

Economic analysis of corn silage production in Bosnia and Herzegovina

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Abstract

Silage production, or ensiling, is a specific technological process of processing and preserving certain forage crops with the help of lactic acid fermentation bacteria, which preserves the natural properties and nutritional value of the plants. Various forage crops are used for silage production, but the highest quality silage is obtained from corn, which is also the most widely used roughage in animal production. Between 2011 and 2020, the area sown with silage corn in Bosnia and Herzegovina increased by 39.7 %, total silage production by 78 %, and yield per hectare by 27.4 %. However, a satisfactory level of domestic production has not yet been achieved. Corn silage production in Bosnia and Herzegovina is predominantly concentrated on large farms oriented toward animal production. Therefore, the focus of this research was on two large cattle farms: “Farma Spreča” d.o.o. Kalesija (Farm A) and the Cantonal Public Enterprise “Poljoprivredno dobro Butmir” d.o.o. Sarajevo-Ilidža (Farm B). Primary data for the research were collected through semi-structured interviews with relevant representatives of these farms and by analyzing collected documentation. Production and economic indicators of corn silage production for the period 2016–2018 were identified and analyzed. Through analytical calculations, the scope and costs of corn silage production were determined for the total area and per hectare, as well as production value and indicators of financial results and cost-effectiveness. The research results show that during the 2016–2018 period, both farms achieved positive financial results in corn silage production, indicating economically viable production. In general, it can be stated that the economic indicators of corn silage production in Bosnia and Herzegovina show positive financial performance, but the production indicators point to the need for technical and technological improvements in order to achieve higher production volumes and better silage quality, and that it is necessary to manage production costs with the aim of reducing them.

Keywords: *production, farm, Corn Silage, costs, indicators*

Introduction

Farmers and other participants are increasingly exposed to challenges linked to globalization, market instability, complexity, and heightened scrutiny (Stiring et al., 2013; Falan et al., 2021). In addition, climate change significantly affects agriculture, causing a wide range of issues—from feed shortages and reduced yields to declines in the quality of products and inputs—ultimately impacting production and overall farm management (Sahoo, 2018; Falan et al., 2021). Consequently, farmers aim to reduce the previously mentioned risks by producing their own inputs, particularly feed for livestock production. Silage stands out as the most commonly used livestock feed globally. Silage is typically described as a technological process in which selected fodder crops are processed and preserved using lactic acid bacteria, thereby maintaining their natural characteristics and nutritional value (Khan et al., 2014; Khan et al., 2015; Milašinović Šeremešić, 2017). Corn (*Zea mays* L.) is the most widely used crop for silage due to its high productivity, good nutritional and energy value, ease of fermentation, and strong acceptance by ruminants (Terzić et al., 2020; Neumann et al., 2024). Corn, alongside wheat and rice, represents one of the most important agricultural crops in the world (Erenstein et al., 2022). The growing popularity of this crop is driven by its numerous advantages, including low harvesting costs, minimal production risks, high yields, high energy value for livestock, improved lactation performance, as well as excellent digestibility, palatability,

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and storage potential (Allen et al., 2003; Schroede, 2004; Ferraretto et al., 2018; Falan et al., 2021).

In 2014, the world area under corn was about 182 million hectares, total grain production was about 1.1 billion tons, and average yield was 5.61 t/ha (Zrakić et al., 2017). Globally, corn production increased by 24.58% over the period 2011–2020, while in the USA it rose by 15.45% (USDA, 2021). In contrast, corn production in the EU decreased by 7.6% during the same period (EUROSTAT, 2021). The yield of dry corn grain can reach up to 25 tons per hectare, and the potential yield of dry matter is between 50–60 tons, which exceeds all other field crops (Falan et al., 2021). The largest producers of corn in Europe are Ukraine, France, Romania, Hungary, and Italy (EUROSTAT, 2021). In neighboring countries, the harvested areas, total production, and yield per hectare in 2012 were as follows: Serbia – 1 268 544 ha; 3 526 552 tons; 2.78 t/ha; Hungary – 1 190 000 ha; 4 736 200 tons; 3.98 t/ha; Croatia – 299 162 ha; 1 298 363 tons; 4.34 t/ha; Romania – 2 722 180 ha; 5 961 574 tons; 2.19 t/ha; Bosnia and Herzegovina – 196 504 ha; 538 421 tons; 2.74 t/ha (Kovačević et al., 2013). Corn is an important grain for human consumption, but its importance is even greater as animal feed and as raw material in the food, textile, chemical, and other industries. About 67% of world corn production is used in animal husbandry, providing 33% of energy needs and 13% of protein needs of livestock (Erenstein et al., 2022).

Silage refers to the preservation of forage crops through lactic acid fermentation, enabling the retention of their natural properties and nutritional value (Muck, 2018; Muck et al., 2018). Various plants are used for silage, but the highest quality silage is obtained from the whole maize plant, which is also the most commonly used roughage in livestock production, especially in cattle farming (Falan et al., 2021). The production of maize and forage crops has traditionally represented an important agricultural sector in Bosnia and Herzegovina due to its favorable geo-climatic conditions and the strong presence of livestock farming. During the period 2011–2020, forage crop production in Bosnia and Herzegovina showed a noticeable increase (17%). The highest growth was recorded in maize grain production (55%), followed by alfalfa (25%), silage maize (16%), and clover and clover-grass mixtures (10%) (BHAS, 2021; Falan et al., 2021).

The areas sown with silage maize in Bosnia and Herzegovina generally increased over the observed period, with the exception of 2018, when a decrease of 3.5% was recorded compared to the previous year. The smallest increase in sown area was recorded in 2012 (2.3%), and the largest in 2015 (10.2%). The largest sown area was recorded in 2020, while the smallest was recorded in 2011. The sown area in 2020 was 39.7% higher compared to 2011. Total silage maize production in Bosnia and Herzegovina fluctuated over the years, with increases ranging from 16.2% in 2020 to a maximum of 59% in 2018, and decreases ranging from 33% in 2017 to 5.4% in 2019. The significant reduction in production in 2017 was primarily caused by drought conditions. The highest total production was achieved in 2020, while the lowest was recorded in 2012. Total production in 2020 was 78% higher compared to 2011. Production yield per hectare also varied, increasing from 13.9% in 2014 to 65.3% in 2018, and decreasing from 35.2% in 2017 to 9.7% in 2019. The highest yield per hectare was achieved in 2020, and the lowest in 2017. Yield per hectare in 2020 was 27.4% higher compared to 2011. These findings indicate that the increase in sown areas did not always result in higher production levels, mainly due to lower yields on newly cultivated leased land that had not previously been used for agricultural production.

In corn silage production in Serbia, similar year-to-year variations are present as in Bosnia and Herzegovina, with slightly larger sown areas and overall production volumes, while yields per hectare are approximately the same. The areas sown with silage maize in Serbia in the period 2011–2017 were: 30 157; 47 927; 32 418; 32 143; 34 046; 30 524; and 33 244 hectares, with total production of: 655 618; 736 943; 693 258; 617 447; 589 166; 650 741; and 534 521 tons, and production (yields) per hectare of: 21.1; 14.9; 20.7; 19.2;

17.3; 21.3; and 16.1 tons (Nastić et al., 2018). In corn silage production in Croatia, fluctuations are also present; the sown areas are somewhat larger, but both the total production volumes and yields per hectare are significantly higher compared to Bosnia and Herzegovina. The areas sown with silage maize in Croatia in the period 2010–2018 were: 31 358; 28 762; 29 461; 28 662; 32 198; 29 913; 26 022; 23 951; and 28 481 hectares, with total production of: 932 225; 744 063; 1 034 886; 1 011 502; 1 150 555; 1 259 560; 841 934; 1 003 135; and 996 194 tons, and production (yields) per hectare of: 29.7; 25.9; 35.1; 35.3; 35.7; 42.1; 32.4; 41.9; and 35.1 tons (Croatian Bureau of Statistics, 2021).

Silage production is primarily intended for livestock farming and constitutes a significant portion of the roughage in animal diets (Milašinović Šeremešić, 2017). By producing their own corn silage, farms can achieve significant savings in livestock feeding costs (Veljković et al., 2018). In addition to its use in livestock production, in recent years it has also been used as biomass for energy production. Silage is mostly considered a semi-finished product and often does not have a known market price. It is rarely traded, and thus usually has a negotiated price (Vukoje, 2014; Veljković et al., 2018). The growing importance of this crop in our region is reflected in the interest of both producers and researchers (Zrakić et al., 2017; Veljković et al., 2018; Falan et al., 2021), who are focused on enhancing production technologies, developing new silage maize hybrids, improving biomass quality and yields, and strengthening its market position.

Accordingly, the primary aim of this study is to assess key production and economic indicators and conduct an economic evaluation of corn silage production in Bosnia and Herzegovina to promote this well-established practice for feed management in livestock production.

Material and methods

Corn silage production in BiH is predominantly concentrated in a small number of large farms focused on cattle breeding, which produce corn silage primarily for the needs of their own livestock production, i.e., for animal feed. The subject of the research were two large farms: “Farma Spreča” d.o.o. Kalesija (Farm A) and the Cantonal Public Enterprise “Poljoprivredno dobro Butmir” d.o.o. Sarajevo-Ilidža (Farm B). Farm A, which produced silage corn on an area of 400 to 490 hectares during the observed period, is one of the largest and most modern dairy farms in BiH, with a capacity of 1 500 dairy cows, 1 000 head of supporting categories (heifers, calves, and fattening cattle), and milk production of about 12 million liters annually. During the observed period, the number of dairy cows was around 700 and supporting categories around 950, while annual milk production was about six million liters. Farm A has 9.1 hectares of its own land and 800 hectares of leased land, modern facilities and equipment, and a biogas production plant. In addition to silage corn, other forage crops are produced on approximately 300 hectares: alfalfa, grass-legume mixtures, triticale, barley, and wheat, while fruit production is present on 18 hectares. Farm B, which produced silage corn on an area of 170 to 190 hectares during the study period, is a modern farm for dairy cow production, breeding of heifers and slaughter cattle, as well as the production of bulky animal feed. The capacity of the farm is 500 dairy cows and 600 female breeding heifers and calves. Annual milk production during the observed period was about three million liters. Farm B has 275 hectares of its own land, on which, in addition to silage corn, other forage crops are also produced.

In order to achieve the study objective, data were collected and processed, analytical calculations were performed, and production and economic indicators of corn silage production for the years 2016, 2017, and 2018 were determined and analyzed. These data were collected through semi-structured interviews with relevant farm representatives and by analyzing farm accounting and production documentation. Data on sown area, total production, and yield of silage maize in Bosnia and Herzegovina for the period 2011–2020 were obtained from publications of the Agency for Statistics of Bosnia and Herzegovina. The data were processed using descriptive and comparative analysis methods, and the results are presented in tabular form.

The volumes and costs of corn silage production were determined for the total cultivated area and per hectare, along with the production value and indicators of financial performance and cost-effectiveness. The following economic indicators were used to evaluate production performance.

The calculation of economic indicators was based on standard methodological approaches in agricultural economics and farm management analysis, commonly applied in cost and production analysis (Dillon & Hardaker, 1993; Veljković et al., 2018). These approaches are widely used for evaluating the economic performance of agricultural production systems through the relationship between output and input values.

The cost price (CP), representing costs per unit of output, was calculated as the ratio between total costs and production volume:

CP = Total Costs / Production Volume

The production value (PV), representing the total value of realized production, was calculated as the product of production volume and the product selling price:

PV = Production Volume × Product Selling Price

The financial result (FR), representing the difference between production value and total costs, was calculated as:

FR = Production Value – Total Costs

The production efficiency coefficient (EC), representing the ratio between production value and total costs, was calculated as:

EC = Production Value / Total Costs

These indicators are commonly used in farm economic analysis to assess profitability, efficiency, and sustainability of agricultural production systems (Dillon & Hardaker, 1993).

All monetary values in this study are expressed in BAM (Bosnian Convertible Mark, the official currency of Bosnia and Herzegovina).

Results and discussion

The results and discussion section presents general trends in silage maize production in Bosnia and Herzegovina, as well as a detailed analysis of production and economic indicators for two farms.

The areas sown with silage maize, total production, and silage maize yield per hectare in Bosnia and Herzegovina for the period 2011–2020 are presented in Table 1.

Table 1: Areas sown with silage maize, total production, and silage maize yield per hectare in Bosnia and Herzegovina for the period 2011–2020

Year	Sown area (ha)	Rate of change (%)	Total production (t)	Rate of change (%)	Production per ha (t)	Rate of change (%)
2011	25 050		438 816		17.52	
2012	25 635	2.3	379 373	-13.5	14.80	-15.5
2013	27 018	5.4	475 788	25.4	17.61	19.0
2014	28 934	7.1	580 196	21.9	20.05	13.9
2015	31 887	10.2	532 614	-8.2	16.70	-16.7
2016	32 777	2.8	668 667	25.5	20.40	22.2
2017	33 713	2.9	445 618	-33.4	13.22	-35.2
2018	32 525	-3.5	710 750	59.5	21.85	65.3
2019	34 078	4.8	672 103	-5.4	19.72	-9.7
2020	35 000	2.7	781 100	16.2	22.32	13.2
Average	30 662		568 503		18.42	

Table 1 shows that the areas sown with silage maize in Bosnia and Herzegovina increased over the observed period, except in 2018, when a decrease of 3.5% was recorded compared to the previous year. The smallest increase in sown area was recorded in 2012 (2.3%), and the largest in 2015 (10.2%). The largest sown area was recorded in the last observed year (2020), and the smallest in the 2011. The sown area in 2020 was 39.7% higher compared to 2011. The total production of silage maize in Bosnia and Herzegovina fluctuated over the years, with increases ranging from 16.2% in 2020 to a maximum of 59% in 2018, and decreases from 33% in 2017 to 5.4% in 2019. The primary cause of the significant reduction in production in 2017 was the drought. The highest total production was achieved in 2020, and the lowest in 2012. Total production in 2020 was 78% higher than in 2011. Production (yield) per hectare also varied, with increases ranging from 13.9% in 2014 to 65.3% in 2018, and decreases from 35.2% in 2017 to 9.7% in 2019. The highest yield per hectare was achieved in 2020, and the lowest in 2017. Yield per hectare in 2020 was 27.4% higher compared to 2011. It is evident that the increase in sown areas has not always resulted

in increased production. The reason for this lies in the low yields on newly sown land, which was mostly leased and had not previously been used for agricultural production.

In corn silage production in Serbia, similar year-to-year variations are present as in Bosnia and Herzegovina, with slightly larger sown areas and overall production volumes, while yields per hectare are approximately the same. The areas sown with silage maize in Serbia in the period 2011–2017 were: 30 157; 47 927; 32 418; 32 143; 34 046; 30 524; and 33 244 hectares, with total production of: 655 618; 736 943; 693 258; 617 447; 589 166; 650 741; and 534 521 tons, and production (yields) per hectare of: 21.1; 14.9; 20.7; 19.2; 17.3; 21.3; and 16.1 tons (Nastić et al., 2018). In corn silage production in Croatia, fluctuations are also present; the sown areas are somewhat larger, but both the total production volumes and yields per hectare are significantly higher compared to Bosnia and Herzegovina. The areas sown with silage maize in Croatia in the period 2010–2018 were: 31 358; 28 762; 29 461; 28 662; 32 198; 29 913; 26 022; 23 951; and 28 481 hectares, with total production of: 932 225; 744 063; 1 034 886; 1 011 502; 1 150 555; 1 259 560; 841 934; 1 003 135; and 996 194 tons, and production (yields) per hectare of: 29.7; 25.9; 35.1; 35.3; 35.7; 42.1; 32.4; 41.9; and 35.1 tons (Croatian Bureau of Statistics, 2021).

Table 2 presents the established production and economic indicators of maize silage production on Farm A and Farm B in the years 2016, 2017, and 2018 for the total production area and per hectare.

Table 2: Production and Economic Indicators of Maize Silage Production on Farm A and Farm B for the Period 2016–2018

Farm	Farm A			Farm B		
Year of Production	2016	2017	2018	2016	2017	2018
Production Area (ha)	400	400	490	170	170	190
Total Production Volume (kg)	11 612 980	10 010 000	7 989 000	5 846 300	5 139 100	6 251 000
Production Volume per ha (kg/ha)	29 032	25 025	16 304	34 390	30 230	32 900
Total Production Costs (BAM)	1 159 252	815 502	705 691	526 762	515 458	586 300
Production Costs per ha (BAM/ha)	2 898	2 039	1 440	3 099	3 032	3 086
Cost Price (BAM/kg)	0.10	0.08	0.09	0.09	0.10	0.09
Selling Price (BAM/kg)	0.14	0.14	0.14	0.15	0.17	0.16
Total Production Value (BAM)	1 625 817	1 401 400	1 118 460	876 900	873 647	1 000 160
Production Value per ha (BAM/ha)	4 065	3 504	2 283	5 158	5 139	5 264
Total Financial Result (BAM)	466 566	585 898	412 769	350 138	358 189	413 860
Financial Result per ha (BAM/ha)	1 166	1 465	842	2 060	2 107	2 178
Production Profitability	1.40	1.72	1.58	1.66	1.69	1.71

Table 2 shows that silage maize production in 2016 and 2017 was conducted on an area of 400 ha on Farm A and 170 ha on Farm B, while in 2018 it increased to 490 ha on Farm A and 190 ha on Farm B. In Bosnia and Herzegovina, there is a trend of increasing areas under silage maize due to growing demand for corn silage in livestock production. The land owned by Farm A is insufficient to meet the rising demand for corn silage; therefore, production is expanded by leasing state-owned land under concession and renting private land. Farm B primarily bases its silage maize production on its own land, and any increase in area is usually the result of reducing land previously used for other forage crops. The production volumes of silage maize on Farm A decreased over the observed three-year period. In 2017, both total production and yield per hectare were 16% lower compared to 2016. In 2018, total production decreased by 31.2%, while yield per hectare declined by 43.8% compared to 2016, and by 20.2% and 34.9% compared to 2017, respectively. On Farm B, both total production and yield per hectare in 2017 were 13.8% lower than in 2016. In 2018, total production increased by 6.5%, while yield per hectare decreased by

4.5% compared to 2016, and increased by 17% and 8.1% compared to 2017, respectively. The decline in production on both farms in 2017 was caused by a drought period, while the reduction in production on Farm A in 2018 was due to the sowing of silage maize on 90 ha of newly cultivated pseudogley soil.

Based on the data in Table 2, Figure 1 presents the costs, values, and financial results of production per hectare on Farm A and Farm B for the period 2016–2018.

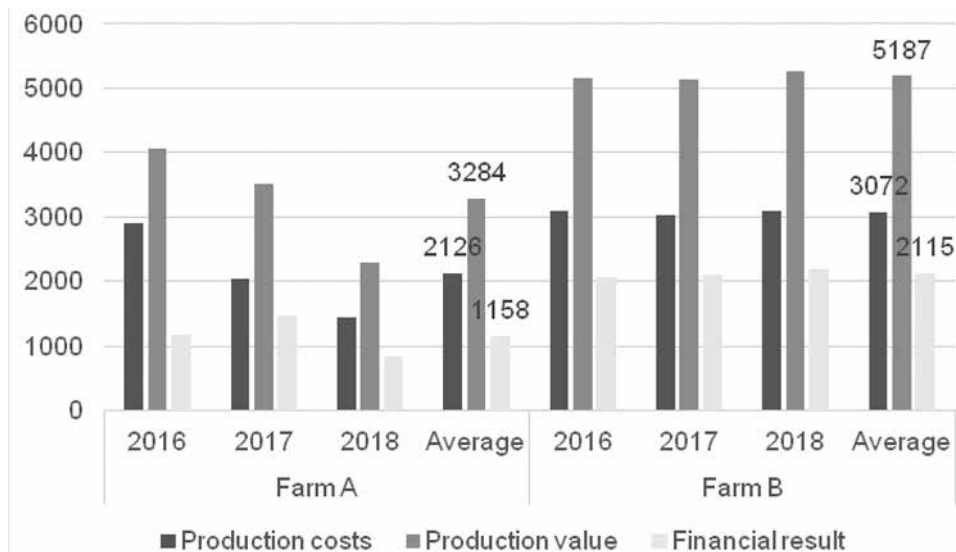


Figure 1. Costs, values, and financial results of production per hectare (BAM/ha) on Farm A and Farm B for the period 2016–2018

Figure 1 shows that the costs and production values on Farm A declined, with the financial result being positive in all three years, highest in 2017 and lowest in 2018. The costs and production values on Farm B varied slightly, with the financial result positive in all three years, highest in 2018 and lowest in 2016. On average, the costs on Farm B were 30.8% higher than on Farm A, the production value was 36.7% higher, and the financial result was 45.3% higher. The selling price of corn silage at Farm A did not change during the observed period, unlike Farm B, where it fluctuated. Higher selling prices at Farm B, along with larger production volumes, resulted in higher production values compared to Farm A. The production costs per kilogram on both farms ranged from 0.08 to 0.10 BAM, with an average of 0.092 BAM. In comparison with the production costs determined in a study conducted on two farms in Serbia (2013–2015), which were 0.019 BAM, 0.023 BAM, and 0.036 BAM on the first farm, and 0.025 BAM, 0.022 BAM, and 0.028 BAM on the second, averaging 0.026 BAM (Veljković et al., 2018), the production cost in Bosnia and Herzegovina is over 70% higher, indicating high production expenses and the necessity of managing them. According to the same study, the unofficial market price of silage per kilogram ranged from 0.06 BAM to 0.08 BAM, averaging 0.073 BAM (Veljković et al., 2018), which is about 50% lower compared to Bosnia and Herzegovina, where the price ranged from 0.14 to 0.17 BAM, with an average of 0.15 BAM. At such prices, the economic production of corn silage in Bosnia and Herzegovina is feasible.

Table 3 shows the structure of production costs per hectare for maize silage on Farm A and Farm B for the period 2016–2018.

Table 3. Structure of Production Costs per Hectare (BAM/ha) for Maize Silage on Farm A and Farm B for the Period 2016–2018

Farm	Farm A				Farm B			
	2016	2017	2018	Average	2016	2017	2018	Average
Year of Production	2016	2017	2018	Average	2016	2017	2018	Average
Total Costs	2 898	2 039	1 440	2 126	3 099	3 032	3 086	3 072
Variable Costs	2 685	1 821	1 240	1 915	2 561	2 660	2 703	2 641
Material Costs	1 654	1 117	906	1 226	1 366	1 286	1 201	1 284
Maize Seed	388	270	268	309	225	255	255	245
Mineral Fertilizers	682	522	350	518	515	490	546	517
Plant Protection Agents	394	174	165	244	588	512	368	489
Film, Inoculant, Lime, etc.	190	151	124	155	38	29	33	33
Mechanized Services	847	622	267	578	1 000	1 173	1 232	1 135
Worker Salaries	184	83	67	111	195	201	270	222
Fixed Costs	213	218	200	210	538	372	383	431
Land Rent	150	150	150	150	0	0	0	0
Depreciation	21	23	20	21	34	24	23	27
General Expenses	42	45	30	39	504	348	361	404

Based on the data in Table 3, it can be observed that variable costs (material costs, mechanized services, and labor) account for the largest share of total costs, averaging 90.1% on Farm A and 86% on Farm B. Material costs (seed, fertilizers, plant protection agents, and others) account for 57.7% of total costs on Farm A and 41.8% on Farm B, followed by mechanized services costs at 27.2% on Farm A and 36.9% on Farm B, and labor wages at 5.2% on Farm A and 7.2% on Farm B. Among fixed costs, the largest share of total costs on Farm A is land rent at 7.1%, while on Farm B it is general expenses at 13.2%. Variable costs per hectare ranged from 1 240 BAM to 2 703 BAM, with an average of 2 278 BAM, which, compared to the research results from Serbia, indicates high production costs in Bosnia and Herzegovina. For the two studied farms in Serbia (2013–2015), variable costs per hectare on the first farm were: 1 127 BAM, 1 197 BAM, and 1 086 BAM, and on the second: 1 061 BAM, 0 971 BAM, and 1 103 BAM (Veljković et al., 2018). In corn silage production on farms in the Mačva district (2015–2017), variable costs per hectare amounted to: 1 188 BAM, 1 192 BAM, and 1 006 BAM (Nastić et al., 2018).

Conclusion

Silage maize processed into silage is the most important bulky feed in animal production. In Bosnia and Herzegovina, during the observed period (2011–2020), the production of maize silage saw an increase in sown area (39.7%), total production (78%), and yield per hectare (27.4%). However, the level of production required to meet domestic silage needs has not yet been reached. The area under silage maize in Bosnia and Herzegovina increased during the observed period, with the exception of 2018, and averaged 30 662 ha. Total maize silage production and yields per hectare varied over the years, averaging 568 503 tons and 18.42 tons/ha. The largest sown area was recorded in 2020 (35 000 ha), when the highest total production and yield per hectare were also achieved (781 100 tons and 22.32 tons, respectively). The research results show that maize silage production on both farms during the period 2016–2018 achieved positive financial results, indicating economically viable production. Corn silage production at Farm A took place on an area of 400–490 ha, and at Farm B on 170–190 ha. The production volumes of corn silage at Farm A decreased during the observed period, while Farm B experienced a decline in 2017 followed by

an increase in 2018. The decline in production volume on both farms in 2017 was the result of a drought period, while the decline in production on Farm A in 2018 was due to the sowing of silage maize on 90 ha of newly cultivated pseudogley soil. Production costs and values on Farm A also declined, with the financial result being positive in all three years (indicating economically viable production), highest in 2017 and lowest in 2018. On Farm B, production costs and values varied slightly, and the financial result was positive in all three years, highest in 2018 and lowest in 2016. On average, the costs on Farm B were 30.8% higher than on Farm A, the production value was 36.7% higher, and the financial result was 45.3% higher. These elements clearly demonstrate that corn silage production offers stability to agricultural producers.

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