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The Potential of Sorghum as Climate Resilient Crop

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ABSTRACT

With climate change impacting agricultural practices globally, the potential of sorghum as a forage crop for dairy cattle has triggered attention. This paper is presenting a literature review on economic importance of sorghum, the research carried out in Romanian space and a brief analysis on the nutritional and economic importance of using green sorghum as forage for dairy cattle in the context of climate change. Scientific literature highlights the adaptability of different sorghum hybrids to local conditions and their production potential, demonstrating that optimized crop management techniques can significantly improve sorghum yield and nutritional quality. The projected economic results of the average size farm of 100 milking cows, with an average production of 5,000 liters of milk/year/head, indicate obtaining of 230,875.5 euro as total income, of which 211,267.61 euro from milk. Forages cost is of 0.23 euro/liter of milk of a total cost of 0.39 euro/liter and the minimum net profit rate of 9.8% per year. Total necessary surface for producing all forages in the farm is of 110.45 ha, but if the farmer purchases all concentrated forages (including grain corn), the surfaces reduce at 72.27 ha. Our analysis has shown that including sorghum in summer and winter rations for dairy cows can meet nutrient and protein requirements while keeping costs reasonable.

Keywords: sorghum, climate change, sustainable cropping, livestock systems.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is known for its heat and drought tolerance.

This resilience makes it an important crop in agronomic systems, especially in regions with challenging environmental conditions (Liaquat et al., 2023). Beyond grain production, sorghum serves as a valuable forage, hay and silage crop (Kopec, 2024). As a food crop, sorghum is one of the most important carbohydrate-rich crops globally, following wheat, corn, barley, and rice (Hossain et al., 2022). Sorghum serves as both a staple food and animal feed, adapting to diverse agronomic and environmental conditions, especially low rainfall, limited irrigation and salinity. It demonstrates resilience to climate variations, maintaining high productivity and providing food and feed, as well as raw material for industries (Venkateswarlu, 2019; Widodo et al., 2023). The resilience of sorghum and its potential for biomass production make it an excellent alternative feedstock for sustainable agriculture. This aligns with the findings of Rodino et al. (2019) in their analysis of Romania's biomass production sector, where the importance of utilizing resilient crops to support bioeconomy initiatives and enhance agricultural productivity in response to environmental challenges was analysed (Rodino et al., 2019).

With climate change impacting agricultural practices globally, the potential of sorghum as a forage crop for dairy cattle has triggered attention. This paper is presenting a literature review on economic importance of sorghum, the research carried out in Romanian space and a brief analysis on the nutritional and economic importance of using green sorghum as forage for dairy cattle in the context of climate change.

MATERIAL AND METHODS

Considering the need for solutions to reduce the vulnerability of livestock farms' incomes to the effects of climate change, technical-economic models were developed for production levels and farm sizes, with the

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use of sorghum as an alternative feed for dairy cows. Taking into account the characteristics of sorghum, as a drought-resistant plant, as well as its nutritional technical and economic model for a typical cow farm, with a milk production of 5,000 liters/head, 12,000-250,000 Standard Output.

Fodder rations adapted to climate change conditions were developed, based on the norms of Milk Nutritive Units - UNL and digestible protein PDIN, established according to the productive level and the weight of the animal, norms developed by specialists in nutrition and animal biology.

The rations were optimized both from a technical point of view, in the sense of covering the necessary UNL and PDI for maintenance and for milk production, and from an economic point of view, in the sense of obtaining the necessary income to cover the expenses allocated by the farmer for carrying out production processes.

LITERATURE REVIEW

By incorporating sorghum into forage systems, farmers can achieve more stable income levels. The economic viability of sorghum as forage is a significant consideration for farmers. Sorghum requires less water and inputs compared to other forage crops like maize. According to research by Baral et al. (2020), sorghum can be grown with lower costs and still produce high biomass yields.

In the same time the water use efficiency of sorghum is an ecological benefit of this crop. As climate change exacerbates water scarcity, crops that use water efficiently become fundamental for sustainable agriculture. Sorghum has a deep root system that allows it to access water from deeper soil layers, making it highly drought-tolerant (Jabereldar et al., 2017; Laestari et al., 2023).

Research by Bhattarai et al. (2020) highlights that sorghum requires less water than maize, making it an environmentally sustainable option for forage production (Bhattarai et al., 2020).

Studies by Salehin et al. (2020) indicate that sorghum can play a vital role in sustainable land management practices.

Sorghum contributes to soil health through its root structure and organic matter qualities, on the basis of which some of the addition. The deep roots of sorghum help prevent soil erosion and improve soil structure. Furthermore, sorghum residues, when left in the field, can enhance soil organic matter, promoting better nutrient cycling and soil fertility (Salehin et al., 2020).

The nutritional importance of sorghum is to be analysed in terms of nutrient profile and Digestibility and Milk Production. In this context, the scientific literature contains data related to nutrients content of green sorghum, pointing that it is rich in essential nutrients such as carbohydrates, proteins, vitamins, and minerals (Lv et al., 2023). In an experimental study, Lv et al. (2023), have demonstrated that feeding 75% sorghum silage as a replacement for corn silage in dairy cows can increase milk yield and fat, promote rumen microbe growth, and provide more rumen fluid amino acids for body and microbial utilization (Lv et al., 2023).

Other studies have shown that sorghum forage can sustain high milk production levels when included in the diet of dairy cows and sorghum silage has comparable nutritional value to other common forages like maize, making it a suitable alternative for cattle feed (Keten Gökkuş and Degirmenci, 2023)

In the same time, the digestibility of sorghum forage is a key factor in its effectiveness as cattle feed. Research by Zhang et al. (2024) indicates that the digestibility of sorghum can be enhanced through various processing techniques, such as ensiling. Improved digestibility results in better nutrient absorption and higher milk yields. Additionally, the inclusion of sorghum in the diet can help diversify the feed resources, reducing dependency on a single forage type and improving overall herd health (Sarubi et al., 2014; Ran et al., 2021; Terler et al., 2021). The study comparing the rumen degradability of fibre fractions of maize and sorghum silages found that the effective degradability of acid detergent fibre and hemicellulose in sorghum was comparable to that in maize, making it a

nutritionally viable option for cattle diets (Sarubbi et al., 2014).

RESULTS AND DISCUSSION

Taking into account the Standard Output SOC 2017 value (Source: AFIR) for dairy cows, of 1,232.70 Euro/head, the size of the average farm established according to the description in the materials and methods section, was 100 heads.

In order to analyze the introduction of sorghum in the feed of dairy cows, as a viable alternative under the conditions of climate change, we have illustrated the summer and winter rations designed for dairy cows with a production of 5,000 liters per head, as well as the feed requirement on the farm and the required areas for their production.

The summer ration for dairy cows, including green sorghum, provides a significant supply of nutrients at a relatively low cost (0.03 euro/kg). Combining alfalfa hay, sunflower meal and grain corn, this ration achieves the required energy and protein standards for milk production.

Table 1. Summer ratio, green fodder sorghum

Feed	Kg /head/ day	UNL	PDIN (g)	Quantity /head/	Price euro/kg	Value euro /head/ year
Hay	5.00	2.85	375.00	910	0.18	164.79
Green fodder sorghum	30.00	4.80	360.00	5,460	0.03	153.72
Sunflower cake	1.30	1.01	293.80	237	0.24	55.73
Corn	3.20	4.06	233.60	582	0.22	126.56
Total		**12.73**	**1,262.40**			**500.80**
Ratio		***12.60***	***1,260.00***			

Source: own calculations (exchange 1 Euro = 4.97 Lei)

Table 2. Winter ratio, sorghum silage

Feed	Kg /head/ day	UNL	PDIN (g)	Quantity /head/	Price euro/kg	Value euro /head/ year
Hay	5.00	2.85	375.00	915	0.18	165.79
Sorghum silage	24.00	4.80	288.00	4,392	0.06	265.19
Sunflower cake	1.10	0.86	248.60	201	0.24	47.48
Corn	1.90	2.41	138.70	348	0.22	75.65
Wheat bran	2.10	1.764	212.10	384	0.18	69.62
Total		**12.69**	**1,262.40**			**623.34**
Ratio		***12.60***	***1,260.00***			

Source: own calculations (exchange 1 Euro = 4.97 Lei)

The winter ratio includes sorghum silage, which provides a nutritious and affordable alternative in the cold season. In combination with alfalfa hay, sunflower meal, grain corn and wheat bran, the ration meets the energy and protein needs of cows, keeping costs within a reasonable range.

The use of green fodder sorghum and sorghum silage allows the reduction of the required areas due to the high productivity per hectare, thus ensuring an efficient management of resources in the context of climate change.

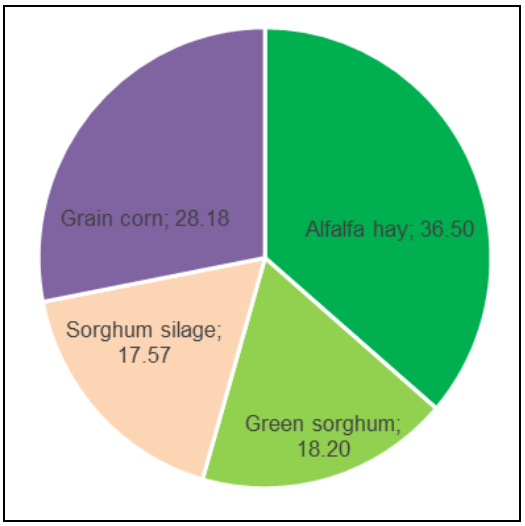
Therefore, the use of green fodder sorghum and sorghum silage as feed alternatives for dairy cows not only supports efficient milk production, but also contributes to the adaptation of agriculture to changing climate conditions, while keeping costs under control and maximizing utilization available lands.

The fodder produced on the farm requires a total area of 100.45 ha, and sunflower meal and wheat bran are purchased as external inputs (Figure 1).

Table 3. Estimation of farm fodder requirement and fodder area

Feed	Quantity, kg	kg/ha	Area head, ha	Area/farm, ha
Hay	1,825	5,000	0.37	36.50
Green fodder sorghum	5,460	30,000	0.18	18.20
Sorghum silage	4,392	25,000	0.18	17.57
Corn	930	3,300	0.28	28.18
Sunflower cake	438	External input		
Wheat bran	384	External input		
TOTAL area needed				**100.45**

Source: own calculations



Source: own calculations

Figure 1. The structure of the farm area cultivated for feed crops

Table 4. Main farm technical-economic indicators

Indicators	euro/head	euro/l	Value euro/farm
1. Total expenditures, of which:	2,163.20	0.43	21,631.99
1.1 Variable expenditures, of which:	1,502.80	0.30	150,279.68
1.1.1 Fodder expenditures	1,124.19	0.23	112,418.91
1.2 Fixed expenditures	660.40	0.13	66,040.64
2. Value of production	2,308.75	0.46	230,875.45
3. Taxable income	145.55	0.03	14,554.93
4. Rate of taxable income %	***7.4***	***7.4***	***7.4***
5. Production cost	1,967.12	0.39	196,712.68
6. Price	2,112.68	0.42	211,267.61

Source: own calculations

The economic results of the average farm, with 100 milk cows and with an average production of 5,000 liters of milk/head, indicate obtaining an annual taxable income of 14,554.93 euro/farm and a net profit rate of 9.8% per year (Table 4). Table 4 provides a detailed picture of the main technical-economic indicators on the farm, essential for evaluating financial and economic performance. Analyzing indicators can help identify strengths and areas for improvement.

Total expenses are significant, reflecting the costs necessary to maintain production. Relative to the liter of milk, the cost is 0.39 euro.

Variable expenses represent the largest part of total expenses (approximately 70%), being directly influenced by the volume of production. Feed costs dominate this category. Feed costs account for approximately 75% of variable costs, highlighting the importance of optimizing

feed costs to improve profitability. Fixed expenses include costs that do not vary directly with production volume, such as equipment depreciation and administrative expenses. The production value is higher than the total expenses, indicating a profitable production. Income per head and per liter of milk is significant. Taxable income is the difference between the value of production and total expenses, showing the profitability of the farm before tax (Figure 2).

The rate of taxable income is an indicator of profitability, showing that the farm has a profit margin of 7.4% of total revenues. The production cost per liter of milk is 0.39 euro, which provides a useful comparison with the price.

The estimated price of milk is 0.43 euro/liter, slightly below the production value, indicating the income potential and establishing a basis for financial planning.

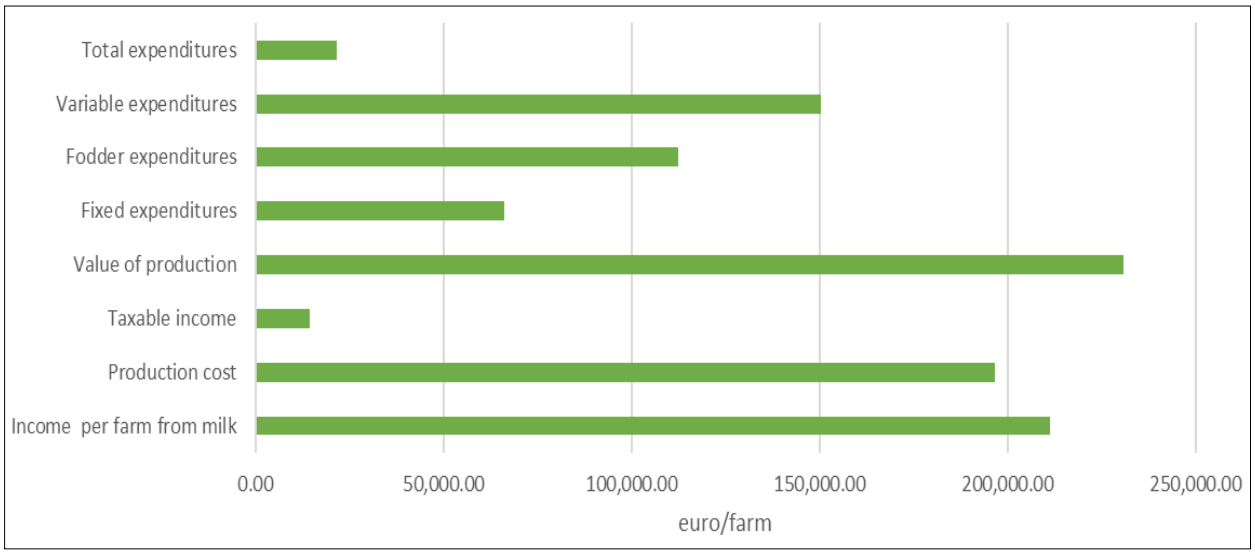


Figure 2. Main farm technical-economic indicators

The technical-economic indicators calculated provide a clear picture of the economic performance of the farm. Optimizing variable costs, especially feed costs, and maintaining a production cost below the recovery price are essential to increase profitability.

The importance of sorghum in Romanian research ecosystem

The sorghum varieties grown in Romania have specific characteristics that make them suitable for different regions and agricultural purposes. In central Moldova, research has identified eight sorghum hybrids cultivated for grains: Arsky, Foehn, Albanus, Shamal, Kalatur, Armorik, Elan and Alimentar. Studies have focused on the adaptability of these hybrids to local conditions and their nutritional value, considering the current problems of agriculture caused by climate change and the need to find solutions to fight hunger and improve human health (Isticioaia et al., 2020).

In the south-east of Romania, the researches were oriented towards the analysis of the behavior of grain sorghum hybrids (*Sorghum bicolor* L. Moench var. Eusorghum) and the evaluation of their production potential. The studies were carried out at Moara Domnească, Ilfov County, analyzing factors such as sorghum hybrids, row spacing and fertilization treatments. Hybrids analyzed included Alize, Aquilon and Arack, with results varying according to fertilization treatments and row spacing (Oprea et al., 2015).

The study by Mocanu et al. (2023) revealed that both planting density and hybrid selection significantly impact the biomass and dry matter yields of grain sorghum cultivated in Romania. Higher planting densities generally increased biomass production, though the response varied

among hybrids. Certain hybrids maintained higher yields even at lower densities, indicating their efficiency in resource utilization. The research underscores the importance of optimizing these agronomic factors to achieve maximum yield and economic sustainability, especially in regions with variable environmental conditions. These findings are crucial for enhancing sorghum production efficiency in the face of climate change.

In Dobrogea, research has focused on identifying solutions for the global fuel crisis, by obtaining biofuels from grain sorghum (*Sorghum bicolor* L. Moench). Studies have shown that grain sorghum adapts well to the agro-pedo-meteorological conditions in Dobrogea, allowing high yields to be obtained (Panaitescu et al., 2016).

Studies on the chemical composition of some sorghum hybrids cultivated in central Moldova indicated significant variations depending on the cultivated hybrid. The analyzed hybrids, originating from France and Romania, presented different chemical compositions, with major importance for food and fodder uses (Isticioaia et al., 2018).

A study by Pochiscanu et al. (2017) investigated the impact of various crop management techniques on the yield and quality of Sorghum bicolor grains in central Moldavia, Romania. The research evaluates different sequences of crop management, including variations in fertilization, planting density, and hybrid selection. Findings indicate that optimizing these factors can significantly enhance both the yield and nutritional quality of sorghum grains. Key results show that specific hybrids and management practices lead to higher grain production and improved grain quality, demonstrating sorghum's potential as a resilient crop in the face of climate change. In the context of climate change, sorghum has been identified as a resilient crop for Romanian territory due to its adaptability to harsh environmental conditions and its potential to maintain productivity. This adaptability is crucial for sustainable agriculture and biodiversity, as highlighted in the study by Simion et al. (2023), which provides a comprehensive bibliometric analysis of biodiversity and emphasizes the need for resilient agricultural practices. The findings from Pochiscanu et al. (2017) support this by demonstrating that optimized crop management techniques can significantly improve the yield and quality of Sorghum bicolor, making it a viable option for maintaining agricultural productivity and biodiversity in changing climatic conditions (Simion et al., 2023).

CONCLUSIONS

Sorghum (*Sorghum bicolor* L. Moench) demonstrates significant potential as a resilient and economically viable crop in the context of climate change, due to is heat and drought tolerance. This study highlights the benefits of sorghum, not only as a grain but also as a forage, hay, and silage crop, capable of maintaining high productivity under variable climatic conditions. According to the literature review, the research conducted in Romania demonstrated the adaptability of various sorghum hybrids to local conditions, demonstrating their potential to improve both yield and nutritional quality through optimized crop management techniques. Integrating sorghum into dairy cow rations has proven to be nutritionally beneficial and cost-effective, supporting stable farm incomes and efficient resource utilization.

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