidence showing that large-scale livestock owners, who move their animals to distant pastures, achieve economies of scale and have heavier animals compared to small-scale village-based livestock owners. These larger operations benefit from better utilization of available pasture resources, leading to improved economic returns (Behnke, 2008).

In low-wage or labour-intensive production systems an inverse relationship between farm size measured in hectare and production efficiency may exist due to high monitoring costs of hired workers (Otsuka et al., 2016). However, as labour costs rise the introduction of farm machinery may lead to a positive relationship between farm size and productivity , as has been observed in Japan and in some parts of India (Otsuka et al., 2016). But the role of farm machinery is bigger in crop production than livestock production. Jumabayeva (2010) stated in 2010 that Kazakhstan has a low level of technology in production of beef. While the World Bank (2023) refers to Kazakhstan as a upper middle-income economy. It also highlights its vulnerabilities and unevenness in the country’s development model by impressive economic growth due to abundant mineral resources extraction. Therefore, this finding may not fit. Farms with a large number of hectare benefit from scale economies observed in land-abundant countries in Latin America, Eastern Europe, and Central Asia (Otsuka et al., 2016). The common limitations on farm growth, such as access to pasture, suggest that these challenges are not exclusive to any scale.

The relationship between herd size and profitability in livestock farming is complex. Research conducted in Central Asia, including studies by Kerven et al. (2004) and Jobirov et al. (2022), reveals a negative correlation between herd size and profitability per head, indicating that profitability per head tends to decrease as herd sizes increase. In Tajikistan, for instance, feed costs represent the largest expense in livestock farming, as noted by Jobirov et al. (2022). Similarly, both herd size and profitability per head exhibit a negative correlation. This pattern of declining per head profitability with increasing herd size is also observed in beef cattle farming in America (Koknaroglu et al., 2005). Kerven et al. (2004) highlights the substantial fixed costs associated with relocating ruminants to distant pastures. To mitigate these expenses, smaller livestock owners have the option to collaborate, sharing the burden of fixed costs such as shepherd wages and water pumps required for remote grazing are. Households often benefit from family members who work on the farm without a monetary wage. This is an essential factor that is not typically included in gross margin analyses, and it can be seen as an indicator of cost efficiency. As mentioned in the research by Delgado et al. (2003), the gross margin analysis does not account for opportunity costs, and family members contribute valuable labour without incurring additional expenses.

Small farms in Southern Asia, predominantly family-based, rely on family labour for cost-effective and efficient cultivation, especially in low-wage economies (Otsuka et al., 2016). Family labour provides a strong work incentive, reducing labour costs and maintaining competitiveness, unlike large farms that often rely on hired labour (Otsuka et al., 2016). However, the paper does not gather specific insights in the field of livestock farming and is not covering Central Asia. The efficiency of small farms is linked to lower production costs associated with labour-intensive, family-based cultivation methods in crop farming (Otsuka et al., 2016). Additionally, the motivation and dedication of family members working on households, as mentioned in studies by Delgado et al. (2003) and Jobirov et al. (2022), may result in a decreased need for monitoring and management costs, further contributing to cost efficiency.

In conclusion, the evidence suggests that larger producers tend to have higher gross margins per herd, while smallholders may have an advantage in terms of gross margin per head (Jobirov et al., 2022; Kerven et al., 2004).

2. Which effect does feeding strategy have on profit of (i) cattle farming and (ii) livestock farming?

- *Null Hypothesis (H0): There is no significant difference in the gross margin of (i) cattle farming and (ii) livestock farming between farms employing different feeding strategies, including those that produce their own feed, those that purchase fodder, and those that rely on grazing.*
- *Alternative Hypothesis (H2a): The gross margin for farms employing a self-producing feeding strategy is significantly higher than the gross margin of farms purchasing fodder.*
- *Alternative Hypothesis (H2b): Cattle and livestock farms that predominantly rely on natural grazing have lower variable costs and higher gross margins than those that do not, despite the potential transportation costs.*

To understand the implications of feeding strategy on profit, it's essential to consider the unique agricultural landscape of Kazakhstan. Kazakhstan boasts vast expanses of land that are primarily suitable for grazing, making land, in many regions, a plentiful resource (Thornton, 2003). On the other hand, feed costs constitute a substantial proportion of variable expenses in livestock farming in Kazakhstan (Kerven et al., 2006).

Research in Ireland has shown that the profitability of pasture-based dairy systems is intricately linked to the extent of pasture utilization on farms while considering purchased feed levels (Hanrahan et al., 2018). Given the abundant availability of pasture land in Kazakhstan, it's logical to assume that reducing the presumably highest component of variable costs, namely fodder costs (Jobirov et al., 2022), would lead to increased profits measured as gross margin. After all, if pastures are nearly free for use, one might expect a substantial improvement in profitability.

However, it's essential to recognize that there are still expenses associated with the use of pastures. These expenses arise from transportation to and grazing on pastures, as compared to feeding animals in a fixed stable facility. The transportation to pastures and the costs of grazing can affect the overall profitability of a farming operation (Kerven et al., 2006; Kerven et al., 2004). Winter pastures require substantial fixed investments in for example barns, shepherds housing and wells. In contrast, the purchase of fodder can be easily adapted to herd size.

Across different scales and feeding approaches, self-reported limitations on farm growth have remained relatively consistent. Access to pasture emerges as the most frequently cited constraint, affecting over 30% of farms and households. This constraint is particularly significant, given that it pertains to a critical resource for cattle and livestock farming. Following this, challenges related to insufficient land for fodder and other fodder-related issues, including pricing concerns, are commonly reported. These limitations affect both large and small farms alike. Additionally, financial obstacles, such as liquidity and access to credit, are mentioned as constraints, suggesting that these financial challenges are not exclusive to either larger or smaller operations (Robinson et al., 2021). The degree of intensification, influenced by feeding strategy and the associated costs, raises important questions about the relationship between intensification, size, and profitability. Empirical studies in Kazakhstan have shown that wealthier herders who have achieved economies of scale are better positioned to meet the expenses tied to labour and transportation while maintaining profitability (Kerven et al., 2006; Milner-Gulland et al., 2006; Robinson et al., 2021). Smaller-scale flock owners attempting to join larger flock owners who move animals to seasonal pastures also need to consider the intricacies of scaling up their operations (Kerven et al., 2006).

3. What are the main factors that create differences between the gross margins of farms with similar scale/structures? Are these disparities related to revenue, variable costs or a combination of both? What is the impact of changes in input costs on the farms' gross margin?

- *Null Hypothesis (H0): There are no significant differences in the proportion of input cost components and the structure of income sources among farms with different scales or structures.*
- *Alternative Hypothesis (H3a): The proportion of expenditures on fodder decreases with the size of the farm, indicating economies of scale in fodder costs among farms with different scales.*
- *Alternative Hypothesis (H3b): Larger farms have a higher proportion of their variable costs allocated to labour compared to smaller farms, reflecting the increased labour needs and efficiency gains at larger scales.*
- *Alternative Hypothesis (H3c): The structure of income sources varies significantly with farm size, with larger farms having a greater diversity of income sources compared to smaller farms.*
- *Alternative Hypothesis (H3d): The cost of fodder <u>per head</u> is substantially lower for large, mobile flocks but higher for small, sedentary ones.*

It is important to consider in understanding the differences in gross margins among farms of various scales and structures is the concept of economies of scale. Market prices for agricultural products are often fixed, leading to a consistent gross income for all sellers. Economies of scale can significantly influence the variable costs associated with farming operations. Empirical evidence suggests that the impact of scale on variable costs varies across different cost components.

A study by Kerven et al. (2006) conducted in southeast Kazakhstan shed light on this issue. Their research revealed limited evidence of economies of scale in recurrent input costs, except for fodder costs. Fodder costs were found to exhibit a notable scale-related variation. Fodder constitutes a primary expenditure for all flocks, regardless of their size or seasonal migration patterns. During the cold winter period, smaller, village-based flocks tend to face notably higher costs per animal when providing winter feed. This is because they require additional feed in confined spaces. In contrast, larger flock owners who relocate their animals to winter grazing areas usually do not need to provide supplementary feed during the winter season (Kerven et al., 2006). As a result, the cost of fodder per individual animal is substantially lower for large, mobile flocks but higher for small, sedentary ones.

This supports the idea that as farms get bigger in size, variable costs like fodder expenses tend to decrease, contributing to differences in gross margins. While there is limited correlation between flock size and crucial input costs such as marketing, veterinary care, and moving animals to pastures, it's essential to consider labour costs. The relationship between labour costs per head of livestock and flock size varies. Additionally, although larger flocks may benefit from economies of scale in some variable costs, their fixed costs might be higher due to increased investment in infrastructure, equipment, and management systems necessary to support larger operations. Large flock owners often find it necessary to hire additional labour, which can increase their variable costs. In contrast, smaller flock owners tend to rely more on family labour per animal in their possession, which may keep their labour costs relatively stable. These nuances in labour costs further contribute to differences in gross margins among farms with varying scales and structures.

This thesis acknowledges that farm size and feeding strategies are part of a complex array of factors that affect farm profitability. A multitude of elements contribute to profitability, thus necessitating a comprehensive analytical method. Section 4 investigates not only the primary impacts of farm size and feeding practices but also evaluates how they compare to other factors that may affect gross margins, such as pasture use, the education level of the farmer, family size, and the proximity of the farm to Almaty. Employing multiple regression analysis allows for the examination and understanding of the separate and combined effects of these various factors on farm profit margins. This technique is beneficial for controlling for extraneous variables, enabling the research to identify the influence of each variable. A key area of focus is on whether larger farms can lower their costs for feed and labour because of their scale, and if such savings correlate with increased profit margins.

4 Data and Methods

4.1 Survey Data

The data set which will be applied to the analysis originates from the ANICANET Survey Data Kazakhstan, which was implemented in 2018. This field survey data set covers 200 farms and 50 households in the eastern end of Enbekshikazakh district and (former) Raiymbek district in Almaty province. The region has a vertical transhumance regime between settlements and isolated winter pastures on south-facing or other snow-free areas, as well as alpine summer pastures. Therefore, if they are mobile, animals could theoretically be kept on pasture almost the entire year (Ferret, 2018). The farms were selected through a two-stage sampling process by Robinson et al. (2021). The first step was to choose the sample by sub-district. In the second step farmers and households were sampled at random using existing lists for farmers and random visits for households.

In addition, farms were divided into quartiles by cattle herd size (Table 4), and into six groups (Tables 5 and 6) based on their feeding strategy. The groups were formed using K-means clustering based on variables such as size (cattle (bulls), large cattle unit), supplemental feed (purchased concentrate, cultivated concentrate, purchased roughage, produced roughage, cropland used), pasture use, and livestock mobility (pasture used, time on pasture outside the village). The 200 individual farms, which were divided into four quartiles and six feeding strategies, households were examined as a single group. The information was collected using a questionnaire.

The division into quartiles by holding size in Table 4 shows how larger operations are associated with greater use of cropland and pasture and more mobile practices. As farms increase in herd size, there is a notable increase in their access to both cropland and pasture. The data shows that crop and hayland per farm generally increases with cattle ownership quartile (with the exception of cropland in Q3). On the other hand, combining total crop and hayland access *per head*, larger farms have lower mean availability than smaller farms or households The higher quartiles, especially Q4, having more land for hay and pasture. The data on mobility, including months on remote pasture and the usage of remote pasture in different seasons, illustrates a gradient of pastoral practices that become more prevalent as farm size increases. This might reflect both a necessity due to the larger herd sizes needing more grazing land and a capability, as larger operations may have more resources to manage seasonal migrations. Additionally, the revenue generated from selling animal products—such as cattle, milk, milk products, and beef—offers valuable insights into the farm's economic performance, often constituting a significant portion of overall sales. While larger farms are more likely to sell cattle and beef, potentially indicating a focus on meat production, the distribution of milk and milk product sales does not follow a clear trend with respect to farm size. It depends more on proximity to markets than farm size (Robinson et al., 2021).

Table 4 Farm Characteristics by Household and Farm Quartile

	Variable	Household or farm (cattle ownership) quartile					
		HH	Q1	Q2	Q3	Q4	Farms
	N	50	56	49	45	50	200
Livestock	Cattle (head) †	**9**	8	14	24	85	**33**
	Cattle (head, range)	**1-39**	3-10	11-18	19-30	31-395	**3-395**
	Sheep & goats (head)	**20**	36	51	82	363	**132**
	Livestock units††	**66**	89	133	223	891	**330**
	Proportion of cattle in LU	**0.60**	0.47	0.48	0.52	0.48	**0.49**
Land	Cropland (ha)	**1.2**	3.5	12.3	5.9	21.4	**11**
	Hayland (ha)	**4.2**	3.8	12.6	13	29.3	**14**
	Hayland + cropland /head (ha)	**0.99**	0.92	1.64	0.76	0.71	**1.01**
	Pasture (ha)	**6.4**	21.3	52.5	85.2	259.9	**103**
	Pasture area per LU (ha)	**0.52**	0.53	0.60	0.49	0.42	**0.5**
Mobility	Months on remote pasture	**2**	4	5	7	9	**6**
	Remote pasture winter (1/0)	**0.04**	0.13	0.16	0.40	0.64	**33**
	Remote pasture summer (1/0)	**0.28**	0.57	0.63	0.84	0.92	**73**
	Any mobile stock (1/0)	**0.28**	0.57	0.61	0.84	0.88	**72**
Sales	Cattle (1/0)	**0.44**	0.27	0.51	0.71	0.64	**0.52**
	Milk (1/0)	**0.10**	0.04	0.12	0.16	0.06	**0.09**
	Milk products (1/0)	**0.04**	0.04	0.08	0.11	0.14	**0.09**
	Beef (1/0)	**0.10**	0.05	0.08	0.13	0.18	**0.11**

Source: Robinson et al. (2021)
Note: All values represent means unless otherwise specified.
†Variable used to create a cluster
††Livestock units based on Kazakh sheep units (sheep and goat = 1 LU, horse = 6 LU and cattle = 5 LU)
Sample Means Including Zero Observations Unless Specified in Notes

Tables 5 and 6 provide a detailed breakdown of six production clusters identified. These clusters range from small, sedentary operations to large, highly mobile farms, each with distinct approaches to feed management and land use. Small Sedentary Farms rely heavily on buying feed during winter and use nearby pastures. Medium Mobile Farms are characterized by their high mobility and access to an expanded range of pastures, with a notable emphasis on self-produced roughage, though providing less fodder per head compared to other clusters. Medium Fodder Purchasers represent farms with limited access to arable land, thus relying heavily on purchased supplements. Medium Fodder Producers have a significant amount of farmland where they cultivate crops to feed their animals, demonstrating a strategy of utilizing their crops as animal feed. Large Mobile Fodder Purchasers operate on an extensive scale, using off-village pastures across seasons and relying on poor-quality roughage, which is largely purchased. Large Mobile Fodder Producers also utilize remote pastures year-round but have access to cropland, from which they produce high-quality fodder in smaller quantities.

Table 6 presents key indicators from survey data for the size identified strategies, ranging from a heavy reliance on purchased feed in smaller, stationary farms to greater self-sufficiency in feed production among larger, mobile farms. All (100%) farms provide roughage, while 89% also offer concentrate. The first one is bought more frequently than it is self-produced (25% versus 68% of farms). Natural hay and cultivated lucerne or sainfoin make up roughage, which is primarily self-produced (except for households, which purchase it in proportion to 72%). Notably, there is almost no silage produced by farms at the Kazakhstani site (Robinson, 2020). Small sedentary farms (Cluster 1) rely heavily on purchased feed, particularly concentrate, while large mobile farms (Clusters 5 and 6) have greater access to pastures and either purchase low-quality roughage or produce high-quality fodder themselves. Medium farms show diverse strategies, from high mobility and self-sufficiency in roughage production (Cluster 2) to significant reliance on purchased supplements due to limited land (Cluster 3).

Table 5 Basic Characteristics of the Six Production Clusters Identified

No.	N (of 200)	%	Cluster short title	Description
1	40	20%	Small sedentary	Small sedentary farms using mostly village pasture and having the highest reliance on supplements in winter, including purchased concentrate.
2	56	28%	Medium mobile	Medium farms with high mobility and access to pastures. Provide less fodder per head than other medium operations (3 and 4), mostly in the form of self-produced roughage. Many use off-village pasture all year.
3	25	13%	Medium fodder purchaser	Medium farms with almost no access to arable land, providing large amounts of purchased supplements. Cover a wide range of pasture use and mobility types, but the majority use off-village summer pasture only.
4	32	16%	Medium fodder producer	Medium farms with the highest mean cropland areas and volume of concentrate provided per animal. This group has a range of pasture use and mobility, but the majority use off-village pasture in summer pasture only.
5	27	14%	Large mobile fodder purchaser	Large mobile extensive operation using both off-village winter and summer pastures and providing mostly poor-quality roughage (natural hay) in winter, much of which is purchased.
6	20	10%	Large mobile fodder producer	Large mobile operation using both remote winter and summer pastures, with access to cropland and provision of high-quality self-produced fodder in relatively small quantities.

Source: Robinson et al. (2021)

Table 6 Characteristics of Households and Commercial Farms by Clusters

Variable		Cluster (numbers refer to groups defined in table 5)							
		HH	1	2	3	4	5	6	Total farms
	N	50	40	56	25	32	27	20	200
Livestock	Cattle (head) †	**9**	12	17	22	16	83	89	**33**
	Cattle (head, range)	**1-39**	3—34	6—31	5-80	7-34	18-395	32-340	**3-395**
	Sheep and goats (head)	**20**	31	50	32	49	454	385	**132**
	Livestock units††	**66**	97	155	134	138	979	966	**330**
	Proportion of cattle in LU	**0.6**	0.51	49	0.60	0.51	0.36	0.44	**0.49**
fodder	Concentrate (kg), purchased	**0.76**	0.76	0.8	0.84	0.06	0.81	0.35	**0.68**
	Concentrate (kg), self-produced	**0.1**	0.1	0.04	0.04	1	0	0.7	**0.25**
	Roughage (kg), purchased	**0.72**	0.72	0.27	1	1	0.81	0.1	**0.42**
	Roughage (kg), self-produced	**0.56**	0.56	1	0.2	0.97	0.7	0.95	**0.85**
Land	Cropland (ha)t	**1.2**	2	6	1	23	1	46	**11**
	Hayland (ha)	**4.2**	7	11	2	16	26	34	**14**
	Hayland + cropland/ head (ha)	**0.99**	0.91	0.99	0.20	2.34	0.35	1.05	**1.01**
	Pasture (ha)	**6.4**	21	74	11	36	318	279	**103**
	Pasture/LU (ha)	**0.52**	0.54	0.63	0.32	0.46	40	0.46	**0.33**
Mobility	Months on remote pasture	**2**	1	8	5	5	11	10	**6**
	Remote pasture winter (1/0)	**0.04**	0	0.36	0.16	0.19	0.78	0.70	**0.33**
	Remote pasture summer (1/0)	**0.28**	0.20	0.95	0.64	0.75	0.96	1.0	**0.73**
	Any mobile stock (1/0)	**0.28**	0.20	0.95	0.6	0.78	0.89	0.95	**0.72**
Sales	Cattle (1/0)	**0.44**	0.33	0.55	0.64	0.38	0.74	0.6	**0.52**
	Milk (1/0)	**0.1**	0.1	0.09	0.2	0.03	0.07	0.05	**0.09**
	Milk products (1/0)	**0.04**	0.07	0.11	0.08	0	0.11	0.2	**0.09**
	Beef (1/0)	**0.1**	0.07	0.09	0.12	0.03	0.15	0.30	**0.11**

Excerpt from table 3 in Robinson et al. (2021). See this paper for further information
†Variable used to create a cluster
††Livestock units based on Kazakh sheep units

4.1.1 Data Cleaning

This chapter outlines the data cleaning process that is an integral part of the research methodology for this thesis. This process is a critical step in preparing the dataset for analysis, ensuring that subsequent findings on livestock farming profitability are based on accurate and reliable information.

The initial assessment involved importing the raw data from the 250 interviews into R Studio, the software used for conducting the calculations. This dataset, sourced from the ANICANET Survey Data Kazakhstan mentioned in the chapter above, was first reviewed to understand its structure and content. Key variables relevant to the analysis, detailed in the annex, were scrutinized for inconsistencies and potential errors. These initial observations guided the subsequent cleaning steps. Documentation included noting any anomalies, missing values, and initial thoughts on the dataset's quality and completeness. This comprehensive documentation was crucial for ensuring transparency and reproducibility in the data cleaning process. All outliers removed from the calculation can be found in table 7.

While the dataset did not have missing data per se, challenges arose in calculating the value of home-consumed animals and animal by-products. Initially, the value of home-consumed goods was calculated by multiplying their quantity by the sale price, but many farms did not sell these products, resulting in a zero value. To address this issue, if a farm's sale price was zero, the quantity of home-consumed goods was multiplied by the median district price instead of the farm's sale price. This approach ensured that home-consumed goods were assigned a realistic monetary value. Additionally, adjustments were made to the reported prices for fodder and total farming expenses. For cases where the price paid for a kilogram of fodder, such as hay, was significantly higher than typical, the reported price was adjusted to match the district's median price, disregarding any zero values. This method of correction was applied equally to general farming costs. The instances of exceptionally high fodder prices may stem from misunderstandings during data collection, as the questionnaire requested prices per kilogram, but some respondents appear to have recorded the total purchase price instead.

Outliers were identified as data points falling outside 1.5 times the interquartile range (IQR) of the gross margin per head across different quartiles and clusters. Using descriptive statistics and box plots, outliers were flagged for further investigation. Each outlier was examined by analysing the gross income and variable costs of the farms, delving into individual cost and revenue components to determine their validity. Decisions on handling outliers involved either retaining, adjusting, or removing them based on their potential impact on the analysis. Due to the relatively small dataset, each outlier was individually assessed to determine if it should be excluded due to unexplained distortions. For example, one observation (number 1113) reported consuming an unrealistic amount of milk, so the value of the variable "C5_3_5" was replaced with the median for all positive values. Similarly, another observation (number 1194) with unrealistic wool consumption had its value adjusted in the same manner.

To ensure the study’s reliability, farms not primarily engaged in livestock farming were excluded due to the challenge of separating variable costs between crop and livestock operations. Based on a question asking farmers to assess their own specialisation, thirteen farms were identified as crop or mixed farms, as opposed to specialised livestock farms. These farms had higher variable costs compared to others with similar livestock numbers, indicating that the costs included crop farming expenses. To reduce distortion, these farms were excluded from the analysis.

Additionally, twelve other farms were excluded due to extreme outliers in some cost components that could not be explained. Specifically, one observation (identified by number 1158) was removed from the dataset due to its extremely negative gross margins. This negative gross margin was largely attributed to the method used to calculate "change in stock," as described in the annex. This calculation involves subtracting the current number of cattle on the farm from the number owned 12 months prior. The substantial reduction in livestock numbers at these two farms led to a significant distortion of their gross margins in a negative direction. For instance, one farm (observation 1142) had disproportionately high labour costs, where compensation to workers exceeded sales revenue despite managing only six cattle.

Among the sample, 29 farms reported low or negative gross income, primarily because they did not engage in selling animals, animal products, or by-products. For these farms, the only contribution to their gross income came from the valuation of items consumed at home, which only partially offset their costs. This phenomenon is typical of subsistence farming, where production is primarily for household sustenance rather than for sale. However, it is important to note that subsistence farming does not necessarily result in negative gross margins. In some cases, the value of self-consumed products can lead to a positive gross margin if the savings are substantial enough to balance production costs. Within this dataset, most of the subsistence farms fall into the low or negative gross income category, but this is not universally the case. Retaining these 29 observations is crucial, as they offer insights into the livelihood strategies of households that rely primarily on their own production. This inclusion helps to capture the diversity within the agricultural sector, ensuring the analysis reflects economic behaviours and decision-making processes in settings with minimal market engagement. Excluding subsistence farms could lead to an incomplete or biased understanding of the agricultural sector, potentially skewing the analysis towards commercially oriented farms. By retaining these observations, a more comprehensive view of the sector, encompassing both market-oriented and subsistence-based livelihood strategies is ensured.

The data cleaning process involved multiple steps, each contributing to the overall reliability and validity of the dataset. By systematically addressing missing data, outliers and inconsistencies the dataset was prepared for rigorous analysis. This thorough cleaning process ensures that the research findings are grounded in accurate and reliable data. This approach acknowledges that real-world data can sometimes present anomalies that, while challenging, do not necessarily indicate errors.

Table 7 Observations Excluded from the Calculations

Num	Explanation
Observations excluded due to unrealistic high labour costs	
1142	Disproportionately high labour costs; compensation to workers exceeds sales revenue. With only 6 cattle and no sales of animals or by-products, its husbandry costs are unusually high.
1188	Labour costs reach 2 million tenge in cash, with total costs exceeding 4 million tenge. Despite high home consumption, no sales of animals or by-products make this pattern unconventional for farms of similar size and strategy.
Observations excluded due to high costs relative to gross income/sales	
1003	Low gross income compared to very high farming costs per head, attributed to high interest and loan repayment costs.
1033	Replacement costs more than double the gross income, indicating unreasonably high expenses.
1156	Replacement costs are more than six times the gross income, highlighting disproportionate expenses.
1199	Replacement costs exceed gross income by more than five times, underscoring unsustainable financial ratios.
1158	Excluded for extremely high replacement costs, not aligned with typical farm operations.
Observations excluded due to unrealistic high feed and farming costs	
1147	Significantly higher feed costs than typical but considered for retention in the calculation.
1148	Excessively high feed costs but suggested for retention in the calculation.
1195	Elevated feed costs with no income nor home consumption, resulting in a gross income of 0.
1172	Farming costs significantly above average, mainly due to high interest and loan repayments.
1119	Zero income reported; only consumption noted with very high costs, presenting an unsustainable financial model.
(1027)	This observation was excluded for cattle farming due to not being specialized in cattle farming and costs that cannot be divided into cattle and livestock farming and therefore really high negative values
Observations with a specific value that appears unrealistic but, after adjusting this value are included in the calculation.	
1113	This farm consumes way more milk than can be produced by this size of farm.

	The value of the variable "C5_3_5" was replaced with the median of "C5_3_5" for all observations with a value greater than zero.
1194	This farm consumes way more wool than can be produced by this size of farm. The value of the variable "C5_3_6" was replaced with the median of "C5_3_6" for all observations with a value greater than zero.
Oberservations excluded due to not being specialized in livestock farming	
1011	
1024	
1029	
1030	
1035	
1038	
1056	These numbers were excluded by using the variable farm_spec. When farm_spec was 0, the observations were excluded.
1063	
1066	
1070	
1081	
1187	
1216	

4.2 Generation of Outcome Variable

4.2.1 Unit of Analysis

There are three potential levels of analysis: farm, herd (cattle and all livestock) and head of (i) cattle or (ii) livestock. This thesis opted to utilise gross margin per herd as the chosen outcome measure, focusing on the profitability of the (i) cattle and (ii) livestock herd but also the gross margin per head to make them more comparable. This decision aligns with my research goals of assessing overall livestock profitability

While calculations are based on variable costs and animal count, allowing for easy computation of gross margin per head, interpreting implications from this data presents nuanced challenges. Assessing Gross Margin per farm offers a holistic view of economic performance, aiding answers to research questions. It evaluates resource management and profit generation across various agricultural and livestock enterprises. This approach supports strategic farm-level decisions and overall profitability assessment. However, relying solely on Gross Margin per farm might obscure variations in profitability among individual livestock and specific management methods, possibly overlooking opportunities for improvement. This data also offers limited insights into the overall economic performance of farms, providing a broad perspective on profitability in livestock farming while lacking detailed information on potential gains from arable farming, vegetable cultivation, or additional income streams. Detailed information about the calculation of the gross margin for cattle and livestock farming can be found in chapter 4.2.3. The complete calculations, including the variables from the dataset utilized for this purpose, are detailed in the annex, specifically within tables 25 and 26.

In addition to assessing the gross margin per herd, it is essential to consider the analysis of gross margin per head of animal. This perspective provides a more comprehensive understanding of farm profitability. While evaluating the gross margin per herd offers insights into the overall economic performance of a livestock operation, examining gross margin per head allows for a better comparison of the economic performance between farms. This distinction becomes especially valuable considering the diversity of farm sizes and management practices. Furthermore, the variable cost per unit of output is expected to be lower in large farms due to economies of scale (H1a). A key question is whether this cost advantage holds for farms that are more mobile or more dependent on purchased fodder, keeping herd size constant. This consideration shows the importance of looking at profitability per head of livestock, as it can reveal how different farming strategies impact economic efficiency across varying operational scales. Larger farms may indeed exhibit higher overall gross margins due to economies of scale, but assessing gross margin per head can uncover subtler insights. Smaller farms or smallholders might achieve larger gross margins per head, indicating the efficiency and success of their specific management methods (Kerven et al., 2004). By analysing both gross margin per herd and per head for cattle and livestock farming, a more holistic view of profitability that accommodates the varying scales of agricultural operations and offers a well-rounded perspective for stakeholders and policymakers is offered.

The thesis employs the EU standard units for counting livestock, which enables a comparison across different types of livestock, including cattle, sheep, goats and others. while also considering factors such as age and sex, to conduct a comprehensive analysis of gross margins. This method acknowledges the heterogeneity within cattle populations and recognises the varying economic values that arise from their diverse characteristics.

4.2.2 Gross Margin Analysis

Gross margin analysis has been and is still used for farm budgeting, planning and management, although the number of alternative analysis tools is high (Esmael et al., 2016; Jobirov et al., 2022). As highlighted by Kibona and Yuejie (2021), the initial step involves establishing the physical attributes and unit prices of input and output variables, facilitating the computation of variable costs, revenues, and, consequently the gross margin. For a comprehensive overview of the inputs used in these calculations, refer to chapter 4.2.3. Consequently, the functional equation of the Gross Margin Analysis model is presented and explained below.

$$GM_i = GI_i - TVC_i$$

Where:

GM_i stands for gross margin of farming of (i) cattle or (ii) livestock in local currency.

GI_i stands for the gross income from sales in local currency.

TVC_i stands for the total variable cost of farming per head of livestock in local currency. Fodder and husbandry costs (such as costs of medicine) were some of these expenses.

i stands for the farm observed.

Gross income is made up of two parts: sales of goods (including sold livestock and livestock products) and inventory changes (Makeham & Malcolm, 1986). It is the total value of production and includes also any produce consumed on the farm. The value of transfers out of the farm and livestock purchases must be deducted (Barnard & Nix, 1979). Because the revenue from the sale of produce is not always received immediately or in full, calculating the gross income is challenging.

In a family farm, produce that is consumed by the household but not sold can be viewed as potential income, as it represents goods that could have been marketed and sold (FAO, 2017). On farms that are semi-subsistence, some of the produce is consumed while some is sold therefore the simplification that all the saleable animals and animal products consumed have the same value as sold livestock (market price) is used (Makeham & Malcolm, 1986). A subsistence input or terminal product should always be valued at the cash cost of replacing it rather than using household animals (Behnke, 1985). Another perspective is that own consumption frees the household from needing to buy an equivalent amount of food from the market (FAO, 2017). Also, by-products like manure or skins must be considered. These are accounted for by the number of skins sold multiplied by their price. While this example uses skins, it's crucial to note the absence of data for other potential by-products, such as sold manure, which could also influence the gross income.

In this study, we conduct two sets of gross margin calculations: one for cattle and another for all livestock combined. The data available for these two analyses are not the same, which necessitates different approaches to ensure accuracy and integrity in our financial assessments. The gross margin calculation for cattle includes inventory changes over the past 12 months, aligning with the principles set forth by Makeham and Malcolm (1986), who emphasize the importance of recognizing value increments in livestock as part of gross income. However, data on inventory change were missing for other livestock species, so for consistency we excluded this element for all species in our calculations on total livestock.

Whilst this means that we cannot take changes in livestock population into account, it is important to note that many published analyses do not include inventory changes in their assessment of gross margins. Specifically, Kerven et al. (2004), Jobirov et al. (2022), and Corniaux et al. (2009) have conducted gross margin analyses without incorporating the effect of inventory change. Moreover, market factors may alter the value of animals over time. The analysis can occasionally become distorted and lose its value as a planning tool if it considers changes in gross income numbers as well as changes in stock value caused by market influences (Makeham & Malcolm, 1986).

The gross margin of an enterprise is calculated by subtracting the variable costs associated with it from its enterprise output. Fixed costs are not considered (Kibona & Yuejie, 2021). Feed, husbandry, marketing, and breeding (as well as replacement stock when not raised on the farm) make up the four main parts of the variable costs of any livestock-raising activity (Makeham & Malcolm, 1986). For costs to be categorized as variable costs within the context of gross margin analysis, they must fulfil two criteria that are akin to those met by enterprise outputs: firstly, they should pertain uniquely to a particular enterprise, and secondly, their fluctuations should closely correlate with changes in enterprise size during production (Barnard & Nix, 1979). In the case of non-grazing livestock, the primary variable cost is feed (Barnard & Nix, 1979). Regardless of flock size or seasonal movement, the research underscores that fodder constitutes the predominant component of input costs (Jobirov et al., 2022; Kerven et al., 2006).

Literature is discussing if all labour costs are variable costs and should be included in the calculation of gross margin or if permanent labour is not part of the variable costs and therefore should not be included. Barnard and Nix (1979) urge caution when calculating work as variable costs, as these do not necessarily vary with the size of the enterprise. Thus, the second requirement they set for variable costs is not fulfilled. As an example, they cite a cowman who receives a supplement to his salary if he looks after more cattle, but who has a fixed basic salary. As a compromise, only seasonal work is included in the calculation used in this paper. This is also recommended by Olson (2004). Papers discussing similar research topics are including labour in their gross margin calculation (Igwe & Onyenweaku, 2013; Makhdum, 2020; Mithöfer & Waibel, 2003; Moll, 2005).

In this study, two separate sets of gross margin calculations were conducted: one focusing exclusively on cattle farming and the other encompassing all livestock farming activities. This dual approach was necessitated by the distinct data availability and accuracy concerns specific to cattle versus other livestock types. Most of the observed farms in this study practiced multi-livestock farming with varied strategic focuses, often not maximizing profits solely through cattle farming but utilizing it as part of a diversified farm portfolio. Given these factors, and the overlap of costs between cattle and other livestock activities where costs could not be exclusively attributed to one type without distorting financial insights, it was deemed methodologically sound to analyse and present these sectors separately. The detailed results of the cattle farming analysis are included in the Annex to provide a comprehensive view without overwhelming the primary analysis of broader livestock activities, which is presented in the main body of chapter 5.

4.2.3 Gross Margin Calculation

This chapter presents a methodical approach for the calculation of gross margins for cattle and livestock farming. Through a detailed analysis encapsulated in the annex, this section illustrates the composition of gross income from cattle operations, alongside the variable costs incurred, providing a foundational basis for assessing profitability within diverse farming contexts. The following table shows the different components of the calculation.

Table 8 Gross Margin Calculation

Category		Element	Description	Data Availability
		Gross Income (cash)		
(i) Sales of Animals and Animal Products	(a)	Animal Sales	Value of all cattle, sheep, goats, and horses (head multiplied with price/head).	✓ (Note: Limited to cattle, sheep, goats, horses)
	(b)	Animal Product Sales	Value of animal products sold (amount multiplied with price/unit). Includes beef, other meat, milk, wool, etc.	✓
	(c)	Value of Animals and Their Products Eaten	Value of animal products consumed at home plus value of cattle, sheep, goats, and horses slaughtered for home consumption.	✓
(ii) Sales of By-Products			Number of skins sold multiplied with their price. No data for sold manure.	✓ (Note: Limited to skins)
(iii) Change in Total Value of Stock			Number of cattle now minus number owned 12 months ago multiplied with the mean value of cattle this age and gender in its subdistrict in cash. No data available for all livestock; this part is not included in the livestock gross margin calculation.	✓ for cattle ✗ For livestock
Variable Costs (cash)				
(v) Costs indicating a more intensive feeding strategy	(a)	Cost of Feed	Total purchased fodder fed in a year. These costs can be divided in all fodder purchases and the purchases just for cattle.	✓
	(b)	Cost of fodder production	Seed, fertilizer, pesticides and irrigation water used for fodder crops, machinery hire and spare parts	✓ *
		Cost of seasonal labour	Seasonal labour is the only variable labour cost included as discussed in the text	✓ *
		Cost of Husbandry	Costs for cattle health care and insemination are included. No information on livestock health care or insemination costs.	✓ (Note: Limited to cattle)
(vi) Costs indicating a pasture-based farming strategy	(c)	Costs for grazing	Rental of pastureland, Water for livestock and fuel for well/bore hole pump, other costs	✓ *
		Costs for transport (fuel)	Fuel for machinery and transport	✓ *
	(d)	Purchased animals	Summed up for different cattle and livestock purchases	✓

vii) Other costs	(e)	Marketing costs	Costs like Sanitary compliance, commission, rent of transportation to market, inspection, market fee	✓ *
	(f)	Loan repayments	Interest and loan repayment	✓ *

✓ = Data available; X = Data not available

*= Note: cannot be divided in cattle and other livestock farming

Based on Makeham and Malcolm (1986)

4.3 Statistical Analysis

This study made use of both descriptive statistical analysis and financial metrics. Using R Studio, the data collected through questionnaires and interviews was coded and analysed.

4.3.1 Generation of Descriptive Statistics

In this analysis, descriptive statistics are employed to gain a comprehensive understanding of the dataset. These statistics offer valuable insights into the central tendencies, variability, and distribution of the data. The mean, representing the average value, is calculated to provide an overview of the typical value in the dataset. Alongside this, the median, which is less influenced by outliers, presents an alternative perspective on the central value. The median proves particularly advantageous when handling datasets with outliers, as it is less susceptible to the influence of extreme values. To assess the spread or dispersion of the data, focus is placed on the range, indicating the difference between the highest and lowest values. Understanding the significance of maximum and minimum values aids in identifying potential upper and lower bounds within the dataset. The next step is to compare the economic metrics between households and commercial farms and across farm scale and feeding strategy to determine if there are any significant differences in their economic outcomes. Once the calculations of measures and ratios are completed, it becomes essential to establish a reference point for analysing these figures. There are four approaches for making comparisons: internal, historical, vertical, and horizontal (Olson, 2004). The question of how the business fares in relation to other farms is addressed through horizontal comparison. This entails comparing performance with a group of similar-sized and similar-type farms. It is imperative that the farms undergo financial analysis using comparable methods like the gross margin analysis to enable meaningful comparisons (Olson, 2004). This way of analysis will be used to answer Research question 1-3.

4.3.2 Methodological Approaches Used to Address Research Questions

In this section, the methodological approaches used for the systematic investigation of the individual research questions are presented. The t-test is a foundational statistical tool used in this research to compare the means of two distinct groups. Its primary function is to assess whether the observed differences in means between households and commercial farms are statistically significant or could merely be the result of random variation. This method helps in preliminarily examining the relationship between farm size and profitability and answer Hypothesis H1a and H1b. ANOVA (Analysis of Variance) extends the comparative analysis to more than two groups, enabling the examination of hypotheses H1c and H1d related to the variations in gross margins across different categories of farm sizes. While valuable, it's crucial to acknowledge the limitations of ANOVA in the context of this research, particularly in its ability to handle only one dependent variable without considering multiple independent variables simultaneously. The application of ANOVA necessitates careful consideration of assumptions, including data normality and homogeneity of variances. Where these assumptions are not met, Welch's ANOVA or the non-parametric Kruskal-Wallis test is identified as more appropriate alternatives. This rigorous statistical examination ensures the validity and reliability of conclusions. It is important to acknowledge that the use of ANOVA in this context has limitations due to the artificial segmentation of a continuous variable into four quartiles. Research questions 1-3 can also be answered by using a multiple linear regression focusing on (i) scale and (ii) feeding strategy. It is another approach in addition to the ANOVAs and equivalent non-parametric tests.

Research question 1: Which effect does scale (i.e. holding size) have on profit of (i) cattle farming and (ii) livestock farming?

The methodologies used to answer the first research question include t-tests, ANOVA, simple univariate regression, and multivariate regression, each serving a specific purpose in the analysis. While ANOVA allows for the comparison of means across these created groups, this approach may not fully capture the nuances of the underlying continuous relationship. Therefore, to harness the richer information contained within the continuous nature of farm holding size, scatter plots and univariate regression analyses are employed. These methods facilitate a more direct investigation of the relationship, enabling the visualization and quantification of trends across the entire spectrum of farm sizes without the constraints imposed by artificial categorization. Before applying regression analysis, it is crucial to address the challenge of negative values in the dataset. As logarithmic transformations require positive inputs, a data transformation technique is used. This involves adding a constant to all data values where the constant is equal to the absolute value of the smallest negative number plus one. This shift ensures that all values are positive, enabling the effective application of the logarithmic function. Such transformation is essential for maintaining the inclusion of all observations in the analysis, particularly when dealing with metrics like gross margin that may assume negative values (Osborne, 2002).

To further enhance the analysis, both Gross Margin and Herd Size were log-transformed. This transformation was performed to stabilize variance and normalize the distribution of these variables, allowing for a more accurate application of regression models (Osborne & Jason, 2010). The formula for a simple univariate regression with these transformed variables can be expressed as:

$$log(Y) = \beta_0 + \beta_1 log(X) + \varepsilon$$

Where:

$log(Y)$ = Gross Margin

$log(X)$ = Herd Size

β_0 is the intercept, which represents the estimated value of the dependent variable when the independent variable is 0.

β_1 is the regression coefficient, which represents the change in the dependent variable for a one-unit change in the independent variable/ herd size.

ε represents the error term, which accounts for unexplained variation in the dependent variable.

This analysis aims to estimate the parameters β_0 and β_1, offering insights into how changes in herd size can affect gross margin. The coefficient β_1 represents the change in gross margin for each unit change in herd size.

For a more comprehensive understanding that accounts for multiple influencing factors, multiple regression analysis is also employed, including as independent variables both a binary dummy for household/farm and the continuous metric of holding size (see section 4.3.3). Alongside these analytical methods, scatter plots are utilized to visually depict the relationships between the dependent and independent variables, enhancing the interpretability of the statistical findings.

In conclusion, while the primary methods of analysis are the univariate and multivariate regressions, supplemented by visualizations such as scatter plots, the inclusion of t-tests and ANOVA enriches the research by offering preliminary and broad comparative insights. However, it's important to bear in mind and communicate the specific limitations of each methodological approach within the scope of this study.

Research question 2: Which effect does feeding strategy have on profit of (i) cattle farming and (ii) livestock farming?

Research Question 2 explores the impact of feeding strategies on the profitability of (i) cattle farming and (ii) livestock farming. A greater reliance on feed purchases is hypothesized to be negatively associated with gross margin, reflecting the higher operational costs involved. Conversely, more extensive use of pastures is expected to positively impact gross margin, benefiting from lower feeding costs and potentially healthier livestock. To investigate this, an ANOVA was used to compare gross margins across different feeding strategy clusters defined by unique combinations of feeding strategies and farm sizes. Unlike the variables considered in Research Question 1, these clusters are categorical, derived from combinations of variables including farm size but do not represent a continuous or ordinal variable. This distinction justifies the application of ANOVA, facilitating an analysis of profitability differences between categorically distinct farming strategies. A multiple regression examines further the effect of feeding and mobility on profitability and is further explained in section 4.3.3.

To ensure the robustness of ANOVA results, preliminary checks include assessing outliers using Boxplots, testing for normality via histograms, Q-Q plots, and Shapiro-Wilk tests. If normality is violated, non-parametric alternatives like the Mann-Whitney U test for two groups or the Kruskal-Wallis test for three or more groups are considered. These tests provide reliable comparisons without the strict requirements of parametric tests.

This research question was also addressed through multiple regression analysis (see below), by including a number of feeding metrics as independent variables in that regression.

Research question 3: What are the main factors that create differences between the gross margins of farms with similar scale/structures? Are they related to revenue, variable costs or a combination of both? What is the impact of changes in input costs on the farms' gross margin?

Research Question 3 investigates the key factors contributing to variations in gross margins among farms with similar scales or structures. This inquiry delves into whether these differences are primarily driven by revenue, variable costs, or a combination thereof, and explores the effect of input cost changes on farms' gross margins. The outcome of the gross margin analysis is often used as a planning tool for farms and can also give insight into the cost structures (Makeham & Malcolm, 1986). To address this question, the study conducts a vertical analysis of the data derived from gross margin calculations. This approach involves calculating the average of each cost and revenue component, then assessing their relative contributions to the overall average gross margin across various size categories and feeding strategies. When compared with other farms, vertical analysis aids in discerning variations or similarities in the composition of income and expenses (Olson, 2004). Unlike other analyses that might rely on statistical tests to identify differences, this method is descriptive, focusing on elucidating and visualizing the cost and revenue structures within and across farm groups. The analysis zeroes in on the structure of gross margins across farms, pinpointing significant disparities in how costs and revenues are configured among farms of differing scales or operational models. By dissecting the mean contribution of each cost and revenue element to the total gross margin, this research offers visual and descriptive comparisons. These comparisons illuminate how different farm structures manage and allocate resources, shedding light on efficiency and strategic positioning within the agricultural sector.

The methodology includes a univariate regression analysis for each component of gross margin of interest. These components include the proportion of expenditures on fodder, the allocation of variable costs to labor, and the diversity of income sources. The univariate regressions are utilized to individually assess the impact of these components on the total gross margin, allowing for the isolation of each component's effect. This approach provides insight into how changes in these specific GM components might influence financial outcomes across different farm structures.

The model for each univariate regression can be expressed as:

$$Log(Y) = \beta_0 + \beta_1 X + \epsilon$$

Where:

Y =	gross margin of the farm
β_0 =	the intercept of the regression, indicating the expected value of Y when X is zero
β_1 =	the coefficient of X, quantifying the expected change in Y for a one-unit change in X
X =	represents the independent variable under examination which is fodder costs/total costs for H3a, labour costs/total costs for H3b, HHi of gross income for H3c and fodder costs per head for H3d
ε =	the error term, accounting for the variation in Y not explained by X

Several of the research questions above can be addressed through a single multiple regression analysis including farm size and feeding metrics as independent variables. Multiple regression can capture complex relationships between the dependent variable and multiple predictors and therefore can help identify which independent variables are most important in explaining the variation in the dependent variable. It provides a framework for testing hypotheses about the relationships between variables and helps in understanding how various independent variables are associated with changes in the dependent variable. The detailed approaches used to construct this multiple regression are discussed in the next section.

Regression analysis can therefore be a valuable tool for explaining profitability measurements like gross margins in the context of agricultural or business operations. In this thesis, logarithmic transformations were applied to Gross Margin and certain predictor variables, such as Herd Size, to enhance the statistical analysis and ensure robust results**.** This transformation helped normalize the data distributions, stabilize variance across different sizes of farm operations, and reduce the impact of outliers. Additionally, converting multiplicative relationships into additive ones facilitated more straightforward interpretations of the regression outcomes (Osborne & Jason, 2010).

Before applying regression analysis, it is crucial to address the handling of data that may include negative values, such as gross margins. In this thesis, a data transformation technique was employed by adding a constant to all data values, ensuring all values are positive and suitable for logarithmic transformation. This constant is calculated as the absolute value of the smallest negative number plus one. This adjustment is essential for maintaining the inclusion of all observations in the analysis, allowing for a comprehensive examination of the data (Osborne, 2002). The predictor variables examined in this study can be categorized into two groups: those directly related to feeding, mobility, and holding size, which are the primary focus of the research questions, and those that are likely to have an influence but are not the main subjects.

In this study, a multiple regression analysis to examine the variables that affected the gross margin of the farmers interviewed is used. Livestock farmers' profitability was examined using the Ordinary Least Square (OLS) model. The model is described in detail as follows:

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_n x_n + \varepsilon_i$$

Where

Y_i =	GM (profit)
β_0 =	Constant
$\beta_1, \dots, \beta_n$ =	coefficients to be estimated
$X_1, \dots, X_n$ =	independent variables

ε_i= error term, this represents all factors that influence the variance but are not depicted by the explanatory variables

The OLS approach is a numerical modeling tool that is used to explain the relationship between a continuous dependent variable (log-transformed gross margin profit) and a number of independent factors (determinants of profitability) (Jobirov et al., 2022). The intensity and significance of the relationship between profitability per farm and per head of (i) cattle and (ii) livestock and factors that are anticipated to affect profitability were determined using the multiple linear regression approach (Nkadimeng et al., 2021).These include some of the proposed variables in the two tables below.

As a result, the OLS regression model was further described as follows:

$$Log(Gross\ margin\ per\ head\ (profit)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 \log(X_3) + \beta_4 \log(X_4) + \beta_5 \log(X_5) + \beta_6 \log(X_6) + \beta_7 \log(X_7) + \beta_8 \log(X_8) + \beta_9 \log(X_9) + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \varepsilon_i$$

and

$$Log(Gross\ margin\ on\ a\ farm\ level\ (profit)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 \log(X_3) + \beta_4 \log(X_4) + \beta_5 \log(X_5) + \beta_6 \log(X_6) + \beta_7 \log(X_7) + \beta_8 \log(X_8) + \beta_9 \log(X_9) + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \varepsilon_i$$

Mlote et al. (2013) claimed that the reliability of the results of an OLS regression analysis could be at risk if the underlying assumptions were to fail. Any failure of the hypotheses renders the component estimations invalid for interpretation.

Table 9 The Pre-Hypothesized Effects of the Independent Variables on Livestock Farming Profitability

	X_n	Variables	**Variable name**	**measurement**	**Hypothesized effect**
Land access	1	**Distance to Almaty**	Distance	km	-
	2	**Months spent on off-village pasture**	ms_offvpast	Number of months (0-12)	+
	3	**Total cropland used**	B1_1	ha	+
	4	**Total hayland used**	B1_4	ha	+
Fodder	5a	**Purchase of concentrate for cattle, total**	conc_purch_kgcat1	kg	-
	5b	**Purchase of concentrate for livestock, total**	conc_purch_kg1	kg	-
	6a	**Self-production of concentrate for cattle, total**	conc_self_kgcat1	kg	+
	6b	**Self-production of concentrate for livestock, total**	conc_self_kg1	Kg	+
	7a	**Purchase of roughage for cattle, total**	rough_purch_kgcat1	kg	-
	7b	**Purchase of roughage for livestock, total**	rough_purch_kg1	kg	-
	8a	**Self-production of roughage for cattle, total**	rough_self_kgcat1	kg	+
	8b	**Self-production of roughage for livestock, total**	rough_self_kg1	kg	+
Farm size	9a	**Total cattle numbers**	cattle	EU cattle units	+
	9b	**Total livestock numbers**	lunit_eu	EU livestock units	+
Farm characteristics	10	**Members of household total**	E14_2_4_1	Number of members	+
	11	**Educational level**	edu_index	Scale (0-2) *	+
	12	**Commercial farm**	hhfarm	If yes=0, if no=1**	+

EU cattle units gen cattle: bulls+ steers+ cows+ (0.8*heifers)+(0.7*bullocks)+ (0.4*(calves_m+calves_f));
EU livestock units: (sheep*0.1) + (goat*0.1) + (horse*0.8) + (cattle*1), See Eurostat (2023) for further Information
***Explanation:**0= "Primary education"; 1= "Secondary education"; 2= "Higher
****Explanation**: if no=1= household

Table 10 Explanations and the Expected Influence

1	**Distance to Almaty (km):** Almaty is still the cultural, scientific, and economic centre of the country, alongside the capital, Astana. Even if land prices and costs are maybe higher, you have also a better infrastructure and better market access. The closer the livestock farm is to Almaty, the bigger the influence of the advantages of the capital. Ceteris paribus there should be a negative relationship between distance to market and gross margin.
2	**Months spent on off-village pastures (number):** Mobility comes with costs, such as transportation expenses, transaction costs, housing costs for farmers at pastures, and costs associated with trucks, among others. These costs are largely fixed in nature. As a result, pasture-based farms can benefit significantly from economies of scale. Consequently, off-village pastures are often predominantly utilized by larger pastoralists. The more animals a farm owns, the higher its gross margin is expected to be (see X_9). However, it's worth noting that in Kerven et al. (2004) study, gross margins per head were found to be higher for sedentary farms with small numbers of animals (which had to purchase fodder) compared to large mobile producers. While larger pastoralists may prioritize owning a high volume of animals, potentially incurring higher costs and achieving a smaller gross margin per animal, they tend to have a higher gross margin overall. Jobirov et al. (2022) finds a positive correlation between pasture availability and profitability.
3, 4	**Total cropland and hayland used (ha):** Arable land provides an input into the livestock production system. It can also be an indicator on how much fodder can be self-produced. The more fodder is self-produced, the less must be bought. This can have a positive impact on profitability. Nkadimeng et al. (2021) also find a positive correlation between farm size and profitability.
5, 6, 7, 8	**Purchase and Self-production of roughage and concentrate (kg): S**elf-production of feed can reduce expenses, leading to higher profit margins therefore high feed self-sufficiency and low variable costs enhance the economic performance (per labour unit) of the farms(Ripoll-Bosch et al., 2014). Transportation and transaction costs, as well as price volatility, are expenses that arise only when purchasing fodder and are added to the base price of the fodder. Consequently, the act of purchasing fodder is expected to have a negative impact.
9	**Total cattle/ livestock (number):** If the gross margin per head of livestock is above zero, which should be the case- otherwise the operation should be ceased. the higher the count of animals the higher the gross margin of the farm will be. Therefore, the number of livestock is expected to have a positive effect on the gross margin per farm. Some studies in Central Asia found a negative correlation between herd size and profitability per head (Jobirov et al., 2022; Kerven et al., 2004).
10	**Members of household total (number):** Household members often work for free on the farm. The gross margin analysis does not include opportunity costs, therefore are household members an indicator for cheap labour(Delgado et al., 2003). Family members are often also more motivated, therefore there is less need for monitoring (Delgado et al., 2003; Jobirov et al., 2022).
11	**Educational level (ranking scale):** More education might positively affect decision making on the farm, and thus profitability. Also, higher education can indicate that the farmer has access to assets, resources, or wealth that one generation passes down to the next within a family, creating a legacy of financial stability (Jobirov et al., 2022).
12	**Commercial farm (yes/no):** The primary objective for commercial farms is to maximize profit. However, subsistence herders have different priorities (Behnke, 1985). They are not only focused on farm profitability but also tend to be cautious about investing extensively. This caution often leads to lower income, consequently resulting in a smaller gross margin.

5 Results

This thesis seeks to examine the profitability of different scales of farming operations in Kazakhstan, with a focus on livestock. The results of the broader livestock farming analysis are presented in this section, reflecting the diverse strategies and profitability across the multiple livestock activities observed.

It is important to note that while cattle farming data is also analysed, it has been placed in the Annex. The results regarding the cattle farming calculation are not discussed in detail in this chapter but serve more as a comparison in this and the subsequent chapter. The key issue was the lack of specific data required to disaggregate costs for cattle from those for livestock in general, which could potentially lead to a negative distortion in its profitability analysis. This decision was also guided by the observation that cattle farming, while significant, often did not represent the most profit-maximizing strategy among the surveyed farms. Cattle make up, on average, only about half of the livestock on the farms, as seen in Table 4 and 5. Furthermore, the allocation of costs in multi-livestock farms introduced complexities in accurately attributing expenses solely to cattle farming, potentially leading to a negative distortion in its profitability analysis.

1. Which effect does scale (i.e. holding size) have on profit of livestock farming?

This research question explores how varying farm sizes influence gross margins, providing insights into the potential advantages or disadvantages of scaling operations in diverse livestock enterprises.

Hypothesis (H1a): Farms have a higher gross margin (GM) per herd than households.

The evidence supports Hypothesis H1a, indicating that commercial farms have higher total gross margins compared to households. As shown in tables 11 and 12, the total gross margin is significantly greater for commercial farms. The Independent Sample T-test as well as a non-parametric alternative like the Mann-Whitney U-test show that the difference is significant. These results demonstrate that commercial farms achieve significantly higher total gross margins than households.

Hypothesis (H1b): Households have a higher gross margin (GM) than farms per head.

The data provide mixed evidence regarding Hypothesis H1b, which posits that households achieve a higher gross margin per head of livestock than commercial farms. Table 11 indicates that while commercial farms have a higher mean gross margin per head (as shown by the t-test statistic and p-value), households have a higher median gross margin per head (supported by the Mann-Whitney test result and p-value). Given that median values are less influenced by outliers, they may serve as a more reliable measure in this context.

Table 11 Comparative Analysis of Profitability and Livestock Sales Between Commercial and Household Farms

	Household farms (N=49)	**Commercial farms (N=176)**	**Overall (N=213)**	**Levene's Test**	**Independent Sample T-test**	**Mann-Whitney U Test**
Total gross margin*				F=1.3556, p=0.2464	t=2.2692, df=132, p=0.02488*	
Mean (SD)	508 (1030)	2390 (5830)	1980 (5230)			
Median [Min, Max]	477 [-1350, 5690]	1070 [-1500, 62900]	855 [-1500, 62900]			W=1975, p=0.007209**
Gross margin per head of livestock*				F=0.3971, p=0.5297	t=-2.216, df=132, p=0.0284*	
Mean (SD)	51.8 (181)	67.4 (188)	64.0 (187)			
Median [Min, Max]	61.1 [-561, 825]	41.9 [-173, 2190]	44.3 [-561, 2190]			W=1072, p=0.02415*
Number of livestock sold						
Mean (SD)	8.47 (45.5)	22.1 (75.9)	19.1 (70.5)			
Median [Min, Max]	1.00 [0, 319]	4.00 [0, 912]	2.00 [0, 912]			

**in 1000 Tenge*
*Significance levels: ***p<0.001, **p<0.01, *p<0.05*

Hypothesis (H1c): There is a positive relationship between farm holding size and the gross margin of livestock farming.

The univariate regression in figure 1 (and table 13) supports Hypothesis H1c, indicating that larger farms have higher total gross margins. The parametric and non-parametric tests in table 12 show also a significant difference between quartiles. There is a clear upward trend in both mean and median total gross margins as farm size increases. The mean gross margin significantly increases from households to Quartile 4, suggesting that larger farms tend to have higher total gross margins. The median values also show a progressive increase, although the ranges indicate variability in gross margins within each quartile. The higher standard deviations in Quartiles 3 and 4 suggest greater variability in profitability among larger farms. The median values are less affected by extreme values, and they support the trend observed in mean values, reinforcing the conclusion that larger farms are more profitable on average.

Hypothesis (H1d): There is a negative relationship between farm holding size and the gross margin per head of livestock farming.

The results for Hypothesis H1d indicate a mixed picture regarding the relationship between farm holding size and gross margin per head of livestock farming. While table 12 presents some comparative analysis, it does not conclusively show a negative relationship. However, the univariate regression analysis provides more convincing evidence supporting Hypothesis H1d. The univariate regression analysis, illustrated in figure 2 and table 14, shows a significant negative relationship between herd size and gross margin per head. Specifically, the log-log relationship between gross margin per head and herd size indicates that a 1% increase in herd size is associated with a 0.35% decrease in gross margin per head. This regression model explains 12.3% of the variance in gross margin per head.

Table 12 shows the mean gross margin per head across different farm sizes, with Quartile 4 farms having a lower mean gross margin per head than Quartile 3 farms. However, this does not establish a clear linear trend. The statistical tests, including ANOVA, Welch-ANOVA, and the Kruskal-Wallis test, show significant differences in gross margin per head among different farm sizes, suggesting variability but not necessarily a consistent negative relationship. It is important to note that the results discussed were based on untransformed data. Given the issues with outliers and the distribution of the data, these tests might provide a more accurate assessment of central tendency. The Kruskal-Wallis test confirms significant differences in gross margin per head among different farm sizes, with households showing a higher median gross margin per head compared to Quartile 4 farms. Given the large standard deviations and the skewed nature of the data, the median values are likely a more reliable measure of central tendency. The Kruskal-Wallis test further supports the hypothesis, highlighting significant differences in medians that are less affected by the skewness and outliers in the data. Therefore, despite some conflicting evidence, the overall data suggest a negative relationship between farm holding size and gross margin per head of livestock farming.

Table 12 Comparative Analysis of Profitability Between Different Farm Sizes

	Households (N=48)	**Quartile 1 (N=46)**	**Quartile 2 (N=42)**	**Quartile 3 (N=40)**	**Quartile 4 (N=37)**	**Levene's Test**	**ANOVA**	**Welch-ANOVA**	**Kruskal-Wallis-test**
Total Gross Margin*						F=1.2444, p=0.2959	F=3.871, p=0.0104*		
Mean (SD)	508 (1030)	860 (1630)	1240 (1540)	3500 (9720)	4330 (5930)				
Median [Min, Max]	477 [-1350, 5690]	486 [3,4] [-1490, 9720]	1020 [4] [-1060, 7390]	1630[1] [-1500, 62900]	3120 [1,2] [-1380, 30100]			F=5.1496, p=0.002563**	χ2=24.534, p=0.00002***
Gross Margin per head of livestock*									
Mean (SD)	51.8 (181)	68.7 (153)	62.6 (79.2)	105 (332)	30.6 (45.9)	F=0.9894, p=0.3997	F=1.095, p=0.353	F=2.7852, p=0.04549*	χ2=9.8897, p=0.01953*
Median [Min, Max]	61.1 [-561, 825]	34.4 [-173, 853]	48.9 [4] [-55.9, 330]	50.7 [4] [-112, 2190]	24.6 [3,4] [-44.6, 235]				
Number of livestock sold									

	House-holds (N=48)	Quartile 1 (N=46)	Quartile 2 (N=42)	Quartile 3 (N=40)	Quartile 4 (N=37)	Levene's Test	ANOVA	Welch-ANOVA	Krus-kal-Wal-lis-test
Mean (SD)	8.47 (45.5)	4.47 (9.62)	8.07 (13.4)	21.9 (40.8)	59.4 (147)				
Median [Min, Max]	1.00 [0, 319]	0 [0, 45.0]	3.00 [0, 52.0]	6.00 [0, 215]	17.5 [0, 912]				

**in 1000 Tenge*
*Significance levels: ***p<0.001, **p<0.01, *p<0.05*
*Superscripts 1, 2, 3, 4, 5 and 6 indicate clusters with which a significant difference exists at *p < 0.05 or lower using pairwise comparisons with Holm correction (Wilcoxon Test)*

Univariate Regression

$$\log(Livestock\ Gross\ Margin) = \beta_0 + \beta_1 \log(Herd\ Size) + \varepsilon.$$

This model explores a log-log relationship, which reveals the elasticity between the two variables—how a percentage change in herd size affects the percentage change in total gross margin in livestock farming.

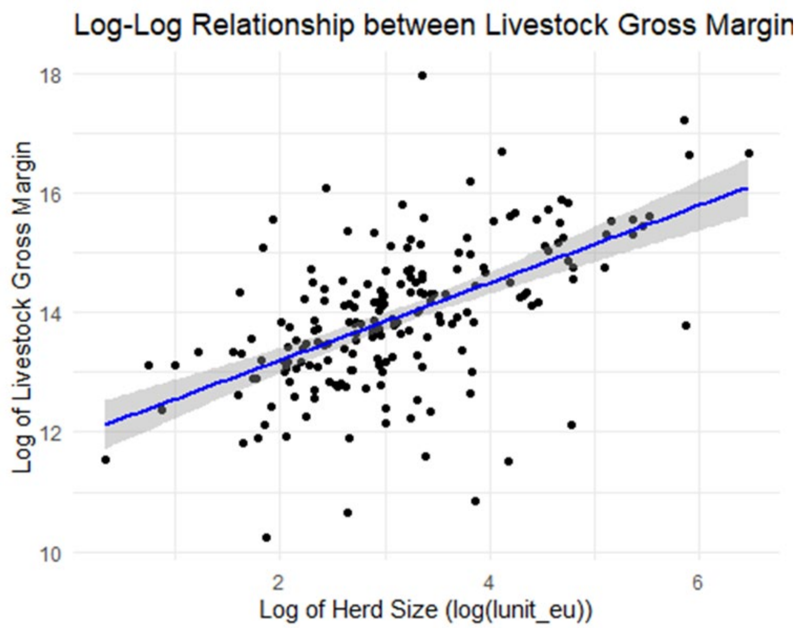
Table 13 Univariate Regression Log-Log-Relationship between Total Gross Margin and Herd Size

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	11.91119	0.22833	52.165	<2e-16 ***
log(lunit_eu)	0.64585	0.06927	9.323	<2e-16 ***

*R^2 = 0.317, Adj. R^2 = 0.314, Residual SE = 1.002 (187 DF), F(1, 187) = 86.92, p < 2.2e-16****
*Significance levels: ***p<0.001, **p<0.01, *p<0.05*

38 observations were deleted due to missing data. A coefficient of 0.64585 suggests that a 1% increase in Herd Size is associated with a 0.64585% increase in Livestock Gross Margin.

Figure 1 Log-Log Relationship between Gross Margin and Herd Size in Livestock Farming



Univariate Regression

$$\log(Livestock\ Gross\ Margin\ per\ Head) = \beta_0 + \beta_1 \log(Herd\ Size) + \varepsilon$$

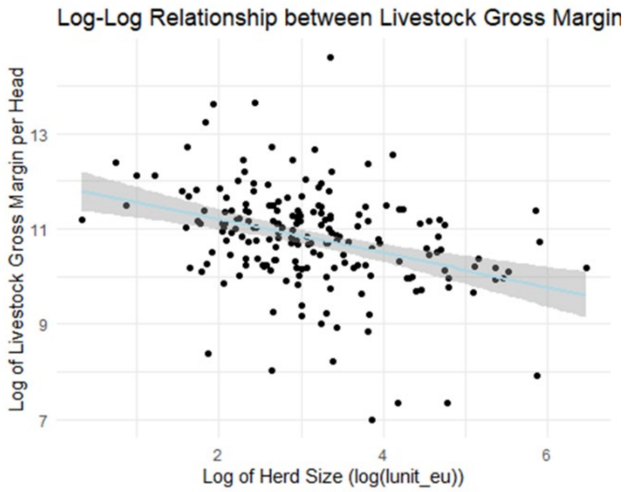
Table 14 Log-Log Relationship between Gross Margin per Head and Herd Size in Livestock Farming

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	11.91119	0.22833	52.165	<2e-16 ***
log(lunit_eu)	-0.35415	0.06927	-5.112	7.83e-07 ***

*R^2 = 0.123, Adj. R^2 = 0.118, Residual SE = 1.002 (187 DF), F(1, 187) = 26.14, p = 7.83e-07****
*Significance levels: ***p<0.001, **p<0.01, *p<0.05*

36 observations were deleted due to missing data. A coefficient of -0.35415 suggests that a 1% increase in Herd Size is associated with a -0.35415% decrease in Livestock Gross Margin per Head.

Figure 2 Log-Log Relationship between Gross Margin per Head and Herd Size in Livestock Farming



In summary, the data consistently demonstrate that while larger farm holdings may increase total gross margins, they tend to reduce the gross margin per head. This inverse relationship is crucial for strategic decision-making in livestock farming, suggesting that expanding herd size could dilute per-head profitability. These insights are essential for optimizing economic outcomes in livestock farming, guiding farm operations, investments, and policy formulations.

2. Which effect does feeding strategy have on profit of (i) cattle farming and (ii) livestock farming?

In Kazakhstan, the profitability of livestock farming seems to be linked to feeding strategies, particularly given the country's vast pastoral lands which are predominantly suitable for grazing.

Hypothesis (H2a): The gross margin for farms employing a self-producing feeding strategy is significantly higher than the gross margin of farms purchasing fodder.

The results for Hypothesis H2a suggest that farms employing a self-producing feeding strategy generally achieve higher gross margins compared to those purchasing fodder. However, this observation must be nuanced by the consideration of farm size.

Table 15 presents a comparative analysis of profitability between different feeding strategies. While the "Large mobile fodder producer" category (Cluster 6) shows the highest mean and median gross margins, this is likely due to the larger size of these farms rather than the feeding strategy alone. When comparing clusters of similar size, such as Clusters 5 and 6 or Clusters 2, 3, and 4, the differences are less pronounced, indicating that size is a significant factor. For example, "Medium fodder purchaser" farms (Cluster 3) have a lower mean gross margin compared to "Medium fodder producer" farms (Cluster 4). However, the median gross margins for these clusters are similar, suggesting that the profitability of producing fodder versus purchasing it is not significantly different when considering the median values. The Welch-ANOVA and Kruskal-Wallis tests confirm significant differences in total gross margin among the clusters, indicating variability based on feeding strategy and farm size.

The multiple regression analysis in table 16 further explores these relationships. The results show that self-production of feed, particularly concentrate, does not have a significant positive impact on gross margin, as the coefficients are negative and not statistically significant. This finding suggests that other factors, such as total livestock numbers, which significantly contribute to the gross margin, are more critical in determining profitability. Overall, the data do not consistently support the hypothesis that self-producing fodder strategies enhance farm profitability compared to purchasing fodder. The significant role of farm size and total livestock numbers indicates that these factors are more influential in driving gross margins.

Hypothesis (H2b): Cattle and livestock farms that predominantly rely on natural grazing have lower variable costs and higher gross margins than those that do not, despite the potential transportation costs.

The results for Hypothesis H2b suggest that cattle and livestock farms relying predominantly on natural grazing generally have lower variable costs and higher gross margins compared to those that do not. Table 15 and table 28 provides evidence supporting this hypothesis. Farms in the "Large mobile fodder producer" category (Cluster 6), which likely rely more on natural grazing, exhibit higher mean gross margins and median gross margins compared to clusters that rely more on purchased fodder. For instance, "Medium fodder purchaser" farms (Cluster 3) have lower mean and median gross margins. Further analysis reveals that farms in the "Large mobile" categories (Clusters 5 and 6) spend the most months on off-village pastures (mean of 10.8 and 10.0 months, respectively), supporting their higher profitability. Notably, the two most pasture-dependent groups are actually Cluster 2 (Medium mobile) and Cluster 5 (Large mobile fodder purchaser), both of which have high gross margins within their respective size categories.

The multiple regression analysis in table 16 reinforces these findings. Both purchasing and self-producing fodder have negative coefficients, indicating a negative impact on gross margin. This suggests that natural grazing and pasture use are more economically efficient, positively influencing gross margins. Although grazing (proxied by months spent on off-village pasture) and other factors do not show significant coefficients, the overall model indicates that reliance on natural grazing positively impacts gross margins. Overall, the data indicate that farms predominantly using natural grazing methods have lower variable costs and achieve higher gross margins, supporting Hypothesis H2b.

Table 15 Comparative Analysis of Profitability Between Different Feeding Strategies

	Small sedentary **Cluster 1 (N=38)**	*Medium mobile* **Cluster 2 (N=53)**	*Medium fodder purchaser* **Cluster 3 (N=19)**	*Medium fodder producer* **Cluster 4 (N=25)**	*Large mobile fodder purchaser* **Cluster 5 (N=23)**	*Large mobile fodder producer* **Cluster 6 (N=18)**	**Overall (N=176)**	**Levene's Test**	**Welch-ANOVA**	**Kruskal-Wallis**
Total gross margin*								F=1.4882, p=0.1961	F=4.4837, p=0.00141**	
Mean (SD)	1290 (2100)	2630 (8650)	721 (1340)	928 (1180)	5080 (7290)	4340 (3890)	2390 (5830)			
Median [Min, Max]	782 [5,6] [-1490, 9720]	1060 [6] [-1500, 62900]	521 [6] [-1380, 3610]	559 [-1060, 4570]	3200 [1] [-1300, 30100]	3870 [1,2,3] [-916, 17100]	1070 [-1500, 62900]			χ2=28.613, p=2.761e−05***
Gross margin per head of livestock*								F=0.6367, p=0.672	F=1.3541, p=0.2519	
Mean (SD)	91.7 (173)	96.7 (299)	30.7 (60.6)	45.9 (75.7)	41.2 (60.6)	32.2 (29.2)	67.4 (188)			
Median [Min, Max]	56.6 [4] [-173, 853]	46.8 [4] [-112, 2190]	26.6 [-48.2, 171]	32.1 [1,2] [-125, 254]	31.7 [-23.4, 284]	24.6 [-24.8, 91.5]	41.9 [-173, 2190]			χ2=10.753, p=0.05651
Number of livestock sold										
Mean (SD)	5.92 (14.1)	15.1 (31.8)	5.79 (5.62)	3.72 (6.49)	90.4 (189)	32.6 (38.6)	22.1 (75.9)			
Median [Min, Max]	0 [5,6] [0, 52.0]	5.00 [5,6] [0, 215]	5.00 [6] [0, 18.0]	1.00 [0, 25.0]	40.0 [1,2] [0, 912]	19.0 [1,2,3] [0, 124]	4.00 [0, 912]			
Purchase of concentrate for livestock (total kg)										
Mean (SD)	1100 (1010)	1660 (2160)	4960 (9200)	56.0 (212)	4980 (8240)	1300 (1820)	2060 (4700)			
Median [Min, Max]	1000 [4] [0, 5000]	1000 [4] [0, 10000]	2500 [4] [0, 40000]	0 [1,2,3] [0, 1000]	2000 [0, 30000]	0 [0, 5000]	950 [0, 40000]			
Self-production of concentrate for livestock*										
Mean (SD)	52.6 (324)	42.6 (229)	0 (0)	5810 (7020)	0 (0)	7120 (9100)	1550 (4670)			
Median [Min, Max]	0 [4,6] [0, 2000]	0 [4,6] [0, 1500]	0 [4,6] [0, 0]	4000 [1,2,3,5] [500, 30000]	0 [4,6] [0, 0]	5000 [1,2,3,5] [0, 30000]	0 [0, 30000]			
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5.6%)	1 (0.6%)			
Purchase of roughage for livestock*										
Mean (SD)	2230 (3360)	2160 (5660)	19200 (18300)	580 (1760)	51700 (110000)	3610 (10800)	10400 (43100)			
Median [Min, Max]	0 [3] [0, 10000]	0 [3] [0, 30000]	15000 [1,2,5,6] [2610, 70000]	0 [0, 7500]	28000 [3] [0, 540000]	0 [3] [0, 40000]	0 [0, 540000]			
Self-production of roughage for livestock										
Mean (SD)	13000 (12500)	21900 (20700)	2420 8120)	24800 (25800)	20900 (29100)	51400 (39000)	21200 (25700)			
Median [Min, Max]	9000 [3,4,5,6] [2000, 75000]	16000 [1500, 115000]	0 [1,4,5,6] ([0, 35000]	17000 [1,3] [0, 120000]	10000 [1,3,6] [0, 100000]	38900 [1,3,5] [0, 130000]	12000 [0, 130000]			

	Small sedentary Cluster 1 (N=38)	*Medium mobile* Cluster 2 (N=53)	*Medium fodder purchaser* Cluster 3 (N=19)	*Medium fodder producer* Cluster 4 (N=25)	*Large mobile fodder purchaser* Cluster 5 (N=23)	*Large mobile fodder producer* Cluster 6 (N=18)	Overall (N=176)	Levene's Test	Welch-ANOVA	Kruskal-Wallis
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (4.3%)	0 (0%)	1 (0.6%)			
Months spent on off-village pasture										
Mean (SD)	0.816 (1.66)	7.89 (3.26)	5.11 (4.43)	4.84 (3.75)	10.8 (2.64)	10.0 (3.38)	6.23 (4.64)			
Median [Min, Max]	0 [2,3,4,5,6] [0, 5.00]	6.00 [1,3,4,5,6] [3.00, 12.0]	5.00 [1,2] [0, 12.0]	5.00 [1,2] [0, 12.0]	12.0 [1,2] [4.00, 12.0]	12.0 [1,2] [3.00, 12.0]	6.00 [0, 12.0]			

**in 1000 Tenge*

*Significance levels: ***p<0.001, **p<0.01, *p<0.05*

Superscripts 1, 2, 3, 4, 5, and 6 indicate clusters with which a significant difference exists at p < 0.05 or lower, based on pairwise comparisons using the Wilcoxon test with Holm correction for multiple comparisons

Multiple Regression at the farm level

$$Gross\ margin = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_4 X_3 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \varepsilon_i$$

$$\log(Gross\ margin) = distance + ms\_offvpast + \log(B1\_1) + \log(B1\_4) + \log(conc\_purch\_kg1) + \log(conc\_self\_kg1) + \log(rough\_purch\_kg1) + \log(rough\_self\_kg1) + \log(lunit\_eu) + E14\_2\_4\_1 + edu\_index + hhfarm$$

Table 16 Multiple Regression for Gross Margin in Livestock Farming

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	11.727971	0.460518	25.467	< 2e-16 ***
Distance to Almaty	0.001946	0.001373	1.418	0.158
Months spent on off-village pasture	0.024458	0.019378	1.262	0.209
Total cropland used	0.013803	0.027246	0.507	0.613
Total hayland used	0.010414	0.024381	0.427	0.67
Purchase of concentrate for livestock, total	-0.018088	0.014703	-1.230	0.220
Self-production of concentrate for livestock, total	-0.024164	0.016204	-1.491	0.138
Purchase of roughage for livestock, total	-0.008538	0.011816	-0.723	0.471
Self-production of roughage for livestock, total	-0.012877	0.018288	-0.704	0.482
Total livestock numbers	0.567999	0.100146	5.672	5.79e-08 ***
Members of household total	0.066107	0.071029	0.931	0.353
Educational level	-0.052134	0.152096	-0.343	0.732
Commercial farm	-0.056375	0.226106	-0.249	0.803

Residual standard error: 1.008 on 174 degrees of freedom, Multiple R-squared: 0.3198, Adjusted R-squared: 0.2729, F-statistic: 6.817 on 12 and 174 DF, p-value: 5.132e-10

*Significance levels: ***p<0.001, **p<0.01, *p<0.05*

Multiple Regression on a head level

$$Gross\ margin\ per\ head = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_4 X_3 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \varepsilon_i$$

$$\log(livestock\_gross\_margin\_pk) = distance + ms\_offvpast + \log(B1\_1) + \log(B1\_4) + \log(conc\_purch\_kg1) + \log(conc\_self\_kg1) + \log(rough\_purch\_kg1) + \log(rough\_self\_kg1) + \log(lunit\_eu) + E14\_2\_4\_1 + edu\_index + hhfarm$$

Table 17 Multiple Regression for Gross Margin per Head in Livestock Farming

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	11.727971	0.460518	25.467	< 2e-16 ***
Distance to Almaty	0.001946	0.001373	1.418	0.158
Months spent on off-village pasture	0.024458	0.019378	1.262	0.209
Total cropland used	0.013803	0.027246	0.507	0.613
Total hayland used	0.010414	0.024381	0.427	0.670
Purchase of concentrate for livestock, total	-0.018088	0.014703	-1.230	0.220
Self-production of concentrate for livestock, total	-0.024164	0.016204	-1.491	0.138
Purchase of roughage for livestock, total	-0.008538	0.011816	-0.723	0.471
Self-production of roughage for livestock, total	-0.012877	0.018288	-0.704	0.482
Total livestock numbers	-0.432001	0.100146	-4.314	2.69e-05 ***
Members of household total	0.066107	0.071029	0.931	0.353
Educational level	-0.052134	0.152096	-0.343	0.732
Commercial farm	-0.056375	0.226106	-0.249	0.803

Residual standard error: 1.008 on 174 degrees of freedom, Multiple R-squared: 0.1715, Adjusted R-squared: 0.1143, F-statistic: 3.001 on 12 and 174 DF, p-value: 0.0007649
*Significance levels: ***p<0.001, **p<0.01, *p<0.05*

3. What are the main factors that create differences between the gross margins of farms with similar scale/structures? Are these disparities related to revenue, variable costs or a combination of both? What is the impact of changes in input costs on the farms' gross margin?

Understanding the factors that contribute to differences in gross margins among farms with similar structures is critical for improving financial viability and sustainability. Figures 3 to 6 present the breakdown of costs and revenues from livestock, by quartile and feeding strategy cluster, for the whole herd and by head. The proportional contributions of each component are presented in the Annex.

Figure 3 Mean Livestock Costs and Revenues by Farm Size Quartiles

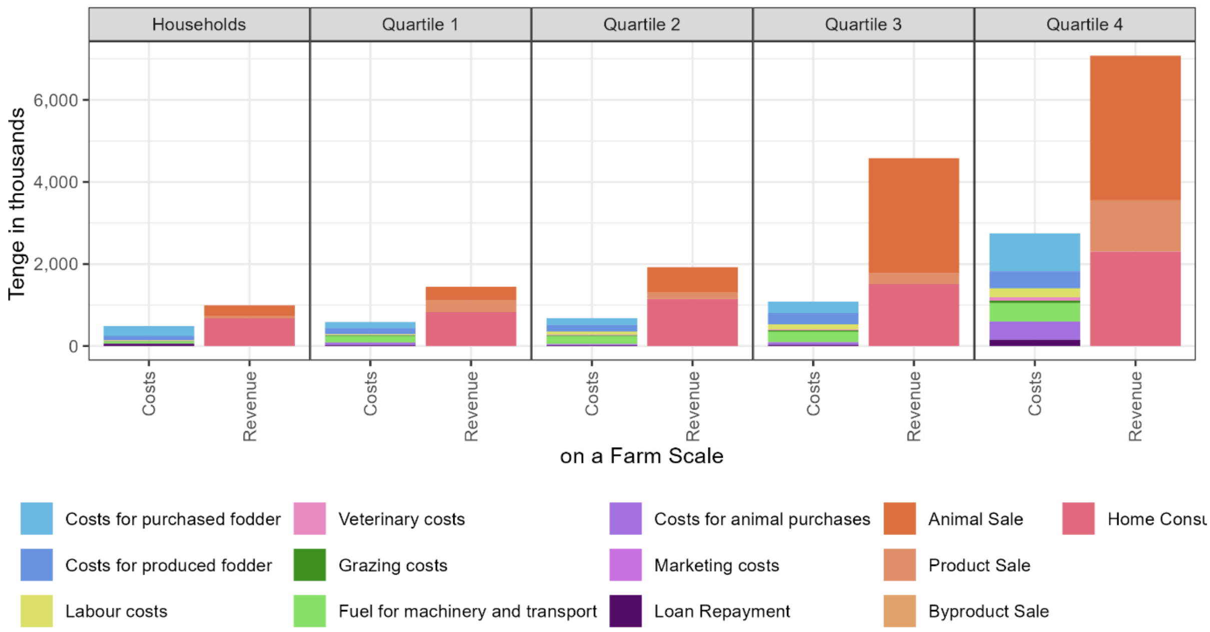


Figure 4 Mean Livestock Costs and Revenues per Head by Farm Size Quartiles

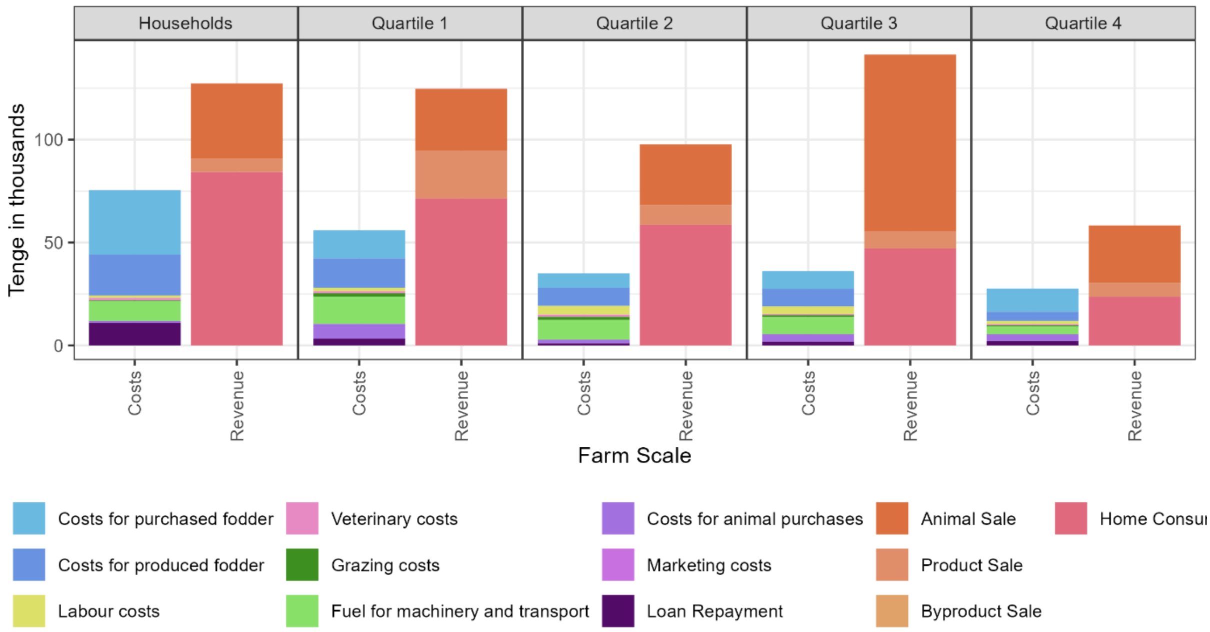


Figure 5 Mean Livestock Costs and Revenues by Feeding Strategy

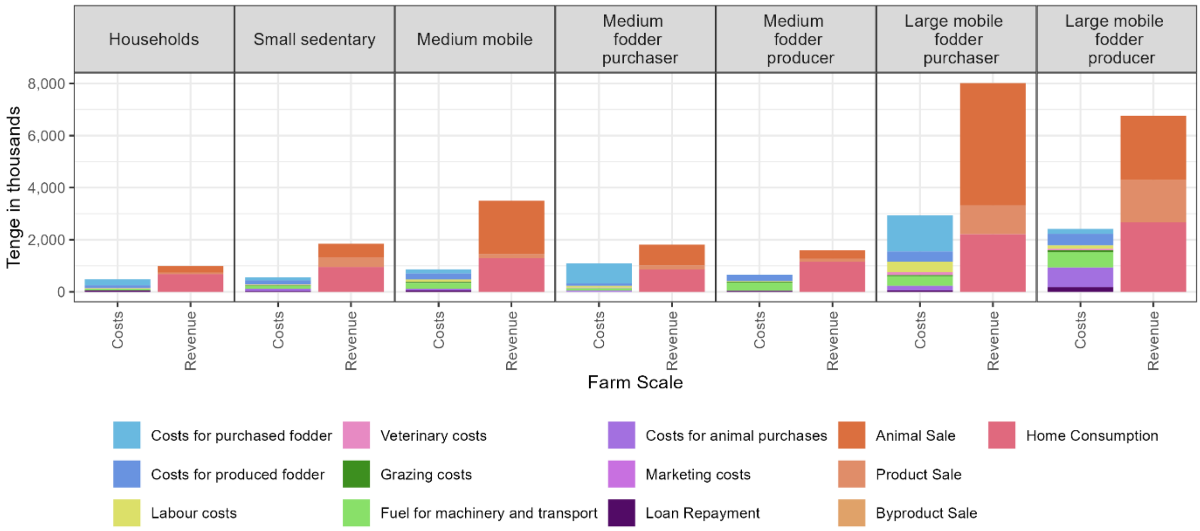
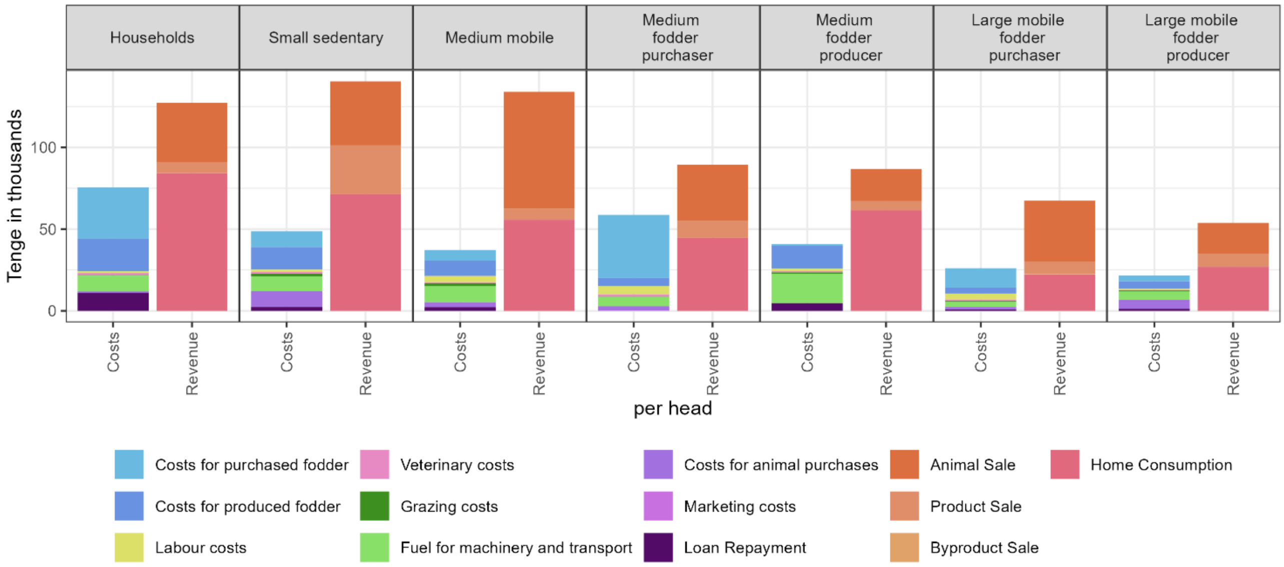


Figure 6 Mean Livestock Costs and Revenues per Head by Feeding Strategy



Hypothesis (H3a): The proportion of expenditures on fodder decreases with the size of the farm, indicating economies of scale in fodder costs among farms with different scales.

The results of the regression below indicate that the proportion of expenditures on fodder decreases with the size of the farm, indicating economies of scale in fodder costs among larger farms. The model's R^2 value shows that it explains only a small fraction of the variance in the data. This suggests that while the negative relationship between farm size and fodder expenditure proportion exists, it is weak, and other factors likely play a significant role.

Univariate Regression Model

$$Livestock\ Proportion\ Fodder = \beta_0 + \beta_1 Farm\ Size + \epsilon$$

This model explores the relationship where the proportion of expenditures on fodder in livestock farming (including both purchased and self-produced fodder) is predicted based on farm size.

Table 18 Univariate Regression Relationship between Proportion of Fodder Expenditures and Farm Size

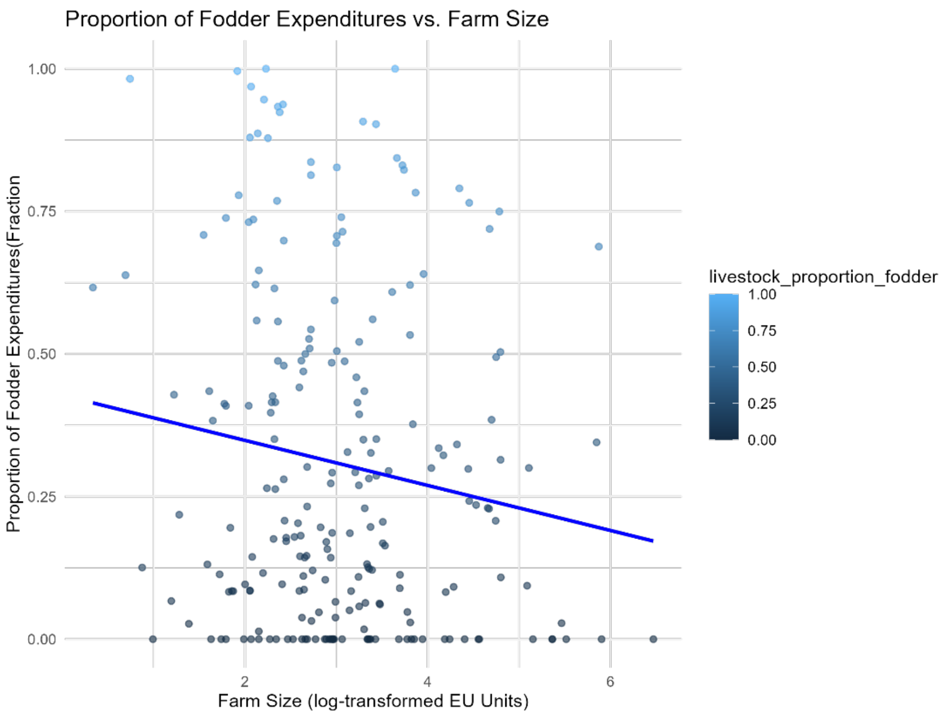
Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	0.42753	0.06003	7.122	1.45e-11 ***
log(lunit_eu)	-0.03950	0.01865	-2.117	0.0353 *

R^2 = 0.01971, Adj. R^2 = 0.01531, Residual SE = 0.2914 (223 DF), F(1, 223) = 4.483, p = 0.03535 Significance levels: ***p<0.001, **p<0.01, *p<0.05*

The regression analysis indicates that small farms have a higher proportion of their total expenditures allocated to fodder. As farm size increases, this proportion decreases, with both the intercept and slope being statistically significant, though the model explains only 2,56% of the variability in fodder proportion.

It's worth noting that ordinary least squares (OLS) regression may not be the ideal model for an outcome variable representing a proportion. Future research might consider alternative approaches better suited for proportional data, such as a generalized linear model (GLM) with a logit link and the binomial family, a Tobit model bounded at 0 and 1, or a fractional logit model.

Figure 7 Relationship between Proportion of Fodder Expenditures and Farm Size



The scatterplot with the updated fitted linear model does not reflect a strong negative relationship between the proportion of fodder expenditures and farm size (log-transformed).

The regression line slopes downward, suggesting a negative relationship between farm size (log-transformed) and the proportion of fodder expenditures. This aligns with the hypothesis that larger farms tend to allocate a smaller proportion of their total expenditures to fodder. The slope of the regression line is relatively shallow, and the scatter of points around the line is broad, indicating that the model explains only a small portion of the variance.

The findings are statistically significant, but the practical utility of the model is limited due to its low explanatory power. Further research could explore additional variables to better understand the factors influencing fodder expenditure proportions in livestock farming.

Hypothesis (H3b): Larger farms have a higher proportion of their variable costs allocated to labour compared to smaller farms, reflecting the increased labour needs and efficiency gains at larger scales.

To calculate the proportion of labour costs relative to total costs for each farm, the total labour costs were divided by the total costs for each farm. The results for Hypothesis H3b suggest a marginally significant positive relationship between farm size and the proportion of variable costs allocated to labour, indicating that larger farms may have a slightly higher proportion of their costs dedicated to labour compared to smaller farms. However, the statistical evidence is not strong.

Univariate Regression Model

$$Livestock\ Proportion\ Labour = \beta_0 + \beta_1 log(Farm\ Size) + \epsilon$$

This model explores the relationship where the proportion of labour costs in livestock farming is predicted based on the logarithm of the farm size.

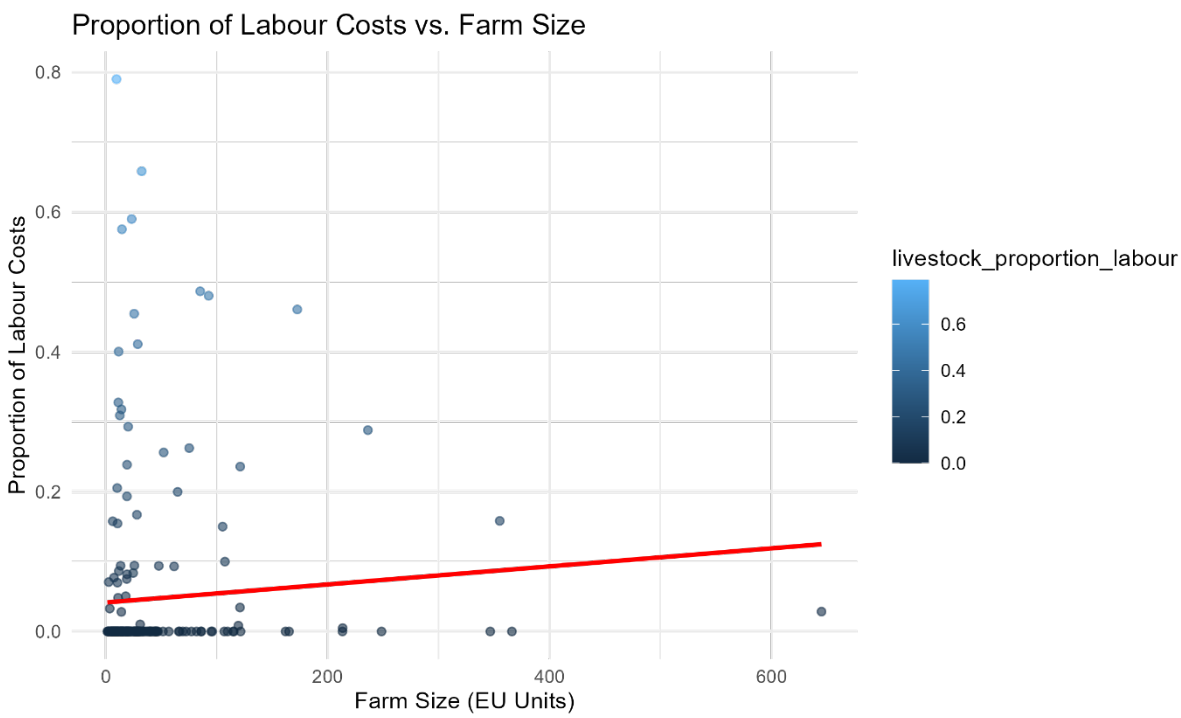
Table 19 Univariate Regression Relationship between Proportion of Labour Costs and Log of Farm Size

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	0.001577	0.025692	0.061	0.9511
log(lunit_eu)	0.014787	0.007984	1.852	0.0653 .

R^2 = 0.01515, Adj. R^2 = 0.01073, Residual SE = 0.1247 (223 DF), F(1, 223) = 3.43, p = 0.06534
*Significance levels: ***p<0.001, **p<0.01, *p<0.05, . p<0.1*

The regression analysis shows that as farm size increases (in log scale), the proportion of labour costs slightly increases, though this relationship is marginally significant and explains only a small portion of the variability.

Figure 8 Proportion of Labour Costs vs. Log of Farm Size



This scatter plot with a fitted linear model shows the relationship between the proportion of labour costs and the log of farm size. The trend line indicates a slight positive relationship, though the spread of the data points suggests considerable variability. The univariate regression and visual analyses provide weak support for Hypothesis H3b. There is a marginally significant positive relationship between farm size and the proportion of variable costs allocated to labour, suggesting that larger farms might allocate a slightly higher proportion of their costs to labour compared to smaller farms. However, the low R-squared value indicates that farm size explains very little of the variability in labour cost proportion. Further research incorporating additional variables and a larger sample size may be necessary to better understand the factors influencing labour cost allocation in livestock farming.

Hypothesis (H3c): The structure of income sources varies significantly with farm size, with larger farms having a greater diversity of income sources compared to smaller farms.

The results for Hypothesis H3c support the assertion that the structure of income sources varies significantly with farm size, with larger farms having a greater diversity of income sources compared to smaller farms. To explore this relationship, the Income Diversity Index, calculated using the Shannon Diversity Index, was employed to measure the diversity of income sources for each farm.

The Shannon Diversity Index (H') quantitatively measures the diversity of income sources, where higher values indicate greater diversity. Lower values suggest that a farm relies heavily on a few income sources, whereas higher values reflect a more diversified income structure. To calculate this index, the proportion of income from various sources (animal sales, product sales, byproduct sales, and home consumption) relative to total livestock gross income was determined. The Shannon Diversity Index formula is:

The Shannon Diversity Index is calculated using the formula:

$$H' = -\sum(p_i log(p_i))$$

where p_i is the proportion of income source i.

Univariate Regression Model

A univariate regression model was applied to assess the relationship between the Income Diversity Index and the logarithm of farm size (log(lunit_eu)):

$$Income\ Diversity\ Index = \beta_0 + \beta_1 log(Farm\ Size) + \epsilon$$

Table 20 Univariate Regression Relationship between Income Diversity Index and Farm Size

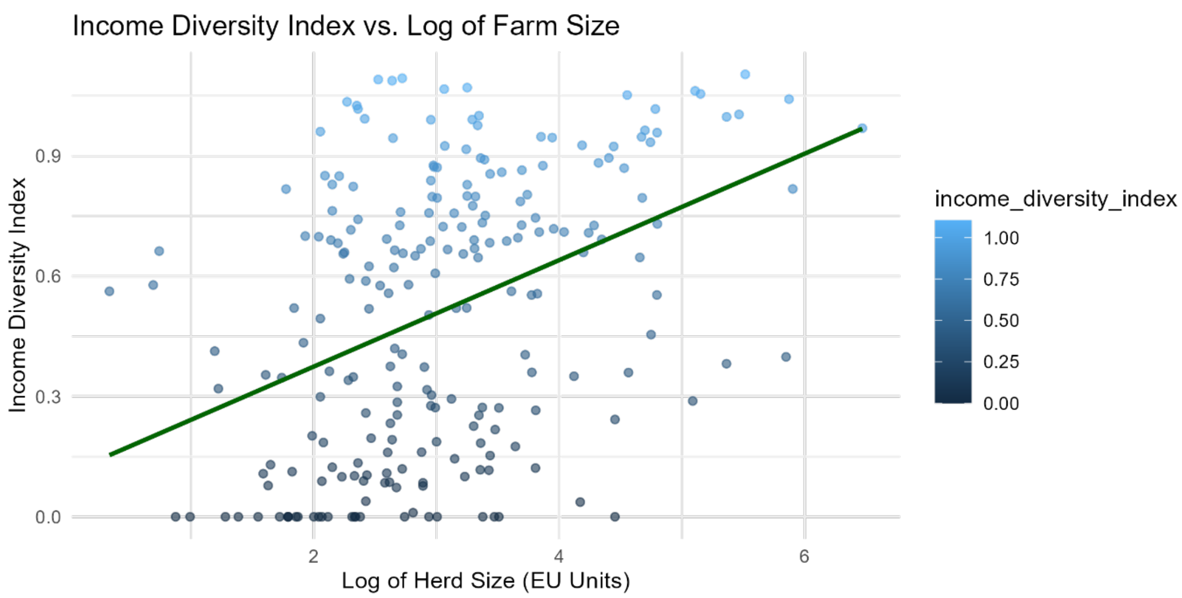
Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	0.10889	0.06548	1.663	0.0977
log(lunit_eu)	0.13278	0.02035	6.525	4.5e-10 ***

R² = 0.1603, Adj. R² = 0.1566, Residual SE = 0.3179 (223 DF), F(1, 223) = 42.58, p = 4.5e-10 Significance levels: ***p<0.001, **p<0.01, *p<0.05*

The regression analysis indicates that smaller farms have a higher income diversity index, as evidenced by a high intercept when the farm size is 1. The negative coefficient for Herd Size and the statistically significant p-values suggest that larger farms have less income source diversity, with approximately 18.35% of the variability in the income diversity index explained by farm size.

The regression analysis demonstrates a significant positive relationship between the logarithm of farm size and the Income Diversity Index. Larger farms tend to have a greater diversity of income sources, as evidenced by the positive coefficient of 0.13278. This suggests that larger farms effectively distribute income across a variety of sources.

Figure 9 Relationship between Income Diversity Index and Farm Size in Livestock Farming



A scatter plot with a fitted linear model (figure 9) illustrates the positive relationship between farm size (log-transformed) and the Income Diversity Index. The plot demonstrates that farms with larger herd sizes have higher diversity indices, supporting the hypothesis that larger farms exhibit more diverse income structures.The univariate regression and visual analyses provide strong evidence for Hypothesis H3c. Larger farms are associated with greater income diversity, as reflected in higher Shannon Diversity Index values. The model explains a moderate portion of the variance in income diversity (16.03%), and the statistical significance of the findings underscores the robustness of the observed relationship.

Hypothesis (H3d): The cost of fodder per head is substantially lower for large, mobile flocks but higher for small, sedentary ones.

The effect of farm size on fodder costs per head is first examined. The univariate regression analysis, depicted in figure 10, shows a significant negative relationship between farm size (in EU units) and the cost of fodder per head. A negative coefficient for farm size suggests that as farm size increases, the cost of fodder per head decreases. While the model explains a modest portion of the variance, the statistical significance of the findings provides strong evidence for the hypothesis.

To further investigate, the interaction between feeding strategy and farm size is analysed by examining fodder costs per head across clusters. Table 28 provides an in-depth comparison of cost and income structures across the clusters, but the findings do not support the results of the univariate regression. The cost for purchased fodder per head of livestock shows significant variation: Cluster 3 (Medium fodder purchaser) has the highest mean and median costs for purchased fodder per head, reflecting reliance on purchased supplements. Figures 5 and 6 illustrate the distribution of costs and revenues across clusters, further highlighting discrepancies with the significant regression results.

An analysis of the mean costs for produced and purchased fodder per head across clusters, derived from table 29, highlights several notable patterns. Smaller and/or more sedentary producers, such as those in Clusters 1 and 3, exhibit the highest total fodder costs per head. Although Cluster 5 demonstrates substantial reliance on purchased fodder, their total fodder costs per head remain lower than those observed in the smaller, sedentary groups.

Table 21: Mean Costs of Produced and Purchased Fodder Per Head Across Clusters

Cluster	1	2	3	4	5	6	Total
Purchased fodder per head	9.68	6.54	38.5	1.04	11.9	3.52	10.3
Produced fodder per head	13.8	9.4	5.02	13.8	3.69	4.49	9.26
Total fodder costs per head	**23.48**	15.94	**43.52**	14.84	15.59	8.01	19.56

Excerpt from table 29

Clusters with greater self-sufficiency in fodder production show significantly reduced costs. For example, Cluster 6 achieves the lowest mean total fodder cost due to a reliance on self-produced fodder, which is less expensive than market-purchased alternatives. Similarly, Cluster 4, despite its limited mobility, maintains relatively low fodder costs by employing a strategy that emphasizes fodder production. These observations underline the cost-saving potential of self-sufficiency in fodder production and highlight the substantial burden of fodder costs faced by smaller and less mobile producers.

In order to take our analysis further, the relationship between mobility, measured by months spent on off-village pastures, and fodder costs, as it is expected that higher mobility is associated with lower expenditure on fodder due to increased access to natural grazing resources is explored. The regression analysis in table 23 reveals a significant negative relationship between the months livestock spend on pastures and table 22 the cost of fodder per head. The negative coefficient for Months spent on pastures indicates that as the duration of pasture usage increases, the cost of fodder per head decreases. Based on the provided data and analyses, the hypothesis that the cost of fodder per head is substantially lower for large, mobile flocks and higher for small, sedentary ones is supported. The regression analyses consistently show significant negative relationships between farm size (and months on pastures) and fodder costs, aligning with the hypothesis.

Univariate Regression

$$\log(Livestock\ Cost\ of\ Fodder\ per\ Head) = \beta_0 + \beta_1 log(Herd\ Size) + \epsilon$$

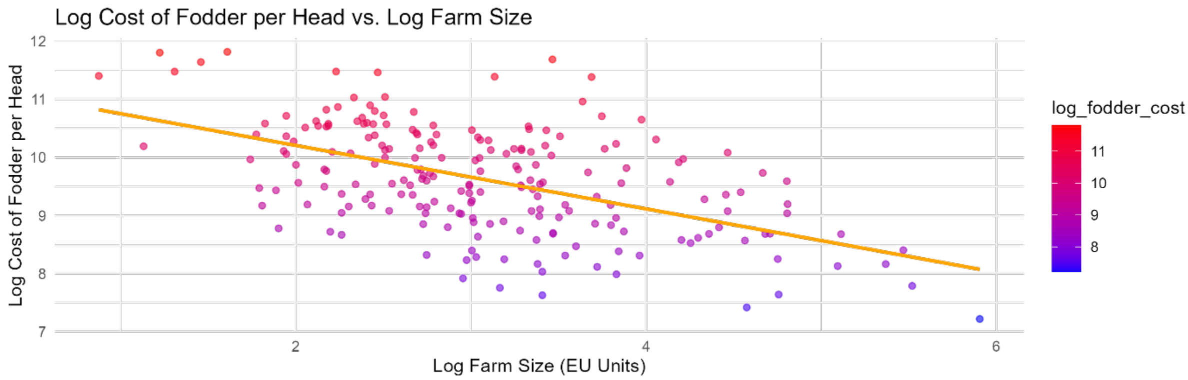
This model explores a relationship where the cost of fodder per head is predicted based on the logarithm of the farm size, revealing how changes in farm size affect fodder costs.

Table 22 Univariate Regression Relationship between Cost of Fodder per Head and Farm Size

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	11.29647	0.19489	57.962	<2e-16 ***
log(lunit_eu)	-0.54561	0.06082	-8.971	<2e-16 ***

R^2 = 0.279, Adj. R^2 = 0.2755, Residual SE = 0.7806 (223 DF), F(1, 208) = 80.48, p = < 2.2e-16
*Significance levels: ***p<0.001, **p<0.01, *p<0.05*

Figure 10 Log-Linear Relationship between Fodder costs per Head and Herd Size in Livestock Farming



Univariate Regression

$$\log(Livestock\ Cost\ of\ Fodder\ per\ Head) = \beta_0 + \beta_1 \log(Months\ Spend\ on\ Pastures) + \epsilon$$

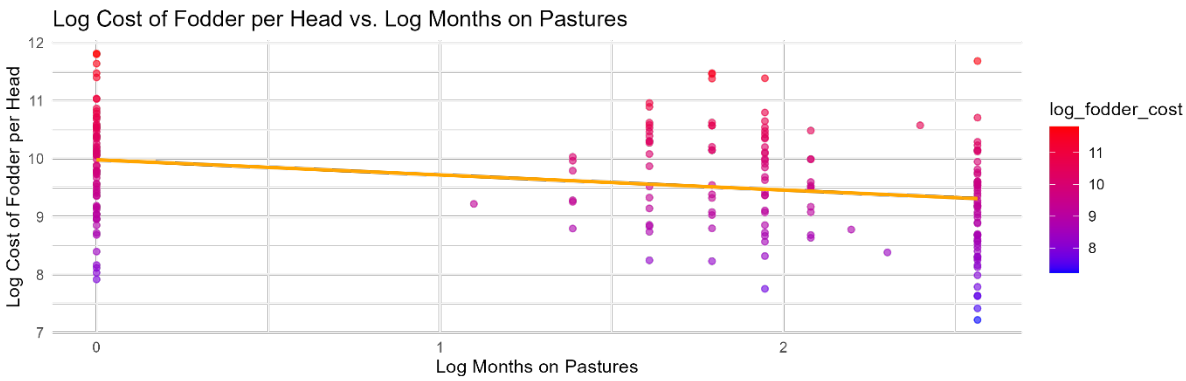
This model explores a relationship where the cost of fodder per head is predicted based on the months the livestock spend on pastures, revealing how changes in pasture duration affect fodder costs.

Table 23 Univariate Regression Relationship between Cost of Fodder per Head and Months on Pastures

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	*9.98119*	*0.10063*	*99.18*	*< 2e-16 ****
Log(ms_offvpast)	*-0.26077*	*0.05744*	*-4.54*	*9.51e-06 ****

R^2 = 0.09016, Adj. R^2 = 0.08579, Residual SE = 0.8768 (208 DF), F(1, 208) = 20.61, p = 9.511e-06
Significance levels:p<0.001, **p<0.01, p<0.05*

Figure 11 Relationship between Fodder Costs per Head and Months on Pastures in Livestock Farming



6 Conclusions and Discussion

The findings from the research conducted on the profitability of livestock farming in Kazakhstan focus on the impacts of farm size and structure, feeding strategies, and pasture use. The analysis covers three main research questions: the effect of farm size on profitability and the influence of feeding strategies on gross margin. By addressing these questions, the study offers insights that can inform sustainable farming practices and policy recommendations for enhancing the financial stability of rural populations in Kazakhstan.

In the first research question the effect of farm size on profitability is investigated with a particular focus on comparing livestock farming between sizes. The analysis shows that commercial farms have a higher total gross margin in livestock farming compared to household farms, which is expected as commercial farms sell more livestock. However, it appears that household farms have a higher gross margin per head of livestock because of a more favourable marginal benefit per head or per unit. This suggests that smaller operations, due to their more intensive management and potentially higher quality of fattening, achieve better profitability on a per-head basis.

This indicates that simply increasing the herd size does not linearly translate into higher profitability per head, likely due to the omission of fixed costs, which only larger herds can efficiently cover. Fixed costs, such as infrastructure and equipment expenses, are generally absorbed more effectively in larger operations. When these costs are excluded from profitability calculations, the resulting figures may disproportionately favor smaller operations with lower fixed-cost burdens per head. Thus, while this study accounted for home consumption, omitting fixed costs from the analysis may obscure some of the scale efficiencies achievable in larger herds. The significant role of non-monetary labour contributions in household farms echoes the observations made by Delgado et al. (2003) and (Otsuka et al., 2016), emphasizing the importance of family labour in maintaining cost efficiency in smaller operations. In smaller farms, the direct link between individual effort and output can lead to higher productivity and better care for each animal. Conversely, larger farms may struggle with the principal-agent problem, where farm workers, with an income not directly linked to output, may lack the same level of motivation and investment in the farm's success (Lerman, 2013). In this thesis only seasonal labour was included in the calculation. This kind of labour can mitigate this problem through incentives in the payment structure. Livestock development policies, including those related to research, commonly emphasize the physical aspects of livestock systems, often with a primary focus on production for the market (Behnke, 1985), resulting in a disregard for the diverse roles that livestock play. This constrained viewpoint becomes evident in how the productivity of "traditional" livestock systems, like communal grazing of cattle or free-ranging goats, is perceived. These systems are frequently labelled as "low productive" that fall significantly short of their potential levels (Moll, 2005).

Giving a monetary value to what's produced and used at home, equivalent to its market replacement cost, is a fundamental method for valuing subsistence activities. However, in livestock-reliant economies, accurately calculating this cost requires addressing multiple practical challenges. These include how the move towards commercial economies alters what people eat, the fluctuating exchange rates between goods from livestock-based and other economies, and the dynamics between farming and livestock raising in mixed agricultural systems. Additionally, assuming the work done within the household has no financial value carries has big consequences. This overlooks the economic contributions of household members' labour (Behnke, 1985).

As farms grow, they are expected to become more productive and profitable (Barnard & Nix, 1979; Chavas & Aliber, 1993). Research by Zweigbaum et al. (1989) and Gillespie et al. (2010) supports the idea that larger farms are generally more profitable because they can spread their costs over a larger output, making each unit cheaper to produce. However, the relationship between farm size and profit is not straightforward. While larger farms may benefit from discounts for buying in bulk or using resources more efficiently, they also face higher costs associated with supporting larger operations. Although big farms may benefit from economies of scale, they may face challenges in providing adequate care for each animal and managing workers over a wide area (Barnard & Nix, 1979; Tomich et al., 1995). Managing a large farm can be complex and costly, which may offset the cost savings from being big. Small farms can remain competitive by using land more efficiently and reducing labour costs (Tomich et al., 1995). Also so-called integer costs are ignored in gross margin calculations (Barnard & Nix, 1979). When examining substantial changes in the size of the operation, potential shifts in these integer costs become notably crucial—sometimes even more so than the variable costs defined in the context of gross margin analysis (Barnard & Nix, 1979).

In the second research question, the impact of different feeding strategies on the gross margin of farming enterprises is examined. The analysis reveals that the relationship between feeding strategies and gross margins is complex and influenced by multiple factors, including farm size and reliance on natural grazing. Table 15 shows that both large farm clusters—Cluster 5 (Large mobile fodder purchaser) and Cluster 6 (Large mobile fodder producer)—have higher total gross margins than smaller clusters. This trend suggests that larger farm size contributes significantly to gross margins, regardless of feeding strategy alone. The regression analysis in table 16 does not significantly confirm the positive impact of self-producing feed on gross margin; in fact, both purchasing and self-producing fodder are associated with negative coefficients, indicating a detrimental effect on gross margins. Farms that predominantly rely on natural grazing tend to have lower variable costs and, in many cases, higher gross margins. This is particularly evident in Clusters 2 (Medium mobile) and 5 (Large mobile fodder purchaser), which are the most pasture-dependent groups and exhibit high gross margins within their respective size categories. These clusters spend the most months on off-village pastures (mean of 7.89 and 10.8 months, respectively), indicating the economic benefits of natural grazing practices. However, the regression analysis shows that while there is a positive correlation between natural grazing and gross margins, this relationship is not statistically significant.

The profitability of livestock farming in Kazakhstan is significantly influenced by feeding strategies, with natural grazing proving to be the most effective method for reducing costs and enhancing gross margins. Robinson (2020) observed that small and medium-sized operations in pastoral areas often rely on a combination of village pasture grazing and increased use of supplements. These producers face challenges due to limited access to remote pastures and the high costs of purchasing feed, exemplified by Cluster 3, which shows the smallest gross margin among the analysed clusters. A strategy developed by a small group of very large herders involves high mobility and relatively low use of supplementary feed per animal. These farms, represented by Clusters 2 and 5, achieve high overall income by scaling up, despite having lower gross income per animal. This approach reflects a cost-leadership strategy, as described by Porter (1990), whereby larger farms prioritize scaling up production to achieve overall higher income despite lower output per animal.

Conversely, smaller farms might focus on quality, achieving higher output per animal. However, some groups, such as Cluster 6, aim to improve both quality and quantity, which might traditionally be seen as "stuck in the middle" according to Porter's framework. Yet, in this context, this dual approach can potentially lead to high returns on investment by balancing the trade-off between cost leadership and differentiation effectively. In summary, the livestock enterprise in Kazakhstan is complex, dependent on rangeland resources affected by climate and external factors. Effective feeding strategies, particularly those emphasizing natural grazing, are crucial for maximizing profitability and sustaining livestock farming operations. The income effect refers to changes in profitability resulting from variations in income or revenue, typically derived from the sale of agricultural products. Larger farms might achieve higher gross incomes due to economies of scale, which allow them to spread fixed costs over a larger output, thus reducing the cost per unit of production. Moreover, marginal revenue (MR), defined as the additional revenue generated from selling one more unit of a good, tends to be higher for smaller farms with healthier and better-cared-for animals, resulting in higher MR per animal. Interestingly, while home consumption of farm products reduces with increasing farm size, the decrease is not as significant as one might expect. This indicates that even larger farms retain a portion of their production for home consumption, albeit to a lesser extent than smaller farms.

In this calculation, only variable costs—those that vary with the level of output—were included. A cost effect is observed when comparing the reducing variable costs per head as the herd size increases, which can lead to higher overall profitability. Economies of scale typically refer to reductions in average costs as the scale of production increases, primarily due to spreading fixed costs over a larger output. However, even when considering only variable costs, larger farms may still experience reduced costs per unit of output for several reasons. These include bulk purchasing, which provides quantity discounts, and higher efficiency due to specialised labour or machinery.

The shared use of pastureland around villages, which functions as a common-pool resource, can lead to what Garret Hardin described as the tragedy of the commons, where multiple users vie for the same resource. In these village areas, where multiple households depend on the same land for grazing, the struggle for fodder and the absence of alternative livelihood strategies often lead pastoralist communities to ignore recommended stocking density guidelines (Hardin, 1968; Sabyrbekov, 2019). In contrast, most of Kazakhstan's pastureland is leased, which allows for more individual control over land use but may still encounter issues of overuse without proper management practices. Understanding the dynamics of both common-pool and leased pasture resources, as well as the use of reserve land, can provide deeper insights into practical implications for farmers of different scales (Kasymov et al., 2020; Tokbergenova et al., 2018). Without investment in sustainable practices, even an abundance of resources may not translate into economic benefits (Behnke, 1985). Research to develop and disseminate best practices for sustainable livestock farming, tailored to the specific environmental and socio-economic conditions of Kazakhstan, can help address these challenges. Subsidies, training, and access to essential equipment and technology can empower farmers to adopt self-sufficient feed production and sustainable land management strategies.

The third research question explores the main factors that create differences in gross margins among farms with similar scales and structures, particularly in the context of fodder and labour costs, and the diversity of income sources. The findings from the analysis of gross margins among farms with similar structures reveal that both revenue and variable costs significantly contribute to the observed disparities in profitability. Specifically, larger farms exhibit lower fodder costs per head compared to smaller farms, as evidenced by the significant negative relationship between farm size and fodder expenditure proportion. This indicates economies of scale, where larger farms benefit from reduced relative fodder costs.

The analysis of labour costs (H3b) suggests a marginally significant positive relationship between farm size and the proportion of variable costs allocated to labour. Larger farms allocate a higher proportion of their variable costs to labour, reflecting increased labour needs but also greater efficiency gains. This is seen in the slightly higher absolute labour costs for larger farms but lower per-unit costs due to economies of scale. However, the statistical evidence is weak (table 19 and figure 8), indicating that further research is needed to fully understand the factors influencing labour cost allocation in livestock farming.

The structure of income sources varies significantly with farm size, supporting Hypothesis H3c. Contrary to the initial assumption, larger farms exhibit a lower diversity of income sources compared to smaller farms, as indicated by the regression analysis (table 20) and figure 9. The significant negative relationship between farm size and the income diversity index suggests that, as farm size increases, income diversity decreases. This finding implies that smaller farms rely on a wider range of income sources, such as animal sales, byproduct sales, and home consumption, which may provide them with greater resilience through diversified revenue streams. Despite having fewer income sources, larger farms often achieve higher profitability by focusing on primary revenue channels and benefiting from economies of scale. Policy initiatives should consider supporting income diversity, especially for larger farms, by offering training and resources for value-added production, such as byproduct sales or alternative products, to enhance resilience. Additionally, understanding the impact of input costs on gross margins is essential to develop strategies that improve the economic sustainability of livestock farms over the long term.

For Hypothesis H3d, the cost of fodder per head is substantially lower for large, mobile flocks compared to small, sedentary ones. This efficiency in fodder usage is a critical factor in the higher profitability of mobile flocks. The univariate regression analysis (table 21) and figure 10 demonstrate a significant negative relationship between farm size (in EU units) and the cost of fodder per head, with larger farms benefiting from lower fodder costs per head. Additionally, the relationship between months spent on pastures and fodder costs (table 22) indicates that as the duration of pasture usage increases, the cost of fodder per head decreases, further supporting the hypothesis that mobility and pasture duration positively impact fodder cost efficiency.

The total gross margin for a farm engaged in multiple activities is the accumulation of the gross margins from each activity (Makeham & Malcolm, 1986). This method is typically used to compare the profitability of different enterprises within a farm. For instance, one might compare the profitability of cattle farming to that of small ruminants like sheep. However, such an analysis was not feasible in this instance due to the dataset not being detailed enough to attribute the information to the various enterprises. The focus of the questionnaire did not encompass this level of detail. Individual data were collected separately for cattle, but not completely separately, making it difficult to examine them. However, it would be interesting to explore how these compare. The gross margin for cattle farming is in 91 cases negative. Reasons for this can include misunderstandings of the questionnaire. According to the questionnaire, 101 farmers indicated that they own fewer cows compared to the previous year. This could be due to the difficulty of recalling accurate numbers from 12 months ago, and the fact that conducting the interviews during the calving season further complicates data comparison. A suspected shift in the region from cattle to other ruminants could not be confirmed based on data from the Bureau of National statistics of Kazakhstan (QAZSTAT, 2023). No evidence of epidemiological or other external influences during the study year was found in the databases and literature, to which a logical connection could be made. Since the number of cattle owned and the number of cattle owned 12 months before were used to calculate the change in stock—a method recommended by Makeham and Malcolm (1986)—this distorted the data. Additionally, many costs could not be accurately divided between livestock farming and cattle farming alone. Therefore, many mixed livestock producers had high costs that couldn’t be properly allocated between cattle and other livestock. This also negatively impacted the calculation.

Misunderstandings, biases, and heuristics that farmers may have relied on could have influenced their responses to the questionnaire. Empirical results are statements that relate, in one way or another, to experiences or observations (Diekmann, 1995). For example, survey participants' attitudes might be influenced by context effects such as leading questions, the halo effect, assimilation or contrast effects, situational effects, and respondent effects such as social desirability. Cognitive responses and other sources of error can also bias research findings (Strack, 1994).

If the variable costs cannot be covered by the income, it is advisable to discontinue this enterprise in its current form. Measures are required to immediately increase the Gross Margin. In terms of gross margin analysis, there are four primary strategies for enhancing farm profitability, as outlined below (Barnard & Nix, 1979):

1. Enhance the overall farm gross margin by improving the individual gross margins of existing enterprises.

2. Elevate the total farm gross margin by adjusting the composition of enterprises, potentially replacing one or more with others.

3. Augment the total gross margin by expanding an existing enterprise or introducing a new one, without necessitating a reduction in other enterprises. In

4. Mitigate costs, primarily labour and machinery expenses, to reduce expenditures.

Farmers and rural population in many developing and emerging countries, including Kazakhstan, often belong to the poorer income strata (Janvry & Sadoulet, 2010). Understanding the profitability of different approaches in the livestock sector and derive recommendations for action from it, can significantly contribute to the financial security of the rural population, thereby not only increasing GDP but also stabilizing the nation's economy, which currently relies heavily on resource extraction. Moreover, it provides stability to the rural population, shielding them from external influences. By comprehensively analyzing and comparing the profitability of various farming enterprises, such as cattle versus sheep farming, policymakers and farmers can make informed decisions that enhance the economic resilience of rural areas. Kazakhstan is described as a resource-based and state-led growth model. This increases the likelihood of Kazakhstan falling into the “middle-income trap” which is based on a growing inequality and elite capture, and weak institutions (World Bank, 2024). Promoting non-agricultural employment is a priority for many governments and is considered a means to alleviate rural poverty. Increasing non-agricultural jobs is linked to greater economic productivity. In nations with higher per capita income, agriculture usually represents only a small fraction of the total economy (Sabyrbekov, 2019). According to Fourastié (1949), a country's development is often attributed to the distribution of labour across four sectors, with a country deemed more developed when a smaller proportion of its population is engaged in farming (Dietrich & Krüger, 2010; Fourastié, 1949). Concluding that migration from the agricultural sector to other sectors should be encouraged can be counterproductive. Historically, agriculture has served as the foundation of Kazakhstan's economy (Tokbergenova et al., 2018). Pastures make up more than 184.3 million hectares, or 67,64%, of Kazakhstan's agricultural land, which places it fifth in the world (FAOSTAT, 2023). A vast country like Kazakhstan, with so much pastureland as a natural resource, is ideally positioned to advance sustainable farming strategies (Tokbergenova et al., 2018). Since more than 20 years research is pointing out that the livestock industry may greatly benefit from the cost-saving effects of pastures (Robinson et al., 2003). Based on the data, it can be assumed that maximizing welfare through the optimal use of natural resources is possible. Therefore, deeper research is crucial. It is essential to consider whether there is a single correct farming strategy or multiple solutions that can utilise various resources.

7 Annex

Table 24 List of Cost and Revenue Variables in the Questionnaire

Variables used to calculate the gross income	
C3.1 & C3.4	Sales quantity & price of cattle
C4.1 & C3.4	Sales quantity & price other animals
C5.4 & C5.5	Sales quantity & price other farm products
C5.3	Own consumption and quantity given away for free or used on the farm
C1.6	Slaughter for family consumption
C4.2	Slaughter for home consumption
C1.1	Number of cattle owned now
C1.2	Number of cattle owned 12 months ago
Cost variables	
C1.9	Total cost of cattle purchased in last 12 months
D8.6 & D8.8	Quantity & cost of supplementary fodder for all livestock and for cattle alone
F1.3	Cost of insemination
E2	Costs of farming inputs related to livestock production used by household/farm over past 12 months (inputs, water, interest)
E5	Investments in fixed assets
E14	Labour input & cost
F2	Animal health costs

Source: Dataset

Table 25 Gross Margin for Cattle and the Variables Used

Gross income (cash)			
(i)		**Sales of animals and animal products**	
	(a)	Cattle sales	C3_1_1 * C3_4_1 + C3_1_2 * C3_4_2 + C3_1_3 * C3_4_3 + C3_1_4 * C3_4_4 + C3_1_5 * C3_4_5 + C3_1_6 * C3_4_6 + C3_1_7 * C3_4_7
	(b)	Animal product sales	C5_4_1 * C5_5_1 + C5_4_4 * C5_5_4 + C5_4_5 * C5_5_5
	(c)	Value of animals and their products eaten	C5_3_1 * median_C5_5_1 + C5_3_3 * C5_5_3 + C5_3_4 * median_C5_5_4 + C5_3_5 * median_C5_5_5 + C5_3_8 * medi-an_C5_5_8 + C1_6_1 * me-dian_C3_4_1 + C1_6_2 * median_C3_4_2 + C1_6_3 * median_C3_4_3 + C1_6_4 * medi-an_C3_4_4 + C1_6_5 * median_C3_4_5 + C1_6_6 * median_C3_4_6 + C1_6_7 * median_C3_4_7
(ii)		Sales of by-products	C5_4_8 * C5_5_8
(iii)		Change in Total Value of Stock over the Year due to increase in numbers	(C1_1_1 - C1_2_1) * median_C3_4_1+ (C1_1_2 - C1_2_2) * median_C3_4_2 + (C1_1_3 - C1_2_3) * median_C3_4_3 +(C1_1_4 - C1_2_4) * median_C3_4_4 + (C1_1_5 - C1_2_5) * median_C3_4_5
(iv)		**Gross Income(i+ii+iii)**	
-			
Variable Costs (cash)			

Variable Costs (cash)

(v)	(a)	Cost of feed	(D8_7_1 * D8_8_1_adjusted + D8_7_2 * D8_8_2_adjusted + D8_7_3 * D8_8_3_ad-justed + D8_7_4 * D8_8_4_adjusted + D8_7_5 * D8_8_5_adjusted + D8_7_6 * D8_8_6_adjusted + D8_7_7 * D8_8_7_adjusted + D8_7_8 * D8_8_8 + D8_7_9 * D8_8_9_adjusted)
		Cost of fodder pro-duction	E2_1_3_adjusted + E2_1_4_adjusted + E2_1_5_adjusted+ E2_1_8_adjusted
	(b)	Cost of seasonal labour	E14_1_3_1 * (E14_3_3_1 + E14_4_3_1)
		Cost of husbandry (veterinary costs)	(F2_4_1 + F2_4_2 + F2_4_3 + F2_4_4 + F2_4_5 + F2_4_6) + (F1_3_3 + F1_3_4 + F1_3_5 + F1_3_6 + F1_3_7)
	(c)	Costs for grazing	E2_1_9_adjusted + E2_1_7
		Costs for machin-ery and transport	E2_1_1_adjusted + E2_1_2_adjusted + E2_1_6_adjusted
	(d)	Purchased animals	C1_9_1 + C1_9_2 + C1_9_3 + C1_9_4 + C1_9_5 + C1_9_6 + C1_9_7
	(e)	Marketing costs	E2_1_10_adjusted
	(f)	Loan repayments	E2_1_11_adjusted
(vii)		**Total variable costs (cash)**	
=			
(viii)		**Total gross margin total (cash)**	

Table 26 Gross Margin for Livestock and the Variables Used

Gross income(cash)			
(i)		**Sales of animals and animal products**	
	(a)	Animal Sales	C3_1_1 * C3_4_1 + C3_1_2 * C3_4_2 + C3_1_3 * C3_4_3 + C3_1_4 * C3_4_4 + C3_1_5 * C3_4_5 + C3_1_6 * C3_4_6 + C3_1_7* C3_4_7 + C4_3_1 * C4_4_1 + C4_3_2 * C4_4_2 + C4_3_3 * C4_4_3
	(b)	Animal product sales	C5_4_1 * C5_5_1 + C5_4_2 * C5_5_2 + C5_4_3 * C5_5_3 + C5_4_4 * C5_5_4 + C5_4_5 * C5_5_5 + C5_4_6 * C5_5_6 + C5_4_7 * C5_5_7
	(c)	Value of animals and their products eaten	C5_3_1 * median_C5_5_1 + C5_3_2 * median_C5_5_2 + C5_3_3 * C5_5_3 + C5_3_4 * median_C5_5_4 + C5_3_5 * median_C5_5_5 + C5_3_6 * me-dian_C5_5_6 + C5_3_7 * median_C5_5_7 + C5_3_8 * median_C5_5_8 + C1_6_1 * medi-an_C3_4_1 + C1_6_2 * median_C3_4_2 + C1_6_3 * median_C3_4_3 + C1_6_4 * median_C3_4_4 + C1_6_5 * medi-an_C3_4_5 + C1_6_6 * me-dian_C3_4_6 + C1_6_7 * median_C3_4_7 + C4_2_1 * median_C4_4_1 + C4_2_2 * medi-an_C4_4_2 + C4_2_3 * median_C4_4_3
(ii)		Sales of by-products	C5_4_8 * C5_5_8 , C5_4_9 * C5_5_9 + C5_4_10 * C5_5_10 + C5_4_11 * C5_5_11 + C5_4_12 * C5_5_12
(iii)		Change in Total Value of Stock over the Year due to increase in numbers	No data for species outside of cattle, therefore inventory change is not included
(iv)		**Gross Income(i+ii+iii)**	
-			
Variable Costs (cash)			
(v)	(a)	Cost of feed	(D8_6_1 * D8_8_1_adjusted + D8_6_2 * D8_8_2_adjusted + D8_6_3 * D8_8_3_ad-justed + D8_6_4 * D8_8_4_adjusted + D8_6_5 * D8_8_5_adjusted + D8_6_6 * D8_8_6_adjusted + D8_6_7 * D8_8_7_adjusted + D8_6_8 * D8_8_8 + D8_6_9 * D8_8_9_adjusted)
		Cost of fodder pro-duction	E2_1_3_adjusted + E2_1_4_adjusted + E2_1_5_adjusted+ E2_1_8_adjusted+ E2_1_2_adjusted + E2_1_6_adjusted
	(b)	Cost of seasonal labour	E14_1_3_1 * (E14_3_3_1 + E14_4_3_1)
		Cost of husbandry (veterinary costs)	(F2_4_1 + F2_4_2 + F2_4_3 + F2_4_4 + F2_4_5 + F2_4_6) + (F1_3_3 + F1_3_4 + F1_3_5 + F1_3_6 + F1_3_7)
	(c)	Costs for grazing	E2_1_9_adjusted + E2_1_7
		Costs for transport (fuel)	E2_1_1_adjusted
	(d)	Purchased animals	C1_9_1 + C1_9_2 + C1_9_3 + C1_9_4 + C1_9_5 + C1_9_6 + C1_9_7 + E5_2_4 + E5_2_5
	(e)	Marketing costs	E2_1_10_adjusted
	(f)	Loan repayments	E2_1_11_adjusted
(vii)		**Total variable costs (cash)**	
=			
(viii)		**Total gross margin total (cash)**	

Table 27 Cost Components of Gross Margin Calculation

Category	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5	Cluster6
Fodder Purchases	116167.89 (20.96%)	165554.53 (19.09%)	770355.26 (70.49%)	15848 (2.4%)	1383602.17 (47.18%)	187777.78 (7.77%)
Fodder Production	157315.79 (28.39%)	226781.13 (26.16%)	94105.26 (8.61%)	239400 (36.18%)	390752.17 (13.32%)	443444.44 (18.36%)
Labour	17881.58 (3.23%)	83320.75 (9.61%)	66368.42 (6.07%)	16360 (2.47%)	402347.83 (13.72%)	136555.56 (5.65%)
Veterinary	13815.79 (2.49%)	14988.68 (1.73%)	23590 (2.16%)	12516 (1.89%)	115739.13 (3.95%)	46388.89 (1.92%)
Grazing	15583.74 (2.81%)	36547.17 (4.22%)	3684.21 (0.34%)	14600 (2.21%)	38956.52 (1.33%)	83277.78 (3.45%)
Transport	113218.42 (20.43%)	227976.89 (26.29%)	90578.95 (8.29%)	324500 (49.04%)	370869.57 (12.65%)	584638.89 (24.2%)
Animal Purchases	88684.21 (16%)	56792.45 (6.55%)	42105.26 (3.85%)	0 (0%)	177391.3 (6.05%)	755555.56 (31.28%)
Marketing	0 (0%)	0 (0%)	2105.26 (0.19%)	0 (0%)	1956.52 (0.07%)	0 (0%)
Loan Repayment	31439.47 (5.67%)	55048.21 (6.35%)	0 (0%)	38480 (5.82%)	50869.57 (1.73%)	177777.78 (7.36%)

Table 28 Cost Components of Gross Margin Calculation by Head

Category	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5	Cluster6
Fodder Purchases	9675.64 (19.86%)	6538.95 (17.55%)	38465.82 (65.55%)	1037.67 (2.54%)	11872.56 (45.43%)	3515.06 (16.23%)
Fodder Production	13827.38 (28.38%)	9396.68 (25.22%)	5018.48 (8.55%)	13804.78 (33.81%)	3687.29 (14.11%)	4489.63 (20.73%)
Labour	1341.49 (2.75%)	3791.21 (10.17%)	5087.74 (8.67%)	1615.28 (3.96%)	3706.89 (14.18%)	853.36 (3.94%)
Veterinary	1124.9 (2.31%)	589.04 (1.58%)	1406.76 (2.4%)	819.06 (2.01%)	813.59 (3.11%)	349.08 (1.61%)
Grazing	1638.88 (3.36%)	1790.48 (4.8%)	195.83 (0.33%)	891.83 (2.18%)	514.13 (1.97%)	525.63 (2.43%)
Transport	8979.31 (18.43%)	9877.86 (26.51%)	5671.27 (9.67%)	17963.3 (43.99%)	3129.15 (11.97%)	5151.45 (23.79%)
Animal Purchases	9739.4 (19.99%)	3069.54 (8.24%)	2631.87 (4.49%)	0 (0%)	1465.73 (5.61%)	5503.21 (25.41%)
Marketing	0 (0%)	0 (0%)	200.5 (0.34%)	0 (0%)	32.79 (0.13%)	0 (0%)
Loan Repayment	2391.8 (4.91%)	2209.29 (5.93%)	0 (0%)	4699.84 (11.51%)	911.38 (3.49%)	1267.94 (5.86%)

Figure 12 Proportions of the Cost and Revenue Components for Livestock Farming

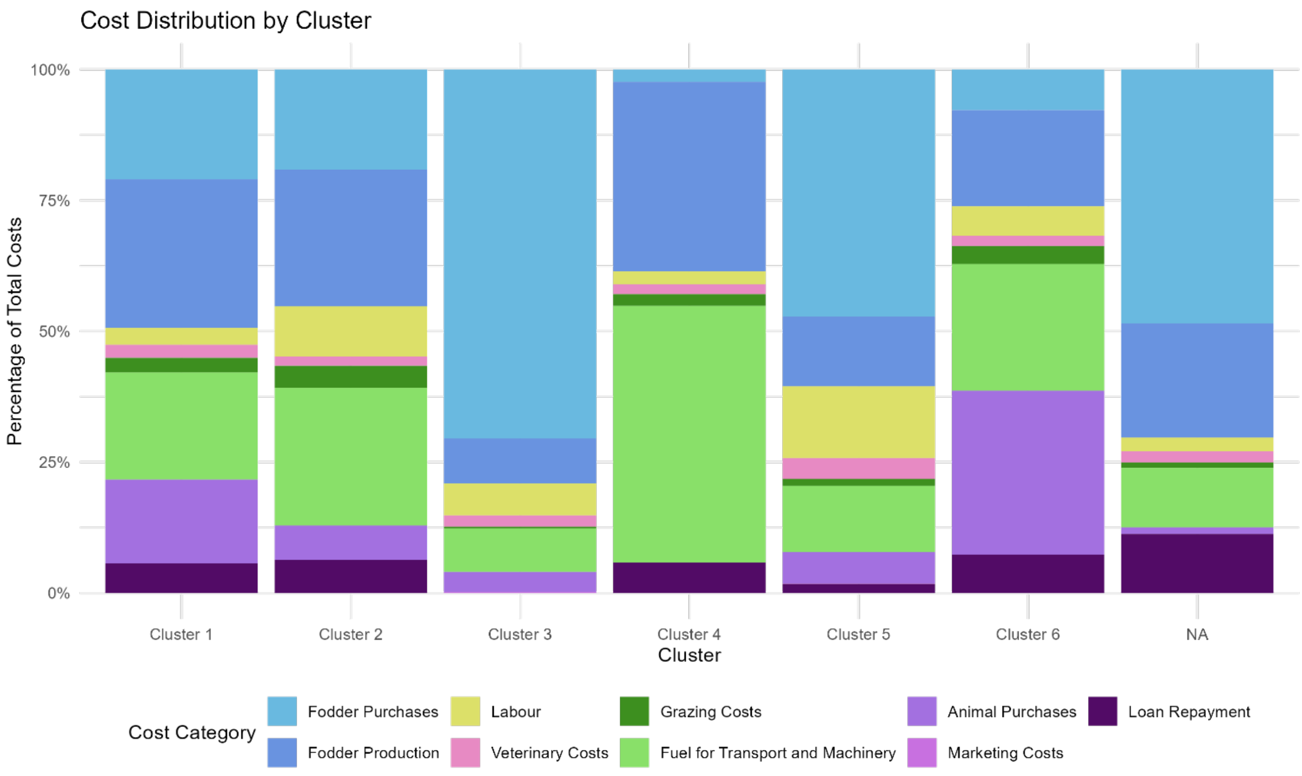


Figure 13 Proportions of the Cost and Revenue Components for Livestock Farming on a Per-Head Level

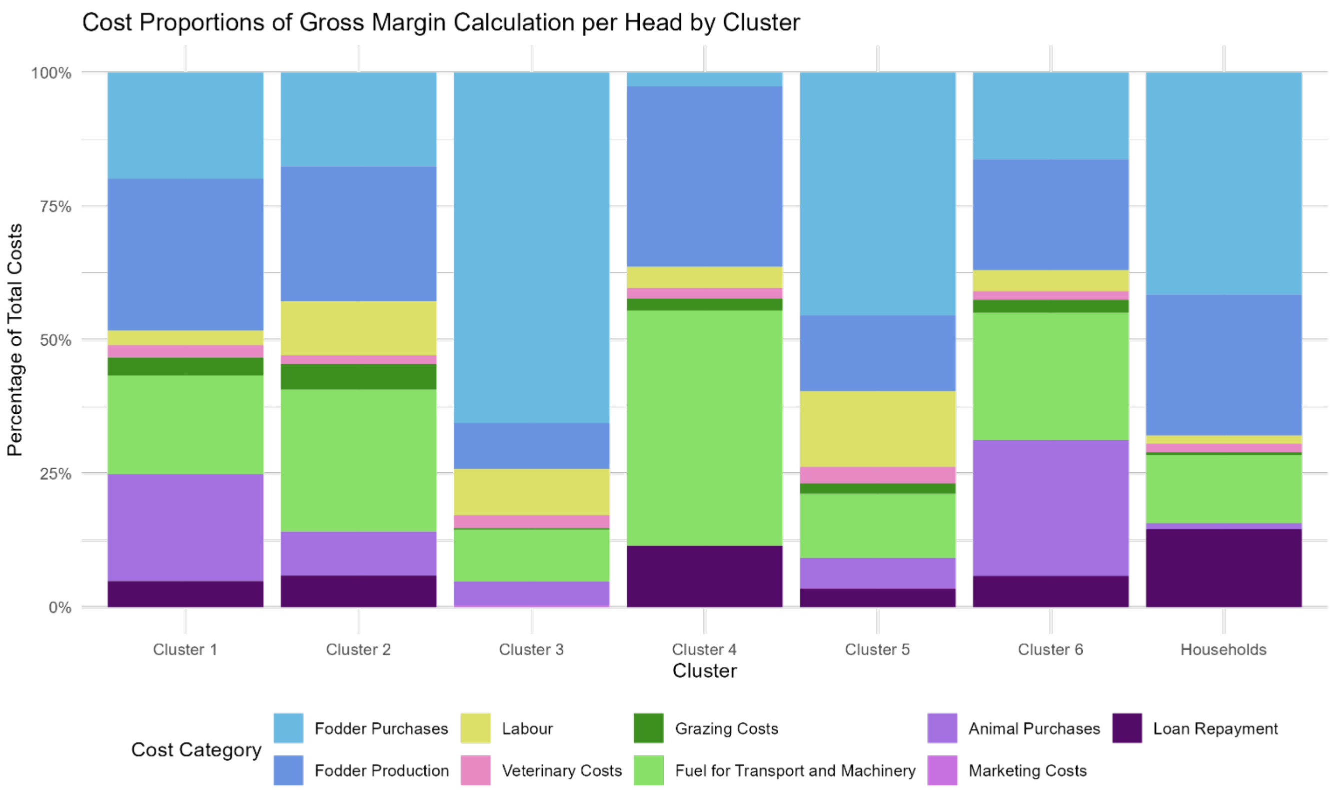


Table 29 Cost and Income Structures of Livestock Farming

	Cluster 1 (N=38)	Cluster 2 (N=53)	Cluster 3 (N=19)	Cluster 4 (N=25)	Cluster 5 (N=23)	Cluster 6 (N=18)	Overall (N=176)
Gross margin per head of livestock*							
Mean (SD)	91.7 (173)	96.7 (299)	30.7 (60.6)	45.9 (75.7)	41.2 (60.6)	32.2 (29.2)	67.4 (188)
Median [Min, Max]	56.6 [-173, 853]	46.8 [-112, 2190]	26.6 [-48.2, 171]	32.1 [-125, 254]	31.7 [-23.4, 284]	24.6 [-24.8, 91.5]	41.9 [-173, 2190]
Total gross margin*							
Mean (SD)	1290 (2100)	2630 (8650)	721 (1340)	928 (1180)	5080 (7290)	4340 (3890)	2390 (5830)
Median [Min, Max]	782 [6] [-1490, 9720]	1060 [6] [-1500, 62900]	521 [5,6] [-1380, 3610]	559 [6] [-1060, 4570]	3200 [3] [-1300, 30100]	3870 [1,2,3,4] [-916, 17100]	1070 [-1500, 62900]
Value of Animal Sales*							
Mean (SD)	39.0 (93.7)	71.3 (295)	34.1 (36.8)	19.6 (44.6)	37.0 (59.3)	18.9 (15.2)	43.1 (170)
Median [Min, Max]	0 [0, 497]	24.5 [0, 2160]	30.4 [0, 151]	0.0694 [0, 223]	18.0 [0, 281]	15.9 [0, 48.9]	14.9 [0, 2160]
Total animal sales*							
Mean (SD)	523 (1190)	2040 (8560)	798 (838)	318 (503)	4700 (7240)	2470 (2250)	1720 (5590)
Median [Min, Max]	0 [5,6] [0, 6500]	500 [5] [0, 61900]	520 [0, 3200]	2.00 [5,6] [0, 2210]	1640 [1,2,4] [0, 31100]	2850 [1,4] [0, 8400]	390 [0, 61900]
Product sales per head of livestock*							
Mean (SD)	30.0 (143)	6.92 (15.5)	10.5 (16.8)	5.63 (8.17)	7.90 (8.11)	8.10 (7.85)	12.4 (67.2)
Median [Min, Max]	1.84 [0, 877]	1.68 [0, 80.6]	2.53 [0, 69.8]	2.78 [0, 30.6]	5.50 [0, 27.0]	6.20 [0, 24.9]	2.58 [0, 877]
Total product sales*							
Mean (SD)	376 (1630)	164 (341)	163 (215)	120 (179)	1090 (1280)	1630 (2790)	474 (1350)
Median [Min, Max]	25.4 [5,6] [0, 10000]	45.0 [5,6] [0, 1640]	63.3 [0, 788]	50.0 [5,6] [0, 655]	392 [1,2,4] [0, 3900]	538 [1,2,4] [0, 11600]	57.8 [0, 11600]
By-product sales per head of livestock*							
Mean (SD)	0.0187 (0.0721)	0.0108 (0.0364)	0.0745 (0.325)	0.0161 (0.0436)	0.150 (0.637)	0.0120 (0.0245)	0.0384 (0.257)
Median [Min, Max]	0 [0, 0.419]	0 [0, 0.181]	0 [0, 1.42]	0 [0, 0.174]	0 [0, 3.07]	0 [0, 0.0789]	0 [0, 3.07]
Total by-product sales*							
Mean (SD)	0.234 (0.767)	0.272 (0.922)	0.789 (3.44)	0.354 (1.10)	8.68 (33.2)	3.06 (6.73)	1.72 (12.4)
Median [Min, Max]	0 [0, 3.60]	0 [0, 5.00]	0 [0, 15.0]	0 [0, 5.00]	0 [0, 160]	0 [0, 25.0]	0 [0, 160]
Gross income per head of livestock*							
Mean (SD)	140 (171)	134 (295)	89.3 (42.3)	86.8 (65.5)	67.4 (61.4)	53.8 (28.5)	107 (186)
Median [Min, Max]	93.4 [6] [18.6, 896]	75.1 [5,6] [7.69, 2210]	85.8 [6] [6.00, 201]	66.8 [29.8, 294]	45.5 [2] [13.4, 310]	40.0 [1,2,3] [25.7, 116]	71.7 [6.00, 2210]
Total gross income*							
Mean (SD)	1850 (2050)	3490 (8630)	1810 (1120)	1590 (1030)	8010 (8050)	6760 (4860)	3610 (6240)
Median [Min, Max]	1330 [5.6] [177, 10200]	1760 [5.6] [80.0, 63300]	1660 [5.6] [36.0, 4260]	1180 [5.6] [352, 5050]	5710 [1,2,3,4] [798, 36000]	6190 [1,2,3,4] [1710, 22700]	1840 [36.0, 63300]
Value of livestock for home consumption*							
Mean (SD)	71.4 (45.3)	55.7 (38.2)	44.7 (25.1)	61.5 (53.4)	22.3 (15.7)	26.8 (19.7)	51.4 (40.9)
Median [Min, Max]	58.2 [3,5,6] [16.3, 263]	47.8 [5,6] [3.78, 210]	38.5 [1,5] [6.00, 93.9]	48.2 [5,6] [6.40, 276]	18.1 [1,2,3,4] [5.03, 74.8]	24.7 [1,2,4] [4.11, 74.1]	43.8 [3.78, 276]

	Cluster 1 (N=38)	Cluster 2 (N=53)	Cluster 3 (N=19)	Cluster 4 (N=25)	Cluster 5 (N=23)	Cluster 6 (N=18)	Overall (N=176)
Total value of livestock for home consumption*							
Mean (SD)	949 (518)	1290 (1000)	852 (520)	1150 (988)	2210 (1310)	2660 (1530)	1410 (1140)
Median [Min, Max]	830 [5,6] [177, 2070]	974 [5,6] [80.0, 5760]	801 [5,6] [36.0, 2230]	899 [5,6] [165, 4960]	1810 [1,2,3,4] [711, 5220]	2570 [1,2,3,4] [549, 6060]	1120 [36.0, 6060]
Costs for purchased fodder per head of livestock							
Mean (SD)	23.5 (22.9)	15.9 (14.7)	43.5 (33.3)	14.8 (11.8)	15.6 (11.3)	8.00 (13.1)	19.5 (20.7)
Median [Min, Max]	17.9 [2.46, 133]	10.3 [2.05, 88.2]	35.1 [5.91, 119]	11.9 [0.282, 41.1]	12.1 [1.37, 42.1]	4.75 [0.310, 57.6]	13.2 [0.282, 133]
Total costs for purchased fodder for livestock							
Mean (SD)	273 (170)	392 (440)	864 (988)	255 (159)	1770 (2240)	631 (509)	603 (1030)
Median [Min, Max]	223 [25.1, 650]	248 [53.0, 1940]	538 [103, 3680]	253 [5.00, 700]	986 [250, 10800]	520 [160, 2130]	323 [5.00, 10800]
Costs for purchased fodder per head of livestock*							
Mean (SD)	9.68 (11.0)	6.54 (9.50)	38.5 (30.9)	1.04 (3.64)	11.9 (11.1)	3.52 (10.3)	10.3 (16.9)
Median [Min, Max]	5.52 [3,4,6] [0, 44.6]	3.13 [3,4,5,6] [0, 51.8]	25.0 [1,2,4,5,6] [5.91, 115]	0 [1,2,3,5] [0, 17.5]	7.57 [2,3,4,6] [0, 41.4]	0 [1,2,3,5] [0, 43.2]	3.79 [0, 115]
Total costs for purchased fodder for livestock*							
Mean (SD)	116 (116)	166 (290)	770 (937)	15.8 (45.2)	1380 (2190)	188 (399)	360 (968)
Median [Min, Max]	77.2 [3,4,5] [0, 500]	63.1 [3,4,5] [0, 1620]	475 [1,2,4,6] [103, 3560]	0 [1,2,3,5] [0, 174]	640 [1,2,4,6] [0, 10400]	0 [3,5] [0, 1600]	100 [0, 10400]
Costs for fodder production per head of livestock*							
Mean (SD)	13.8 (19.0)	9.40 (7.90)	5.02 (6.31)	13.8 (10.9)	3.69 (3.95)	4.49 (3.36)	9.26 (11.6)
Median [Min, Max]	9.19 [0.316, 113]	6.67 [0.761, 36.4]	3.49 [0, 24.1]	11.6 [0.282, 41.1]	2.48 [6] [0, 16.6]	4.10 [5] [0.310, 14.3]	6.19 [0, 113]
Total costs for fodder production for livestock*							
Mean (SD)	157 (138)	227 (236)	94.1 (124)	239 (154)	391 (369)	443 (247)	243 (244)
Median [Min, Max]	103 [6] [3.00, 550]	150 [6] [15.0, 1200]	30.0 [0, 450]	220 [5.00, 700]	337 [6] [0, 1430]	440 [1,2,5] [60.0, 947]	168 [0, 1430]
Labour costs per head of livestock*							
Mean (SD)	1.34 (3.81)	3.79 (11.0)	5.09 (12.1)	1.62 (7.21)	3.71 (5.89)	0.853 (2.42)	2.78 (8.23)
Median [Min, Max]	0 [5] [0, 19.4]	0 [0, 66.7]	0 [0, 42.5]	0 [5] [0, 36.1]	0.826 [1,4] [0, 21.6]	0 [0, 7.62]	0 [0, 66.7]
Total costs for seasonal labour for livestock farming*							
Mean (SD)	17.9 (47.4)	83.3 (308)	66.4 (150)	16.4 (70.0)	402 (659)	137 (431)	105 (345)
Median [Min, Max]	0 [5] [0, 200]	0 [5] [0, 2160]	0 [0, 480]	0 [5] [0, 350]	100 [1,2,4] [0, 2400]	0 [0, 1800]	0 [0, 2400]
Veterinary costs per head of livestock*							
Mean (SD)	1.12 (1.19)	0.589 (0.746)	1.41 (2.31)	0.819 (1.33)	0.814 (0.783)	0.349 (0.318)	0.830 (1.20)
Median [Min, Max]	0.816 [0, 4.69]	0.388 [0, 3.73]	0.669 [0, 8.10]	0.364 [0, 4.43]	0.605 [0, 2.99]	0.303 [0, 1.06]	0.443 [0, 8.10]
Total veterinary costs for livestock*							
Mean (SD)	13.8 (14.2)	15.0 (20.9)	23.6 (35.0)	12.5 (18.2)	116 (220)	46.4 (52.1)	31.7 (88.6)
Median [Min, Max]	10.0 [5] [0, 70.0]	9.00 [5] [0, 100]	12.0 [5] [0, 115]	5.00 [5] [0, 80.0]	50.0 [1,2,3,4] [0, 1060]	40.0 [0, 170]	10.0 [0, 1060]
Grazing costs per head of livestock*							
Mean (SD)	1.64 (4.14)	1.79 (3.65)	0.196 (0.356)	0.892 (1.87)	0.514 (0.722)	0.526 (0.577)	1.16 (2.92)
Median [Min, Max]	0 [0, 18.1]	0.654 [3] [0, 22.7]	0 [2] [0, 1.30]	0.233 [0, 8.90]	0.285 [0, 2.69]	0.272 [0, 1.65]	0.212 [0, 22.7]

	Cluster 1 (N=38)	Cluster 2 (N=53)	Cluster 3 (N=19)	Cluster 4 (N=25)	Cluster 5 (N=23)	Cluster 6 (N=18)	Overall (N=176)
Total costs for grazing in livestock farming*							
Mean (SD)	15.6 (44.3)	36.5 (64.4)	3.68 (6.58)	14.6 (24.4)	39.0 (46.7)	83.3 (162)	30.4 (70.9)
Median [Min, Max]	0 ^{2,5,6} [0, 250]	12.2 ^{1,3} [0, 320]	0 ^{2,5,6} [0, 25.0]	4.50 ^{5} [0, 105]	25.0^{1,3,4} [0, 198]	32.5 ^{1,3} [0, 700]	8.50 [0, 700]
Fuel for machinery and transport per head of livestock*							
Mean (SD)	8.98 (12.2)	9.88 (10.1)	5.67 (5.91)	18.0 (21.0)	3.13 (3.29)	5.15 (3.49)	9.01 (12.2)
Median [Min, Max]	5.85 [0.211, 74.3]	5.56 [0, 36.8]	3.88 [0, 19.3]	8.47 [0, 89.9]	2.39 [0, 15.0]	5.00 [0.0562, 11.8]	5.17 [0, 89.9]
Total costs for fuel for machinery and transport of livestock*							
Mean (SD)	113 (136)	228 (250)	90.6 (78.8)	325 (369)	371 (443)	585 (454)	257 (328)
Median [Min, Max]	86.0 [2.00, 825]	112 [0, 1000]	100 [0, 200]	200 [0, 1700]	250 [0, 2000]	490 [6.00, 2000]	150 [0, 2000]
Costs for animal purchases per head of livestock*							
Mean (SD)	9.74 (56.5)	3.07 (18.0)	2.63 (9.76)	0 (0)	1.47 (3.51)	5.50 (16.6)	4.07 (28.7)
Median [Min, Max]	0 [0, 349]	0 [0, 131]	0 [0, 42.3]	0 [0, 0]	0 [0, 14.6]	0 [0, 70.9]	0 [0, 349]
Total costs for replacement of livestock*							
Mean (SD)	88.7 (487)	56.8 (252)	42.1 (143)	0 (0)	177 (406)	756 (1500)	141 (596)
Median [Min, Max]	0 [0, 3000]	0 [0, 1750]	0 [0, 600]	0 ^{6} [0, 0]	0 [0, 1680]	0 ^{4} [0, 5800]	0 [0, 5800]
Marketing costs per head of livestock*							
Mean (SD)	0 (0)	0 (0)	0.201 (0.874)	0 (0)	0.0328 (0.140)	0 (0)	0.0259 (0.291)
Median [Min, Max]	0 [0, 0]	0 [0, 0]	0 [0, 3.81]	0 [0, 0]	0 [0, 0.670]	0 [0, 0]	0 [0, 3.81]
Total costs for marketing of livestock*							
Mean (SD)	0 (0)	0 (0)	2.11 (9.18)	0 (0)	1.96 (7.50)	0 (0)	0.483 (4.06)
Median [Min, Max]	0 [0, 0]	0 [0, 0]	0 [0, 40.0]	0 [0, 0]	0 [0, 35.0]	0 [0, 0]	0 [0, 40.0]
Loan costs per head of livestock*							
Mean (SD)	2.39 (9.81)	2.21 (10.3)	0 (0)	4.70 (16.2)	0.911 (4.06)	1.27 (3.66)	2.10 (9.66)
Median [Min, Max]	0 [0, 46.5]	0 [0, 64.0]	0 [0, 0]	0 [0, 75.6]	0 [0, 19.5]	0 [0, 14.7]	0 [0, 75.6]
Total costs for loan repayment of livestock*							
Mean (SD)	31.4 (139)	55.0 (273)	0 (0)	38.5 (117)	50.9 (170)	178 (445)	53.7 (230)
Median [Min, Max]	0 [0, 767]	0 [0, 1800]	0 [0, 0]	0 [0, 552]	0 [0, 650]	0 [0, 1500]	0 [0, 1800]
Total costs per head of livestock*							
Mean (SD)	48.7 (67.7)	37.3 (41.3)	58.7 (41.0)	40.8 (36.9)	26.1 (15.1)	21.7 (25.0)	39.5 (45.2)
Median [Min, Max]	33.2 ^{6} [4.23, 407]	24.6 [2.42, 278]	41.4 ^{6} [7.47, 130]	29.0 [3.73, 173]	23.7 [4.78, 64.6]	13.4 ^{1,3} [2.72, 99.4]	26.3 [2.42, 407]
Total costs*							
Mean (SD)	554 (577)	867 (855)	1090 (1030)	662 (430)	2930 (3000)	2420 (2250)	1220 (1660)
Median [Min, Max]	410 ^{3,5,6} [43.1, 3500]	593 ^{5,6} [54.9, 3720]	816^{1,5} [140, 3940]	556 ^{5,6} [66.0, 1960]	2040^{1,2,3,4} [650, 15200]	1640^{1,2,4} [364, 8130]	640 [43.1, 15200]

**in 1000 Tenge*

Superscripts 1, 2, 3, 4, 5, and 6 indicate clusters with which a significant difference exists at p < 0.05 or lower, based on pairwise comparisons using the Wilcoxon test with Holm correction for multiple comparisons

Table 30 Comparative Analysis of Profitability Between Different Farm Sizes in Cattle Farming

	Households (N=48)	Quartile 1 (N=46)	Quartile 2 (N=41)	Quartile 3 (N=40)	Quartile 4 (N=37)	Overall (N=212)
Total gross margin*						
Mean (SD)	39.8 (622)	57.9 (508)	333 (881)	584 (1950)	856 (3760)	346 (1870)
Median [Min, Max]	124 [-1830, 1430]	79.4 [-1280, 979]	334 [-1670, 3750]	339 [-2150, 10500]	622 [-11200, 16300]	173 [-11200, 16300]
Gross margin per cattle*						
Mean (SD)	-0.321 (179)	8.06 (81.5)	31.7 (88.2)	29.0 (95.0)	15.5 (44.1)	16.0 (111)
Median [Min, Max]	21.3 [-711, 336]	12.2 [-194, 180]	38.8 [-185, 395]	16.1 [-113, 484]	19.0 [-102, 116]	19.1 [-711, 484]
Number of cattle sold						
Mean (SD)	1.08 (1.49)	0.674 (1.84)	1.56 (2.37)	4.23 (6.17)	8.00 (10.0)	2.89 (5.79)
Median [Min, Max]	0 [0, 6.00]	0 [0, 11.0]	0 [0, 10.0]	2.50 [0, 30.0]	5.00 [0, 40.0]	0 [0, 40.0]

**in 1000 Tenge*

Figure 14 Mean Cattle Costs and Revenues by Farm Size Quartiles

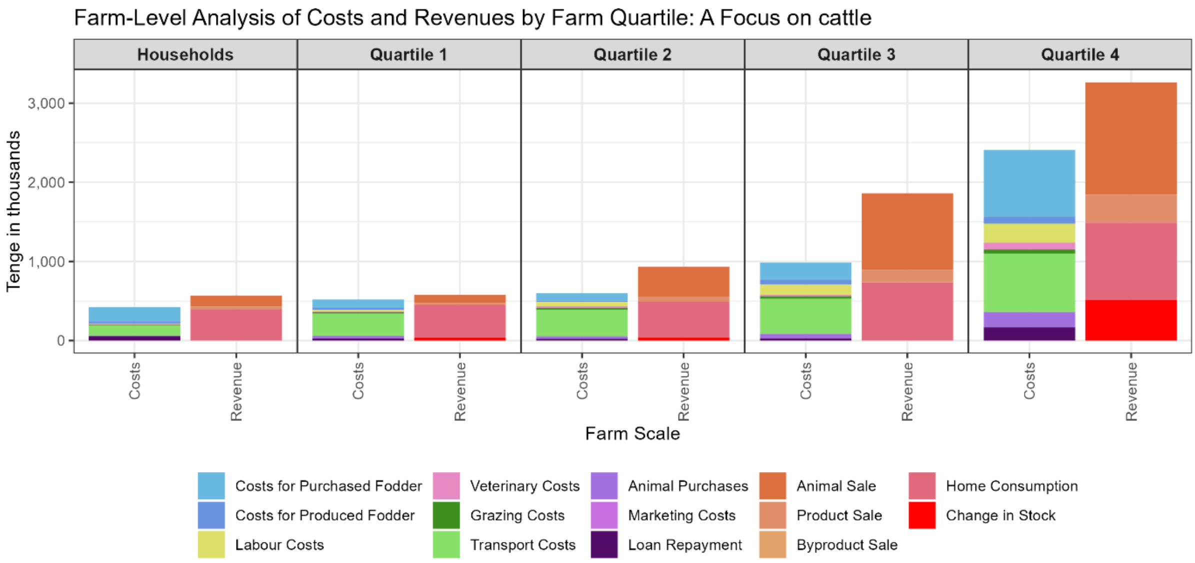


Figure 15 Mean Cattle Costs and Revenues per Head by Farm Size Quartiles

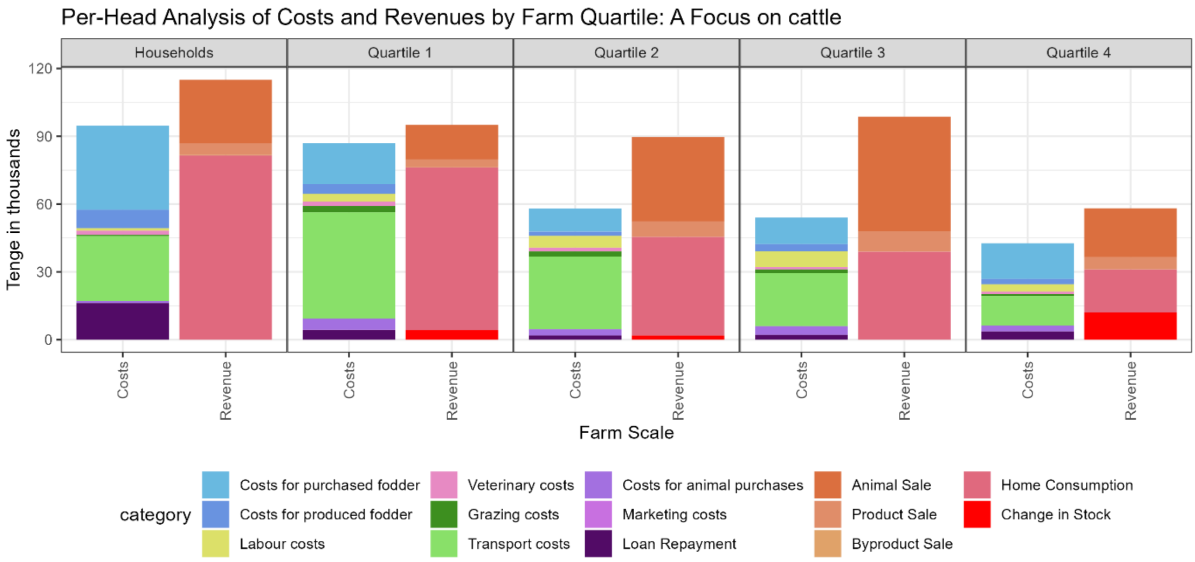


Table 31 Comparative Analysis of Profitability Between Different Farm Strategies in Cattle Farming

	Cluster 1 (N=36)	Cluster 2 (N=51)	Cluster 3 (N=19)	Cluster 4 (N=22)	Cluster 5 (N=19)	Cluster 6 (N=17)	Overall (N=164)
Total gross margin*							
Mean (SD)	398 (923)	241 (910)	-78.8 (1000)	159 (767)	-46.7 (3860)	2570 (3980)	435 (2090)
Median [Min, Max]	248 [-1280, 3750]	140 [-2150, 2790]	42.8 [-3240, 903]	60.1 [-1280, 1700]	-106 [-11200, 10500]	1840 [-1900, 16300]	219 [-11200, 16300]
Gross margin per cattle*							
Mean (SD)	38.1 (94.0)	21.2 (68.1)	-10.7 (72.2)	5.18 (69.1)	24.2 (116)	34.3 (45.8)	20.8 (80.2)
Median [Min, Max]	40.6 [-194, 395]	14.4 [-137, 180]	9.11 [-185, 98.2]	8.87 [-112, 137]	-4.54 [-51.4, 484]	37.5 [-72.1, 116]	18.3 [-194, 484]
Number of cattle sold*							
Mean (SD)	0.889 (1.82)	2.73 (4.22)	3.95 (3.85)	0.591 (1.22)	8.05 (11.0)	8.71 (11.1)	3.41 (6.45)
Median [Min, Max]	0 [0, 8.00]	1.00 [0, 23.0]	3.00 [0, 11.0]	0 [0, 4.00]	5.00 [0, 40.0]	4.00 [0, 40.0]	0.500 [0, 40.0]
Purchase of concentrate for cattle (total kg)							
Mean (SD)	1150 (1020)	1710 (2190)	4960 (9200)	63.6 (226)	5450 (8820)	1080 (1620)	2110 (4800)
Median [Min, Max]	1000 [0, 5000]	1000 [0, 10000]	2500 [0, 40000]	0 [0, 1000]	2400 [0, 30000]	0 [0, 5000]	1000 [0, 40000]
Self-production of concentrate for cattle*							
Mean (SD)	55.6 (333)	44.3 (234)	0 (0)	5490 (6720)	0 (0)	7560 (9210)	1510 (4600)
Median [Min, Max]	0 [0, 2000]	0 [0, 1500]	0 [0, 0]	4000 [600, 30000]	0 [0, 0]	5000 [0, 30000]	0 [0, 30000]
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5.9%)	1 (0.6%)
Purchase of roughage for cattle*							
Mean (SD)	1990 (3180)	2250 (5750)	19200 (18300)	318 (1080)	57600 (120000)	3820 (11100)	10500 (44500)
Median [Min, Max]	0 [0, 10000]	0 [0, 30000]	15000 [2610, 70000]	0 [0, 4500]	29300 [0, 540000]	0 [0, 40000]	0 [0, 540000]
Self-production of roughage for cattle*							
Mean (SD)	13300 (12800)	21500 (20300)	2420 (8120)	24300 (27300)	22800 (31000)	49100 (39000)	20900 (25600)
Median [Min, Max]	9000 [2000, 75000]	16000 [1500, 115000]	0 [0, 35000]	15800 [0, 120000]	10000 [0, 100000]	38800 [0, 130000]	12300 [0, 130000]
Months spent on off-village pasture							
Mean (SD)	0.861 (1.69)	7.82 (3.27)	5.11 (4.43)	4.77 (3.99)	10.9 (2.64)	9.88 (3.44)	6.14 (4.64)
Median [Min, Max]	0 [0, 5.00]	6.00 [3.00, 12.0]	5.00 [0, 12.0]	5.00 [0, 12.0]	12.0 [4.00, 12.0]	12.0 [3.00, 12.0]	6.00 [0, 12.0]

**in 1000 Tenge*

Figure 16 Mean Cattle Costs and Revenues by Feeding Strategy

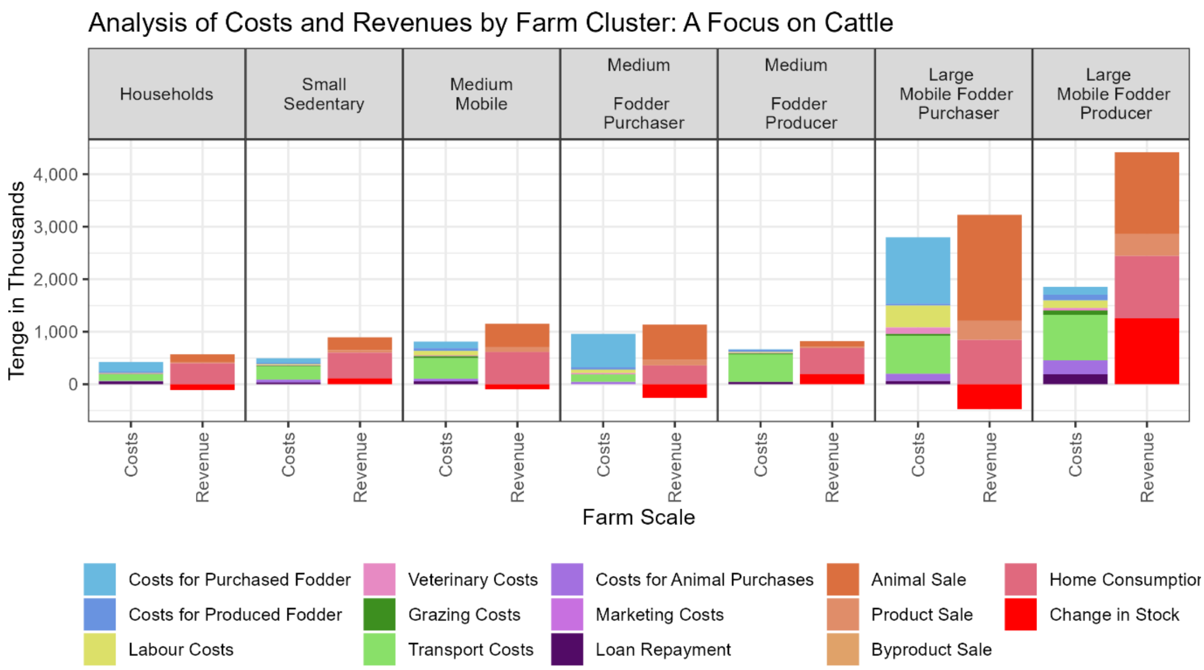
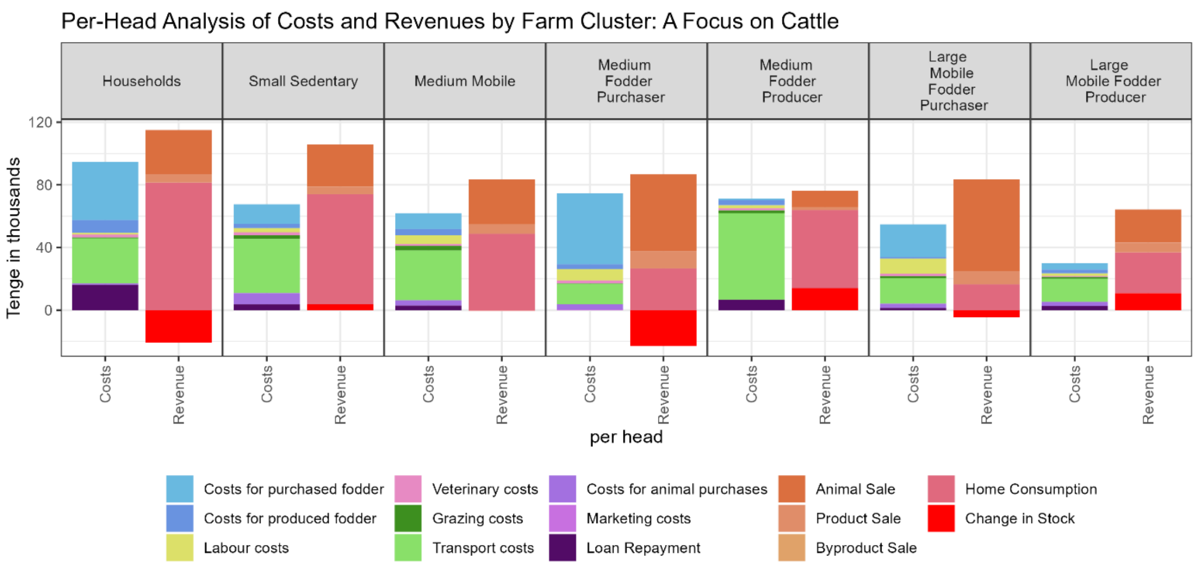


Figure 17 Mean Cattle Costs and Revenues per Head by Feeding Strategy



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