Economics of Milk Production on Permanent Grassland in Mountainous Areas

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Abstract

This paper presents an economic analysis of dairy farms located in the western region of Slovenia, an area characterized by permanent grassland and natural constraints (LFA), which result in limited production conditions and lower labour productivity. Based on three typical agricultural holdings of varying sizes, the study evaluates economic performance using the SiTFarm model. Key indicators such as gross margin, labour productivity, and greenhouse gas emissions are assessed. Results confirm that herd size and milk yield significantly influence economic sustainability, with larger farms generally performing better despite lower productivity per cow. Improving milk yield by 1,000 kg per lactation has a notably positive impact on income and reduces emissions per unit of output. While small farms face economic challenges, milk processing emerges as a viable strategy to enhance their long-term sustainability. The findings underline the importance of targeted development strategies that consider both economic and environmental dimensions.

INTRODUCTION

The dairy sector is an important agricultural sector both in the EU and also in Slovenia. It represents a diverse group of farms that vary in terms of the number of dairy cows, the extent of cultivated land, location, as well as in farming technology and management practices. This paper analyses the economic performance of dairy farms located in the western part of Slovenia. This is a remote area characterized by a predominance of permanent grassland within the agricultural land use structure. The region lies entirely within areas facing natural constraints (LFA), which translates into more challenging production conditions and lower labour productivity. The area is home to both small and large-scale farms engaged in milk production. The dominant dairy breed in the region is the Brown Swiss.

Both small and medium size farms are important from social as well as environmental perspective. As highlighted by Borawski et al. (2020), an important characteristic of milk production is the existence of economies of scale. Small dairy farms are less competitive compared to larger ones. For later it is typical high level of labour productivity mainly due to favourable production potential (Poczta et al., 2020). However, opposite holds for small semi-subsistence and small farms, usually located in LFA region, that achieve much lower labour productivity. They have higher unit production costs in comparison to larger farms and are from economic perspective usually less efficient. On the other hand, this is a region where even medium farms tend to achieve somewhat lower milk yields, primarily due to the fact that the feeding ration is based on forage produced on permanent grassland, requiring the purchase of concentrate feed. Some of these farms are also involved in the processing of milk into dairy products, the other deliver milk into local dairy.

In the paper we present the economic outcomes of these farm types, exploring their performance and examining how moderately higher milk yields affect their overall economic viability. The analysis is conducted using the SiTFarm model—a specialized farm model designed for conducting economic analyses at the farm level in Slovenia. SiTFarm has been applied in various studies of the agricultural sector, including the dairy sector (Žgajnar and Kavčič, 2024). It has been used as decision-support tool for policymakers and agricultural policy planners (Žgajnar et. al, 2023; Žgajnar, 2024). In this context, the model allows for analysis of market revenues and budgetary support payments, while also simulating variable costs, thereby enabling gross margin analysis. The model is based on a mathematical programming approach and utilises optimization capabilities, which support the balancing of material and nutrient flows within the farm system.

In the following sections, we briefly present the modelling approach and the characteristics of defined dairy farms for the analysed region. Then we summarize the results, focusing on key economic indicators under assumed production conditions. Special attention is given to the impact of increased milk yield on overall farm economics. The article concludes with key findings, highlighting the importance of herd size, productivity, and strategic development pathways.

MATERIAL AND METHOD

SiTFarm model

For the purpose of analysing dairy farms in Slovenia, utilising only permanent grassland in mountain LFA region, the SiTFarm tool (Slovenian Typical Farm Model Tool) was employed (Žgajnar et al., 2022). This tool represents a mathematical programming-based farm model that enables a wide range of analyses at the level of a farm's production plan. SiTFarm is structured modularly and integrates three distinct modelling approaches. The first component consists of static models of Typical Agricultural Holdings (TAHs), which represent various farming systems (production models) commonly observed in practice. Each production plan reflects the expected structure and output of a specific type of dairy farm, thereby serving as a representative model for a broader category of similar farms. The second modelling approach involves budget calculations (Model Calculations – MC), which serve as the primary source of economic and technological data at the level of individual production activities. These are static production models developed independently by the Agricultural Institute of Slovenia (AIS, 2025), covering all major agricultural activities—including fodder production, cash crops, vegetable production, and livestock farming. MCs facilitate real-time adjustments of individual budgets in terms of production technology, intensity (yield), and price-cost ratios, aligning them with the conditions of the analysed typical farm. The third approach is a comprehensive farm model (FM) that integrates the two aforementioned approaches. It enables the autonomous calibration of production plans in accordance with technological parameters, as well as each farm's specific production constraints and resource endowments.

The version of SiTFarm applied in this study relies on mathematical programming. This allows for the use of various techniques in solving the production plan, which constitutes the basic analytical level. In this instance, deterministic linear programming was employed. The constructed matrix of production possibilities serves as a framework for production planning, with the primary objective being the maximization of Gross Margin (GM). However, it is important to note that this analysis does not aim to determine the optimal solution for each TAH. Rather, the objective is to reconstruct a production plan that reflects real-world conditions - plans that may diverge from the optimal allocation of resources due to numerous practical constraints. To this end, a "partial optimization process" was utilized - an extension of linear programming incorporating a complex system of equations. This approach facilitates the estimation of uncertain variables, enabling the development of a complete and technologically consistent production plan for a given farm.

Economic Indicators

The economic indicators presented are based on average input prices, hired labour costs, and average purchase prices from the year 2024. Market revenues represent the value of agricultural production sold, always calculated as final output at the farm level. In all analysed cases only primary production is assumed, and therefore, on-farm milk processing is not included in the analysis, although it may represent a significant potential revenue stream if implemented.

Budgetary support payments are based on the current Common Agricultural Policy (CAP) strategic plan in Slovenia for the programming period 2023–2027. These include direct payments and payments for farming in areas facing natural constraints (LFA). Direct payments considered in this analysis encompass non-production-linked support, specifically the Basic Income Support for Sustainability, Complementary Redistributive Income Support for Sustainability, and selected ECO-schemes, as well as coupled support payments for dairy cows in mountain areas. Where eligibility criteria are met, additional payments for animal welfare are also included. Environmental payments, however, are not considered in this particular analysis.

Variable costs are calculated in the manner to avoid duplication where market and non-market activities coexist on an individual farm (TAH). All costs except fixed costs are included, with herd renewal also classified as a variable cost. The magnitude of this cost depends on herd replacement rates and the effectiveness of farm management and is assigned as an input specific to each farm type (TAH).

The central economic indicator observed is Gross margin (GM), calculated as the difference between total revenue and variable costs. To facilitate comparison of economic performance between farms, GM per hour is also calculated. This does not refer to total available working hours on the farm, but rather to effectively utilized labour, estimated using standardized labour input models. These models calculate labour demand based on the type and scale of each activity included in the farm's production plan. Additionally, a 2–3% flat-rate increment is added to account for essential non-technical activities such as record-keeping and farm management, which are crucial for operation but not directly linked to production.

Environmental Indicators

For each typical farm (TAH), a set of simplified environmental indicators has been calculated to monitor the potential impacts of farming practices on climate, water, and soil, and indirectly also on biodiversity. These indicators are expressed per hectare of utilized agricultural area (UAA) or as a percentage of the UAA (Žgajnar et al., 2022).

Greenhouse gas (GHG) emissions are presented in kilograms of CO_2 equivalents. The GHG emissions indicator captures the emissions generated from livestock activities on the farm. Emissions from feed production (except grazing) and the application of livestock manure are excluded from this scope (Žgajnar et al., 2022).

Fuel consumption is reported as the amount of fuel used per hectare of UAA in crop production. This metric depends primarily on the crop type, cultivation methods, and a range of operational factors such as the power of machinery, type and size of implements, driving speed, and overall labour productivity (Žgajnar et al., 2022).

Typical Dairy Agricultural Holdings that farm on permanent grassland in LFA

The analysis includes three types of agricultural holdings commonly found in this region (Table 1). The predominant category consists of numerous medium-sized farms (with 18 dairy cows), but there are also some larger farms by Slovenian standards (with 50 dairy cows) and a few very small farms (with 6 dairy cows) engaged in milk production. The intensity of milk production is below Slovenian average on most of these farms. However, in the medium and large size categories, there are instances of slightly higher milk yields. In all cases, the farms raise Brown Swiss dairy cattle. This is a dual-purpose breed with an emphasis on milk production. Due to the composition of the milk, this breed is particularly important for dairy processing and cheese production, which are typical for this Alpine region in Slovenia.

Table 1. Characteristics of analysed dairy TAHs, farming on permanent grassland in LFA

Production Activities	TAH50_6000	TAH50_7000	TAH18_7000	TAH06_4500	TAH06_5500
Livestock					
Dairy cows (no.)	50	50	18	6	6
Breeding heifers (no.)	15	15	5	2	2
Young fattened cattle (no.)	–	–	5	3	3
Milk yield (kg)	6,000	7,000	7,000	4,500	5,500
Cultivated Areas and Labor					
Permanent grassland (ha)	46	46	18	6	6
Own labor input (h)	4,008	4,172	2,880	1,662	1,700

The animals raised on these farms are of medium size, with an average weight of 650 kg, and their milk production ranges between 4,500 and 7,000 kg. This breed is known for its adaptability to harsh mountainous terrain and its excellent grazing efficiency, allowing it to make optimal use of local feed resources from permanent grassland. On all farms, in addition to home-grown fodder, a necessary portion of concentrated feed is purchased, as the farms lack the capacity to produce it themselves. All of the farms operate only on permanent grassland, where they produce hay and silage, and, with the exception of the smallest farms, often practice grazing for at least half of the year.

As a dual-purpose breed, male calves are usually fattened at home. This is generally the case on smaller and medium-sized farms, which still have the capacity to do so, while larger farms usually sell male calves. All farms, however, breed the majority of female animals needed for replacement from their own stock, with any surplus being sold on the market.

Results

The results present the key economic outcomes for analysed TAHs (Table 2). The effect of increased milk production is also simulated for both the small (TAH_6) and large (TAH_50) farms.

The TAH case (TAH50_6000) represents larger farms that can be found in this area. Despite the large herd size (50 dairy cows), milk yield is relatively low (6,000 kg). This coincides with the LFA, where conditions for forage production are less favourable. The farm manages 46 hectares of permanent grassland. The herd of Brown Swiss cattle consists of 50 dairy cows and an appropriate number of breeding heifers. Male calves are sold before the age of 1 month.

During the growing season, animals graze (36% of UAA). On 43% of the land, grass silage is produced. The required hay is grown on remaining grassland. To meet the nutritional requirements of the animals, the farm purchases 41 tons of concentrated feed annually, mainly energy feed and some protein feed. For this level of production, 2.2 full time equivalent (FTE) are required.

The farm generates approximately 200,000 € annual revenue, of which 34% represents variable costs. The farm receives budgetary payments amounting to 12% of total revenue. Given the relatively high labour efficiency, the expected gross margin per hour (GM/h) is favourable and exceeds 32 €. However, it is true that the share of fixed costs on such a farm can be high, which significantly reduces the income hourly rate. Nevertheless, such a farm is very promising in terms of development, provided it has interested successors. Speculatively, milk processing could be an interesting supplementary activity if enough labour is available. It could potentially be expanded gradually, depending on the farm's capacity and its ability to secure a sufficiently large consumer base for dairy products.

From an environmental perspective, the farm has a slightly larger carbon footprint in terms of equivalent CO_2 emissions, and it is somewhat above average in this regard. However, it does not represent a major environmental burden.

If the milk yield were hypothetically increased by 1,000 kg per cow (TAH_50_7000), this would result in a significant positive impact on economic indicators (Table 2). The expected feed requirements would slightly change, with less grazing and a 68% increase in the purchase of concentrated feed. This would significantly increase variable costs by about 16%. The increased milk production would raise market revenues by approximately 13%, positively affecting GM, which would exceed 144,000 € annually. Of course, such a change would require more labour (+4%), resulting in a 5% increase in the GM hourly rate. The higher milk yield would significantly reduce CO_2 emissions per kg of milk produced (nearly -11%). Overall, the results for this farm are very favourable, and it can undoubtedly be ranked among the top quartile of the most successful dairy farms in Slovenia.

Table 2. Economic and environmental indicators for analysed dairy TAHs

	TAH50_6000	**TAH50_7000**	**TAH18_7000**	**TAH06_4500**	**TAH06_5500**
Economic Indicators					
Revenue (EUR)	200,460	224,092	88,714	23,456	26,931
Market revenue (EUR)	176,580	200,365	79,316	21,136	23,990
Budgetary subsidies (EUR)	23,880	23,727	9,399	2,320	2,940
Variable costs (EUR)	68,381	79,619	30,309	10,549	12,051
Gross margin (EUR)	132,079	144,473	58,405	12,907	14,879
Gross margin per hour (EUR/h)	32.95	34.63	20.28	7.77	8.75
Environmental Indicators					
Emission intensity – milk production (kg CO_2-eq/kg of milk)	0.789	0.705	0.573	0.791	0.68
Emission intensity – beef production (kg CO_2-eq/kg of meat)			5.98	5.98	5.98
Livestock density (LU/ha)	1.27	1.28	1.34	1.55	1.5
Mineral fertilizer use per ha (kg/ha, NPK 15:15:15 eq)	213	210	210	187	187
Fuel consumption per ha (l/ha)	96	101	112	119	118

The second case (TAH18_7000) involves a medium-sized farm, which raises 18 Brown Swiss dairy cows and achieves a milk yield of 7,000 kg. The farm breeds its own heifers for replacement and also raises some male calves for fattening. The farm manages 18 hectares of permanent grassland located in LFA. Grazing accounts for 30% of the land, with more than 50% dedicated to grass silage production, and approximately 14% is used for hay production. To meet the nutritional needs, the farm purchases 26 tons of concentrated feed, which represents an additional cost. Model calculations estimate that the farm requires 1.6 FTE of family labour.

With this scale of production, the farm generates 88,714 € revenue, of which approximately 10% is from budgetary payments (direct payments, including coupled support, LFA payments, and smaller amounts also from one-year ECO schemes and Animal Welfare Payments). Per hectare of cultivated land, this amounts to 524 €.

Variable costs for this farm in total are approximately 30,000 €, which represents 38% of market revenue or 34% of total revenue. GM is relatively favourable, amounting to 58,405 € annually, and when converted to effective working hours, the hourly rate is 20.28 €. This hourly rate places the farm within the above-average range for the dairy sector in Slovenia. To obtain a complete picture of the economic performance, fixed costs should be considered, which ultimately results in a considerably lower income. This farm has some potential for development, and one possible avenue is in dairy processing. From an environmental perspective, the farm's practices are considered favourable, and no significant challenges are foreseen.

The final case (TAH6_4500) represents a smaller dairy farm, one of the types that are gradually disappearing. It is also a type of farm where we often see a transition to family milk processing. This farm raises Brown Swiss cattle in a relatively extensive manner, with milk production of only 4,500 kg per cow. The farm breeds the necessary number of heifers and fattens beef cattle. The farm operates nearly 6 ha of permanent grassland, all within LFA.

On this farm, the animals are not grazed but are kept in the barn year-round, following a tied-in housing system. About 80% of the feed is silage, with the remainder being dried and made into hay. To meet the animals' nutritional needs, the farm purchases approximately 8 tons of concentrated feed. For this level of production, the farm requires just under 1 FTE. The farm's has a stocking rate of 1.55 livestock units per hectare.

This farm generates just over 21,000 € in annual revenue from milk production. Budgetary payments are also important, accounting for about 10% of total revenue. The share of variable costs is high, at 50% of total revenue, resulting in a modest gross margin of 7.77 € per hour. This farm is definitely in need of a new strategy for long-term sustainability. From an economic perspective, this farm is often not viable, and milk processing could be an opportunity for its survival and continued operation. Environmentally, this type of farming is somewhat less favourable, primarily due to the feed ration and the low milk production per cow.

If the milk yield on this farm were increased by 1,000 kg per cow (TAH6_5500), the farm would need to produce more high-quality grass silage and purchase more than double the amount of concentrated feed. Higher milk production would increase revenue by nearly 15%, and variable costs would rise by nearly the same percentage. This would positively impact gross margin, which would increase by 15%. Due to the additional labour required, the hourly rate would improve slightly, by just under 1€. The improved milk yield would result in better environmental indicators, particularly in terms of CO_2 equivalents, while other indicators would remain relatively unchanged.

CONCLUSIONS

As the results indicate, the scale of production has a predictable impact on the economic performance of dairy farms. Despite somewhat lower milk yields, the Brown Swiss breed is undoubtedly a suitable choice due to its efficient use of local feed resources. This is particularly relevant, as farms in the studied area typically operate solely on permanent grassland in mountainous regions.

In spite of the challenging production conditions, medium-sized and especially larger farms can achieve solid economic results. Based on the outcomes, the representative of the larger farm type is positioned in the top quartile of dairy farms in Slovenia. In contrast, small to medium-sized farms face the challenge of identifying viable strategies to ensure economic sustainability. Nonetheless, they are of high significance from both environmental and social sustainability perspectives. Small farms, however, are under considerable pressure in terms of all three pillars of sustainability—economic, environmental, and social.

Moreover, the results demonstrate that, in addition to farm size, milk yield significantly influences economic outcomes. It is, therefore, a crucial factor for improving profitability and should be a primary focus for farms currently achieving lower yields. Although increased production typically results in higher costs, particularly for concentrated feed, these expenses are economically justified and can be offset by the additional revenue generated from increased output.

Value-adding strategies such as on-farm milk processing would undoubtedly enhance economic indicators. This option may be especially relevant for medium-sized, and in some cases also small farms, as it could substantially improve economic sustainability. However, such diversification requires investment, raising critical questions about how to secure funding, implement the necessary infrastructure, and address challenges related to marketing, consumer demand, technical knowledge, and labour availability. One potential strategy is certainly the cooperation and integration of these farms. This could indeed represent a valuable direction for further research.

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