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Assessing Economic Viability of Resilient Sheep Foraging Alternatives in Lowland Regions of Romania

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Abstract: Sheep farming is an important branch of the animal husbandry sector in Europe. In 2023, Romania's sheep and goat herds ranked third in the European Union, with more than 10 million heads, contributing substantially to the production of meat, traditional cheeses, and wool. However, in the current climate context, with extreme weather events and especially long periods of drought, providing optimal fodder ratio becomes a challenge for farmers. As animal nutritionists provide valid alternatives, consistent with the nutritional requirements of the species, the present work aims to present some economically efficient fodder alternatives to use for milk production in sheep farms of different sizes. The study brings added value to research in the field of using fodder alternatives in animal nutrition through the economic aspects researched because profitability is pursued in any activity, thus completing the technical arguments of previous studies in the literature in the field. Several economic indicators were calculated, such as the total value by categories of expenses, the value of production, the level of profit, and the rate of gross and net return. The analysis demonstrated that regardless of their size, the sheep farms located in lowland areas can reach positive values of profitability indicators when using alternative fodder in animal feeding.

Keywords: sheep farming; economic efficiency; millet; climate change; Romania

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1. Introduction

Climate change is among the current global challenges that is pressuring natural ecosystems, agriculture, and economic processes [1]. Climate change was revealed in recent studies as a factor that has clearly affected the productivity of agriculture in large regions of Europe [2–4]. While this lengthening of the growing season may be positive in some northern areas of the European Union, the southern regions are believed to be subject to increased pressure from drought and periods of heat stress on crop yields and animal health [1,5,6]. More specifically, extreme events, such as flooding and wildfires, are also increasing, which serves only to worsen this vulnerability within the agricultural production systems [2,7].

Being an important branch of animal husbandry, sheep farming plays a major socio-economic role in the European area for maintaining biodiversity and supplying valuable products to the market. Therefore, the environmental and economic performance of such farms is of high interest and is continuously being measured and improved, both for decision-makers and farmers [8]. Sheep herds are concentrated in the Mediterranean and Black Sea areas of Europe, and their breeding systems are significant for the rural economy of these regions [9]. Sheep farming is not only relevant for economic stability of the regional business ecosystem but also for adapting the food system to environmental challenges, making it essential to consider the impacts of external factors on this sector. In this context, understanding and mitigating the effects of climate change becomes significant to ensuring the sustainability of agricultural systems [10,11]. Climate change has played a significant role in the evolution of agricultural production systems affecting animal production parameters. Sheep and goat farming is especially susceptible to heat stress, water scarcity, and declining pasture quality [8]. These climatic factors directly influence livestock productivity, reproductive success, and mortality rates. However, climate change has been one of the major barriers to the sustainability of small ruminant farms. Heat stress impairs milk production, feed intake, and reproduction functions in both sheep and goats [12]. Several recent studies suggest that future livestock production faces multiple challenges associated with climate change, making it necessary to study production factors and develop targeted solutions [13,14].

Among the challenges facing sheep and goat farming in European countries, a notable issue is related to thermal stress and livestock welfare. In Mediterranean regions, which are the typical habitats for these livestock, elevated temperatures intensify heat stress, consequently impacting their growth rates, milk yield, and reproductive success. The anticipated rise in both intensity and frequency of heatwaves represents a specific risk to the welfare and productivity of these animals [15].

Another challenge is related to the accessibility of forage and water for grazing livestock. Decreased precipitation coupled with elevated evaporation rates adversely impacts the quality of pastures and water supplies, complicating efforts for farmers in sustaining their herds. The deterioration of pastures not only influences the availability of feed but also results in soil erosion and a reduction in biodiversity [16].

High dependency on subsidies and volatile market prices make it difficult for farmers to invest in climate-resilient technologies and strategies. Many regions, particularly in Southern Europe, have reported decreasing farm incomes and increasing costs of feed and water, further stressing the financial sustainability of these farms [1,17].

Following Raza, A. et al. (2019), extreme temperatures and reduced rainfall have affected crop productivity in Southern Europe, with the greatest effects in countries such as Hungary, Serbia, Bulgaria, and Romania [18]. According to data from the National Institute of Statistics, the production of green forages in arable land in Romania decreased during the period 2013–2022 by 19.2%, from 13 million tons to 10.5 million tons, and the trend remains negative. The production of perennial forages decreased in the respective interval by 15.1%, from 9.7 million tons to 8.2 million tons, and in the case of green maize, both the area decreased by 12.5% and production by 20.9%. These evolutions indicate the decrease in the production of the main lactogenic fodder resources for ruminants, which are essential for the livestock sector. In this context, designing optimal nutrition for farm animals may allow adaptation to difficult environmental conditions, ensuring health, productivity, and well-being throughout periods of heat load [8].

The impact of climate change on livestock farming systems depends both on the environmental and climatic local conditions and on the economic vulnerability [13]. In this context, nutritional interventions can help animals sustain the production in adverse environmental conditions and help optimize economic profitability in sheep farms by minimizing production costs. Therefore, any strategy and interventions must emphasize the development of adaptation strategies that involve the decision-makers in the farms [14,19]. It is expected that the increased frequency and intensity of droughts will lower forage and crop production worldwide. The process of aridification is likely to reduce the carrying capacity in agropastoral and pastoral systems. Maximization of productivity of crops and forages within the livestock systems will then become an imperative strategic response [20].

Among the climate change variables, heat stress, insufficient water, and low feed quantity and quality appear to be the main limiting environmental factors in animal production [21,22]. High temperatures affect the milk production of sheep because they increase the maintenance energy requirement due to the increased rate of respiration [23,24]. At the same time, the relatively small body size of sheep, low water and feed requirements, a good feed conversion ratio, and the ability to convert low-quality feed into quality products are important characteristics in the current environmental and climatic conditions [25].

Optimal nutrition can allow adaptation to adverse environmental conditions, ensuring adequate energy intake during heatwave periods [26]. A promising approach to improve the efficiency of technological processes, including those of feeding, is precision animal breeding, which provides farmers with a real-time monitoring and management system through technological support [27–29]. Some authors believe that these technologies could also be introduced to extensive sheep breeding systems, with the benefits being higher profits and better use of feed resources [30,31]. Precision feeding recommends delivering nutrients in line with individual animal requirements based on real-time feedback from sensors [32].

Climatic features have a significant impact on the year-round availability of pasture and other resources for livestock [33,34]. Extensive animal husbandry depends on natural pastures and cultivated pastures for their nutritional requirements, so low availability of food and water during summer compromises production, especially in low-potential small ruminants in arid and semi-arid areas [33]. Climate change can affect the quantity and quality of products, the reliability of production, and the natural resources on which livestock production depends [1,34].

On the other hand, the demand for animal products provides market and income opportunities for farmers. However, under current environmental and climate conditions, higher temperatures could result in lower milk production, reduced animal weight gain, and lower forage conversion efficiency [35,36]. Nutritional interventions involving feeding sheep in accordance with the season and supplementing with micronutrients can help animals sustain their production in adverse environmental and climatic conditions [37]. This kind of intervention includes the use of alternative forages, like sorghum and millet.

Sorghum has its origin in Africa [38]. Due to the increased capacity to tolerate drought and extreme temperatures, compared to other cereals and to grow on all types of soil [39], it is currently the fifth most widely cultivated cereal worldwide [40], reaching an annual production of 60–65 million tons [41]. Correlated with its multiple possibilities for valorization, the interest in the sorghum crop has grown in Romania as well. The hybrids F 436-Prut and F 465-Doina were analyzed from the point of view of productive and energetic potential for Romania [42,43]. The nutritional content of sorghum grains is 10.4% protein, 1.5 fat, and 6.8% ash, similar to rice, wheat, and corn [40].

According to the previous literature, millet was first cultivated in East Asia then spread throughout Eurasia before emerging as a significant crop in the second millennium BC [44]. Even in extreme heat and drought, millet thrives on land in semi-arid regions, having a brief vegetative phase and producing large yields [45]. The millet crop also has the advantage of being one of the grains that absorbs more carbon dioxide from the atmosphere and converts it to oxygen, which means it can help slow down climate change [46]. After sorghum, the millet crop is the most important cereal cultivated for human and animal sustenance, with high demand in Africa, Russia, India, and China [47]. This plant is regarded as a nutritious cereal that is high in energy, containing as much or more protein than wheat, rice, corn, and sorghum [48], and has a large economic influence on developing countries [49].

Several studies carried out so far [43,50–52] regarding the efficiency of sorghum and millet use refer to the economic results of crop farms, obtained from the utilization of these crops. But they do not extend the research to the economic efficiency of livestock farms and especially of sheep farms, which use in their rations these resilient forage resources. Also, the reports originated mostly in non-European countries with a semi-arid climate, not in those with a temperate-continental climate, like Eastern European countries, which are facing recent changes in the hydrological and climatic regime. The prior research that referred to the use of these forages in animal rations did not aim to study the economic aspects of animal farms that use them. So, the contribution of the present work to the literature in the field consists of the evaluation of different types of costs and economic effects of using these crops in lowland sheep farms, where forage crops adapted to climate change participate in the creation of added value via animal production.

In this context, the main aim of this work is to assess the economic feasibility of alternative feed resources in sheep-farming enterprises in lowland areas of Romania in view of climate change and its impacts on the number of traditional forages available. In this respect, the research questions (RQs) of the study were as follows:

RQ1: What is the economic feasibility of incorporating sorghum as resilient fodder into the feeding of sheep during the drought period? This research question aimed to approach the economic sustainability related to the shift of sheep farmers from conventional fodder toward alternative varieties resistant to drought conditions. Conventional fodder that can be totally or partially replaced by millet and sorghum are those commonly used in sheep feed, and here we refer to bulk fodder, such as silage corn or green corn. For ruminants, millet hay can also replace different types of hay. Regarding grains, millet can replace corn, barley, or wheat.

RQ2: What is the economic feasibility of incorporating millet as resilient fodder into the feeding of sheep during the drought period? This research question aimed to approach the economic sustainability related to the shift of sheep farmers from conventional fodder toward alternative varieties resistant to drought conditions.

RQ3: How do resilient fodder alternatives, namely, sorghum and millet, affect profitability in small- and medium-scale sheep farms? It was explored whether the farm size influenced the economic outcomes of using resilient fodder.

In order to address the proposed research questions, hypotheses were formulated. These hypotheses test the impacts that sorghum and millet may exert on farm profitability, nutritional adequacy, and range in farm size, offering significant insight into the role of climate resilience within farming management decisions.

H1: *The use of sorghum as resilient fodder in sheep feed leads to a marked improvement in the economic viability of the farms.*

This hypothesis suggests that the replacement of traditional, drought-prone fodders like with resilient ones like sorghum will guarantee higher economic returns in the respective sheep farms. That is because sorghum is a drought-resistant crop and can withstand more extreme conditions, providing more seasonally stable feed availability and reducing the costs associated with crop failures or feed shortages in the driest periods. The possible hypothesized economic improvements in this case are related to reduced feed costs or profit margins under drought conditions. This hypothesis of determining the financial impacts of utilizing resilient fodder was aimed at investigating whether the sheep farmers would either maintain their economic stability or even improve it by introducing sorghum into animal nutrition.

H2: *The use of millet as resilient fodder in sheep feed leads to a marked improvement in the economic viability of the farms.*

This hypothesis suggests that the replacement of drought-prone fodders with millet will generate higher economic returns in the respective sheep farms. The possible hypothesized economic improvements in this case are related to reduced feed costs or profit margins under drought conditions. This hypothesis of determining the financial impacts of utilizing resilient fodder was aimed at investigating whether sheep farmers would either maintain their economic stability or even improve it by introducing millet into animal nutrition.

H3: *Resilient fodder alternatives yield more pronounced economic benefits in larger farms.*

This proposition suggests that more extensive agricultural operations might gain greater advantages from economies of scale when implementing resilient fodder alternatives.

Resilient forage options, such as sorghum and millet, would have higher economic returns for medium-scale sheep farms compared to small-scale farming. This hypothesis suggests that the scale of farming is an important determinant of the extent to which farms can benefit from the efficiency, production stability, and resilience values offered by drought-tolerant forages.

These research questions and hypotheses were developed to consider the economic and pragmatic outcomes of utilizing drought-resistant forage in ovine agriculture, in particular, under the challenging conditions posed by climate change. This research aims to investigate the economic and practical implications of using drought-resistant fodder in sheep farming as a response to climate change.

2. Materials and Methods

To illustrate the economic analysis, two sheep farms of different sizes—one with 100 heads and another with 1500 heads—were selected as case studies. The average production for these farms was considered as being 100 L of milk/head and 60 kg live weight/head. The farms were considered for the Western area of Romania, specifically in the Western Plain, where the largest areas of sorghum were cultivated. The climate in those areas is continental–moderate, with temperate–oceanic influences, and the annual temperature averages are between 10 °C and 12 °C. Average annual precipitation amounts to 600 mm in the plains and 700 mm in the hilly areas. Fodder rations for the summer season and for winter were developed and include lowland forages adapted to the conditions of climate change, like green millet and green sorghum (in summer) and millet silage and sorghum silage (in winter) based on the norms of Milk Nutritive Units (UNL) and digestible protein (PDIN), established according to the productive level and weight of the animal, tabular values developed by the Institute of Animal Biology and Nutrition [53]. According to Drăgotoiu et al. (2017), the objective of determining the chemical composition of forages is to estimate their nutritional value [54]. UNL is a conventional nutritional unit which expresses the energy content of a forage, necessary for the maintenance functions and milk production needs of animals. The protein value of forages depends on their protein content, degradability, and digestibility and is calculated using the PDI (intestine digestible protein) system.

The nutritional content of a feed refers to the content of proteins, energy, vitamins, minerals, etc. The nutritional unit UN represents the potential of the forage, illustrating mainly the level and effect of its energy content, which the animal uses for its production, in this case for milk production [42]. Prices for forages are average values on the free market.

The fodder rations were optimized both in terms of covering the UNL and PDI required for the maintenance of the animals' vital functions and for milk production, as well as from an economic point of view, based on the specific technological allocation requirements of inputs at average prices on the market, to obtain the necessary incomes to cover the expenses allocated by the farmer, as well as to obtain a profit. Feed rations for animals can be very varied, depending on local resource availability and on feed purchases made by the farmer, etc. A ration used in an association of sheep breeders with whom we were in contact includes in the winter season 2 kg of alfalfa hay, 1.2 kg of high-moisture fodder like corn silage, and 0.4 kg of concentrated fodder—grains of corn and sunflower meal—and in summer 5 kg of green fodder, like pasture or green maize, and 0.3 kg of concentrated feed—grains of corn and sunflower meal. In the implementation of specific measures during the preparation period for the calving campaign in winter, when sheep are in the stable, vitamin and mineral supplements can be administered at a proportion of 1% of the concentrated feed.

Based on the estimated average yields under climate change conditions for ration forages, the areas required for fodder cultivated on the farm were calculated. The income and expenditures budget was drawn up, with the components of variable expenditure (feed, biological material, energy, medicines, other material expenditure, and supply quota) and fixed expenditure (labor, general expenditure, interest, and amortization) as well as with the component of income indicators: value of production, value of main production, taxable income, net income, and income rates, following the formulas described below:

$$TE = VE + FE,$$

in which TE—total expenditures, VE—variable expenditures, Fe—fixed expenditures.

$$VE = F + b + e + m + o + s + in,$$

in which F—forage costs, b—biologic material, e—energy, m—medicines, o—other materials, s—supply quota, in—insurance.

$$FE = l + g + i + a,$$

in which l—labor, g—general costs, i—interests, a—amortization.

$$VP = VM + VS,$$

in which VP—value of production, VM—value of main production, VS—value of secondary production.

$$TI = VP - TE,$$

in which TI—taxable income.

$$NI = TI - t$$

in which NI—net income, t—taxes.

$$TIR = TI/EM$$

in which TIR—taxable income rate, EM—expenditures for main production.

The calculations in the income and expenditure budgets were carried out for a theoretical model farm on the basis of data from periodic surveys that our research organization is carrying out with farmers as part of business-as-usual work in our research team for providing analysis for median farms across the country for supporting decision-makers. The data were updated with inflation rates, and input prices were calculated as average prices on the free market. Elaborating the income and expenditure budgets consisted of the determination of different categories of expenses, the estimation of incomes, and the analysis of profitability. Production value was determined as a product of market price and the average production yield. Gross product was determined by adding the subsidy to the revenue obtained from the production sale. Total expenses were calculated by summing variable and fixed expenses. Variable expenses were determined by summing the expenses with fodder, the young female sheep starting their first lactation (biologic material), energy, medicines, other materials, supply quota, and insurance (if applicable). Supply expenses represent those expenses necessary for the supply of materials. The fixed expenses include labor costs, general costs, interests, and amortization. The production cost per product unit was determined by dividing the total expenses for the main production by the quantity of milk sold. The value of taxable income was calculated by the difference between the value of total production and total production expenses. The net income was calculated by deducting 10% tax from the taxable income. The rate of taxable income (%) was determined by dividing the taxable income by the total expenses for the main production. The ratio of net income plus subsidies was calculated by dividing net income plus subsidies by total expenditure on primary production.

Moreover, that the resulting values calculated in the budgets were confirmed by sheep breeders' associations, as well as by specialists from the Research and Development Institute for Sheep and Goat Breeding in Romania. On the other hand, in case studies carried out previously, in 47 sheep farms [55], we found that there is a variability between farms for the calculated economic indicators, which can reach 15–30% for the different categories of expenses or even 50% for labor costs. These differences are due to different sizes of farms, different prices for inputs in different areas of the country, and prices for the products sold by the farm (cheese, lambs).

3. Results

3.1. Sheep Farm with 100 Heads

In the summer ration, the green millet replaces part of the pasture, considered to be affected by drought conditions. During the grazing season, animals may face growth constraints due to limited grazing resources for pasture, determined by stocking density and environmental and climatic conditions [56].

Extensive sheep systems have an important role in ensuring food security and the use of pastures, which have no alternative agricultural destination, and responses to climate challenges are decisive for economic and environmental sustainability. Low-quality pastures can have significant implications in providing the nutrients needed by animals [34]. Considering the green type of foraging for the pasture and the nutritional content of the fodders in the ration, when ensuring the PDI requirements, the UNL requirement is slightly exceeded (Table 1).

Table 1. Green millet summer ratio/head—100 L/head, 60 kg live weight.

Forages	kg/Head/Day	UNL	PDI (g)	Quantity/Head/Summer	Price, RON/kg	Value/Head/Summer
Lowland pasture	4.00	0.84	88.00	800	0.1	80
Green millet	5.50	1.32	106.70	1100	0.18	198
Total		2.16	194.70			278
Norm		*1.93*	*195.00*			

Source: Authors' own elaboration.

The winter ration is composed of alfalfa hay, millet silage (as a substitute for corn silage), corn cobs, and a certain amount of corn grain (Table 2). The winter ration is composed of alfalfa hay (33.1%) and millet silage (46.7%).

Table 2. Millet silage winter ratio/head—100 L/head, 60 kg live weight.

Forages	kg/Head/Day	UNL	PDI (g)	Quantity/Head/Winter	Price, RON/kg	Value/Head/Winter
Alfalfa hay	1.56	0.89	117.00	257	0.90	231.7
Millet silage	2.20	0.64	37.95	363	0.40	145.2
Corn cobs	0.80	0.22	29.60	132	0.15	19.8
Corn grains	0.15	0.19	10.95	25	1.08	26.7
Total		1.93	195.50			423.4
Norm		*1.93*	*195.00*			

Source: Authors' own elaboration.

The annual quantities are 800 kg pasture, 1100 kg green millet, 257 kg alfalfa hay, 363 kg millet silage, 132 kg corn cobs, and 25 kg corn grain. Corn cobs and corn grains can be purchased from suppliers (Table 3).

Considering the modest average production obtained in drought conditions, it follows that the area required for fodder is 20.47 ha, of which 8 ha is pasture (Figure 1).

The income and expenditure budget for 100 sheep for milk indicates a total expenditure value of 99,756 RON/farm, of which 47,956 RON/farm related to the main production. Variable expenses represent 82.1% of total costs. Of the total expenses, the cost of feed represents 70.3% (70,139 RON/farm), and that of the variable expenses is 85.6%, being the most important input in obtaining milk production (Table 4).

Table 3. Total forage quantities per year/farm and surface for forages, small farm.

Forages	Quantity, kg	kg/ha	Surface/Head, ha	Surface/Farm, ha
Alfalfa hay	257	5000	0.05	5.15
Lowland pasture	800	10,000	0.08	8.00
Green millet	1100	20,000	0.06	5.50
Millet silage	363	20,000	0.02	1.82
Corn grains	25		purchase	
Corn cobs	132		purchase	
Total surface				20.46

Source: Authors' own elaboration.

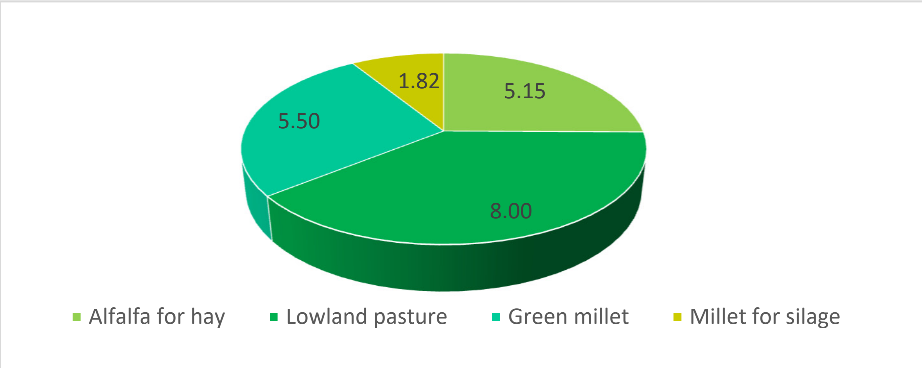

Figure 1. Necessary surface for forages, small farm.

Table 4. Budget of income and expenditures of the small farm.

Indicators	RON/Head	RON/L	Value/Farm, RON
Value of production, of which:	1068.0	10.68	106,800
Value of main production (milk)	550.0	5.50	55,000
Subsidies	0	0	0
Gross product	1068.0	10.68	106,800
Total expenditures, of which:	997.6	9.98	99,756
Expenditures for main production	479.6	4.80	47,956
Variable expenditures, of which:	819.6	8.20	81,956
Forage costs	701.4	7.01	70,139
Biologic material	66.7	0.67	6667
Energy	12.0	0.12	1200
Medicines	12.0	0.12	1200
Other materials	8.0	0.08	800
Supply quota	19.5	0.20	1950
Insurance	0	0	0
Fixed expenditures, of which:	178.0	1.78	17,800
Labor	178.0	1.78	17,800
General costs	0	0	0
Interests	0	0	0
Amortization	0	0	0
Taxable income	70.4	0.70	7044
Taxes	7.0	0.07	704
Net income + subsidies	63.4	0.63	6340
Taxable income rate %	14.7	14.7	14.7
Net income rate %	13.2	13.2	13.2
Production cost	479.6	4.80	47,956
Price	550.0	5.50	55,000

Source: Authors' own elaboration.

The level and quality of fodder are determining factors of animal production. In conditions with a reduced hydrological regime and prolonged periods of drought, the countries of the European Pannonian zone, including Romania, were the most affected, which is why alternatives for feeding animals with crops resistant to the current environmental and climate conditions are required.

The main production of the farm is milk, which is sold at an average price of 5.5 RON/L (as cheese), and the secondary production is the sale of lambs and reformed animals.

The taxable income of the farm is RON 7044, specifically 14.7%, which indicates that farm obtains a profit and overcomes the vulnerability to climatic conditions, falling within the terms of economic sustainability (Figure 2).

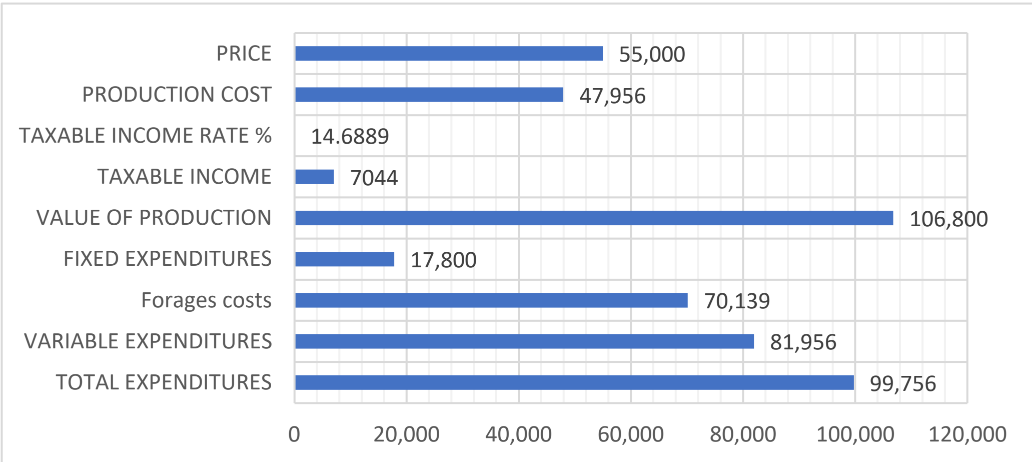

Figure 2. The main economic indicators of the small farm.

3.2. Sheep Farm with 1500 Heads

For the farm of 1500 sheep, sorghum was chosen as an alternative fodder, used in the summer ration as green sorghum and in the winter as sorghum silage. Thus, in the summer, 6 kg of green pasture and 3.8 kg of green sorghum are provided, to which 80 g of sunflower meal is added, to ensure the necessary protein level of the ration (Table 5).

Table 5. Green sorghum summer ratio/head—100 L/head, 60 kg live weight.

Forages	kg/Head/Day	UNL	PDI (g)	Quantity/Head/Summer	Price, RON/kg	Value/Head/Summer
Lowland pasture	6.00	1.26	132.00	1200	0.10	120.0
Green sorghum	3.80	0.61	45.60	760	0.18	136.8
Sunflower meal	0.08	0.06	18.08	16	1.17	18.7
Total		1.93	195.68			275.5
Norm		*1.93*	*195.00*			

Source: Authors' own elaboration.

The winter ration contains equal amounts of 2 kg of alfalfa hay and sorghum silage, as well as 310 g of corn grain, to complete the energy level of the ration (Table 6).

Thus, the annual requirement per sheep is 1200 kg of pasture, 760 kg of green sorghum, 16 kg of sunflower meal, 330 kg of alfalfa hay, 330 kg of sorghum silage, and 51 kg of corn grain (Table 7).

Table 6. Sorghum silage winter ratio/head—100 L/head, 60 kg live weight.

Forages	kg/Head/Day	UNL	PDI (g)	Quantity/Head/Winter	Price, RON/kg	Value/Head/Winter
Alfalfa hay	2.00	1.14	150.00	330	0.90	297.0
Sorghum silage	2.00	0.40	24.00	330	0.30	99.0
Corn grains	0.31	0.39	22.63	51	1.08	55.2
Total		1.93	196.63			451.2
Norm		*1.93*	*195.00*			

Source: Authors' own elaboration.

Table 7. Total forage quantities per year/farm and surface for forages, medium farm.

Forages	Quantity, kg	kg/ha	Surface/Head, ha	Surface/Farm, ha
Alfalfa for hay	330	5000	0.07	99.00
Lowland pasture	1200	15,000	0.08	120.00
Green millet	760	20,000	0.04	57.00
Sorghum silage	330	25,000	0.01	19.80
Corn grains	51		purchase	
Sunflower meal	16		purchase	
TOTAL SURFACE				295.80

Source: Authors' own elaboration.

The surface required for the farm of 1500 sheep, in drought conditions, is 295.8 ha, of which 120 ha is pasture (Figure 3).

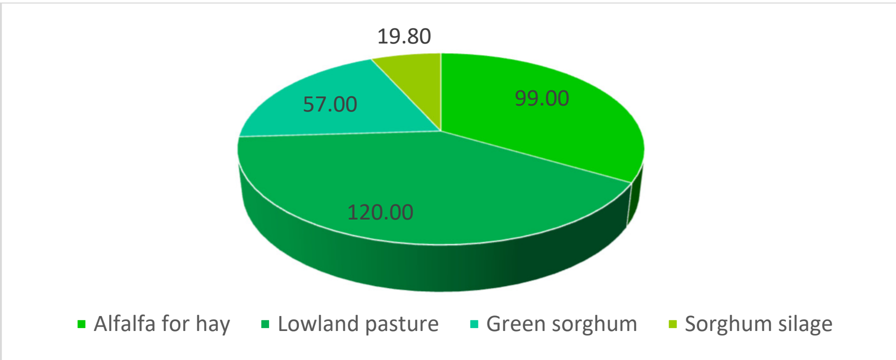

Figure 3. Necessary surface for forages, medium farm.

The concentrated fodders, such as sunflower meal and corn grain, are purchased. Of course, under conditions of a normal hydrological regime, when the production of green fodder on the pasture increases, the surface needed is significantly reduced.

For the 1500-head farm, the budget of income and expenditures indicates a total expenditure value of 1,451,347 Romanian Leu (RON), of which RON 674,347 relates to the main production. Variable expenses represent 87.7% of total expenses. Of total expenses, the cost of feed represents 75.1%, and that of the variable expenses is 85.6% (Table 8).

The taxable income of the farm is RON 150,653, specifically 22.3%, and the net income with subsidies (the farm meets the conditions for obtaining financial support) increases to 25.1% (Figure 4). Taxes are 10% of gross income for both farms, but the taxable income rate, also called the gross income rate (%), was determined by dividing taxable income (gross income) by total expenses for the main production. On the farm with 100 heads, this ratio is only 14.6% compared to the farm with 1500 heads, where the ratio between the two indicators had a higher value (22.3%), and in addition, the money supply is over 21 times higher.

Table 8. Budget of income and expenditures of the medium farm.

Indicators	RON/Head	RON/L	Value/Farm, RON
Value of production, of which:	1068.0	10.68	1,602,000
Value of main production (milk)	550.0	5.50	825,000
Subsidies	22.4	0.22	33,600
Gross product	1090.4	10.90	1,635,600
Total expenditures, of which:	967.6	9.68	1,451,347
Expenditures for main production	449.6	4.50	674,347
VARIABLE EXPENDITURES, of which:	848.6	8.49	1,272,847
Forage costs	726.8	7.27	1,090,143
Biologic material	66.7	0.67	100,000
Energy	15.0	0.15	22,500
Medicines	12.0	0.12	18,000
Other materials	8.0	0.08	12,000
Supply quota	20.1	0.20	30,204
Insurance	0.0	0.00	-
FIXED EXPENDITURES, of which:	119.0	1.19	178,500
Labor	119.0	1.19	178,500
General costs	0.0	0.00	-
Interests	0.0	0.00	-
Amortization	0.0	0.00	-
TAXABLE INCOME	100.4	1.00	150,653
Taxes	10.0	0.10	15,065
NET INCOME + subsidies	112.8	1.13	169,188
TAXABLE INCOME RATE %	22.3	22.3	22.3
NET INCOME RATE %	25.1	25.1	25.1
PRODUCTION COST	449.6	4.50	674,347
PRICE	550.0	5.50	825,000

Source: Authors' own elaboration.

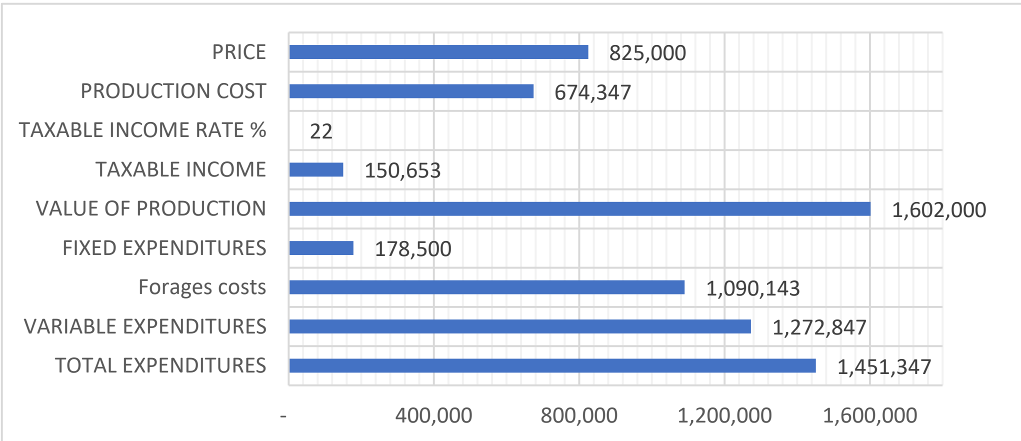

Figure 4. The main economic indicators of the medium farm.

4. Discussion

On a farm with a total of 100 sheep heads, it can be seen that green millet, which is used to replace some of the pasture, meets the nutritional needs of the flock quite well. It is slightly in excess of the UNL needs and meets the standard PDI. The adjustment was an important one, with a view to the resiliency of fodder options, such as in mitigating adverse drought impacts in pasture-based livestock systems.

As the forage costs, accounting for 70.3% of the total farm expenses, become the most important inputs for milk production, the previous observation underlines the importance of feed management regarding the profitability of the sheep farm. Considering that variable expenses make up 82.1% of the total and that 85.6% of those variable expenses constitute forage costs, any efficiency or cost effectiveness in feeding will be directly reflected in farm profitability. This farm compensates for the deficits in grazing brought about by the climatic conditions and increases its productivity and profitability by replacing part of the low-quality pasture with nutrient-rich green millet.

Similarly, the income and expenditure budget for the 100-head farm provides a net profit equivalent to RON 7044, with a taxable income rate of 14.7%. That would imply that the farm is economically viable even in the context of climate stressors, mainly due to the strategic use of such drought-resistant fodder as millet. Although small, the net income rate of 13.2% shows how this farm might stay in profit under the harsh environmental conditions.

The larger-scale farm employing sorghum as a resilient feed alternative in summer and winter rations evidenced a higher taxable income amounting to RON 150,653 or 22.3 percent of total income. Adding subsidies, net income rose to 25.1 percent due to the economic advantages of scaling up production and climate-resilient feed strategies.

Overall, the results showed that while millet and sorghum as resilient fodder options could ensure economic gains accruable to a small farm and medium-scale farm, respectively, the latter made better economic sense since it has the capacity to optimize resources and leverage scale economies and thus access finance. The addition of drought-tolerant fodder species was thus justified for both cases to favor the value of livestock feeding while ensuring economic viability for farms with severe climatic variability.

The analysis indicated the fact that the recommendations of specialists in biology and animal nutrition regarding the use of alternative feeds, like millet and sorghum, in conditions of a reduced water regime, represent, from an economic point of view, a solution to reduce the vulnerability of farmers' incomes. If farmers resort to the use of fodder alternatives in the event that crops more sensitive to the hydrological deficit are affected, such as green maize or maize silage, the question arises regarding the economic viability of these decisions, in the sense of whether the resultant financial expenditure created exceeds the level of expenses and does not reach the profitability threshold of the farm. In other words, is there an economic risk that accompanies this choice? The current calculations demonstrate that the farm's activity can be carried out with profit.

Grazing is one component of a future sustainable agricultural system; it can improve both soil health and plant biodiversity and reduce the need for artificial fertilizers [57].

Previous studies have demonstrated that well-managed grazing encourages nutrient recycling through natural pathways, which improves soil structure and fertility and subsequently supports a great diversity of plant species, including plants otherwise uncommon in grazing lands [19,34,57]. Millet, especially pearl millet, is fast becoming an important forage crop in such grazing systems due to its ability to grow well in arid and semi-arid areas where water and nutrient availability is very poor [46,48]. As previously mentioned, one of the deep-seated aspects of millet is its potential to stabilize soil and improve water infiltration, which eventually opens up more avenues for improving soil health and reducing erosion [44,58,59]. From the standpoint of enhancing sustainability in grazing systems, another very important value of millet is that it thrives in low-nutrient soils and requires minimal artificial fertilization [45,48]. Other studies demonstrate the role of millet in grazing rotation, with a shift toward an increase in forage availability and the maintenance of soil fertility with regard to plant diversity [58]. This makes it a sustainable means of improving pasture productivity.

Cultivating drought-tolerant fodder varieties in warm areas is an effective adaptive strategy to ensure a sufficient supply of fodder during periods of scarcity [37]. For dry continental climates where maize is grown, alternative strategies can be suggested to produce resilient cattle forages such as sorghum so that the feed will contain more ingredients to cope with climate change [60]. It is fundamental that farmers and specialists in the field understand the direct and indirect impacts of climate change on livestock production under extreme weather conditions [61].

Our findings underline the importance of climate variability adaptation in agriculture, particularly within large-scale sheep farming systems. The results highlight that adequate grazing management is crucial with drought-tolerant fodder plants, such as green millet and sorghum, to maintain productivity and thus assure economic viability under drought conditions. This is in line with previous studies showing that proper grazing land use may alleviate some of the adverse effects of climate change on agricultural productivity [62–65].

Previous studies indicated that sorghum and millet are known to have resilience to climate variability, more specifically in the semi-arid region. These crops proved to have the ability to remain productive under water-stressed conditions compared to the conventionally grown cereals such as maize and hence are suitable alternatives in drought-prone areas [65,66]. One of the papers reported that millet and sorghum have high water-use efficiency compared to maize, particularly if they are irrigated in a small area. The research conducted in this study revealed that in an environment where there is limited water, sorghum and pearl millet tend to be more efficient in sustaining forage production [67].

It has been described that the cultivation of millet as the main forage in areas like the dry steppe zone of Northern Kazakhstan considerably enhanced the resilience of forage and had supplementary nutritional values, thus being rather promising in adjusting to the challenges of climate change [68].

According to Sabertanha et al. (2021), the sorghum silage of various varieties can provide total-tract digestibility of nutrients similar to corn silage and can be considered a reliable feed; thus, it is of great benefit. The study revealed that, under anaerobic conditions, sorghum silage showed good fermentation quality with low levels of anti-quality compounds, assuring that it is safe and effective in ruminant diets [69].

5. Conclusions

This study assessed the economic viability of foraging alternatives for sheep farming in lowland regions of Romania as a response to climate change. The results showed that regardless of farm size, implementing alternative forages could lead to positive profitability indicators. It was found that on a small farm with 100 sheep, the use of green millet in summer and millet silage in winter ensured proper nutritional supply and economic stability, characterized by a taxable income of RON 7044 and a net income rate of 13.2%. A larger farm with 1500 sheep showed even higher financial performance, with a taxable income of RON 150,653 and a net income rate of 25.1%, and could be further supported if subsidies are added. The presented results have value for both farmers and policymakers. The provided data show that diversification of the fodder with climate-resilient species would ensure that the sheep farming is able to rise above issues related to drought that lead to low-quality pasture. At the same time, the importance of developing specific public policy support mechanisms through subsidies or other types of technical assistance is also a reality.

While the use of the proposed alternative fodder is economically positive, there are limitations of the study that need to be considered. Firstly, the analysis included potential farms in lowland areas. Hence, it may not be possible to generalize the results to other sheep farms located in mountainous areas, which might have different conditions. Second, the analysis is based on specified drought scenarios and climate conditions; variations in these could significantly affect profitability outcomes. Additionally, the study focused primarily on economic indicators such as profitability and feed costs, but there are other important factors—such as animal health, feed conversion efficiency, and market conditions—that can be taken into consideration. Nevertheless, the results would have been enriched with more diverse indicators for broader geographic areas, thus offering a whole picture of the potentiality of resilient fodder systems. Future research and policy initiatives should focus on promoting the adoption of these practices to enhance the sustainability and economic resilience of livestock farming.

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