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ANIMAL PRODUCTION

Technical and economic indicators of milk production systems in the Caiuá sandstone region

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ABSTRACT. The aim of this study was to analyze technical and economic indicators of family milk production systems, with different technology levels, in the Caiuá sandstone area in Northwestern Paraná, Brazil. The analysis period covers the agricultural years 2002/2003 to 2013/2014. The categorization of the milk production systems was based on information from agricultural farms monitored by the Reference Network for Family Agriculture. The cost-benefit analysis method was used for the economic assessment of milk production. Based on the results, three family milk production systems were identified in the region, characterized by the use of low, medium and high intensification technologies for pasture management. The production costs per unit area were found to be higher in the system with high technology and lower in the system with low technology. However, although the total revenue in the production system with a high technological intensification is greater than in the other systems, the capital needed for a technological transition is higher. In all the systems, when the costs were deducted, including the return on family labor, there was a profit, even with the climate and soil constraints inherent in the region.

Keywords: animal production; dairy farming; economic feasibility; production cost.

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Introduction

The production of bovine milk has significant importance for Brazilian agribusiness. According to the Food and Agriculture Organization of the United Nations (FAO, 2018), in 2016, the country was the fourth largest milk producer in the world. That same year, the state of Paraná was the second-largest milk producer in Brazil, contributing approximately 14.1% of the national production, according to Municipal Livestock Production (Produção da Pecuária Municipal – PPM) data, from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística – IBGE). In the state of Paraná, there has been great technological development in milk production (Bazotti, Nazareno, & Sugamosto, 2012; Ferrazza, Lopes, de Moraes, & Pascoti Bruhn, 2015; Parré, Bánkuti, & Zanmaria, 2011). This is associated with organizational technical factors, such as collaboration between teaching, research and extension institutions, in addition to credit associations, the use of specialized labor, the selection of a herd with greater productivity and an active cooperative structure (Passetti, Eiras, Gomes, Santos, & Prado, 2016). However, there is a great heterogeneity between the producing regions (Capucho & Parré, 2012; Telles, Bacchi, & Shimizu, 2017) and the respective milk producers in Paraná (Lange et al., 2016; Neumann et al., 2016; Passetti et al., 2016). This difference is primarily characterized by the adoption of production techniques, feed supplementation for the dairy herd and genetic enhancements. Furthermore, dairy farming in Paraná is mainly undertaken on family farms, based in small agricultural establishments.

The Northwest Paraná mesoregion has a number of limitations regarding productivity gains in agricultural activities, associated with its climate and soil conditions, primarily because of the soils derived from Caiuá sandstone, considered fragile, with a low natural fertility (Fidalski, Tormena, Alves, & Auler, 2013). The presence of climate and soil characteristics unfavorable to dairy farming activities in the region, particularly with regard to the production of forage species, leads to a large increase in production costs during the winter period, mainly related to feeding the herd. Despite these constraints, the Northwest

Paraná mesoregion has a relative importance in dairy farming; according to the IBGE's PPM data, in 2016, it produced 401 million liters of milk (approximately 8.5% of the production in Paraná), ranking fifth in the state. Between 2002 and 2013, dairy production grew by almost 39%, accompanied by a 40% increase in productivity. It has approximately 23% of the effective cattle herd and 26% of the land used for pasture in the state, and approximately 78% of the establishments are family farms (Bazotti et al., 2012). According to Bánkuti, Caldas, Bánkuti, and Granco (2017) and Telles et al. (2017), this region of Paraná specializes in dairy farming.

However, there is a paucity of studies concerning the Caiuá sandstone area in the Northwest Paraná mesoregion, particularly regarding dairy farming, and it is very important to characterize the technological level of the region's producers. According to Lopes Junior et al. (2012), there is no standard for production; the establishments range from subsistence farms to highly skilled producers with high productivity, and it is thus important to investigate the different production systems. Furthermore, there are problems with modernizing a traditional sector such as dairy farming in Paraná: it is difficult to spread and adopt process and product technologies to increase production and productivity, since technological transformations in agriculture collide with the farmer's level of knowledge, their socioeconomic situation and the presence or absence of skilled and sustained multidisciplinary technical assistance.

It is thus understood that identification of the production systems actually used by milk producers in the Caiuá sandstone area, in the Northwest Paraná mesoregion, is important for supporting agricultural research and rural extension institutions in the creation and transfer of technologies compatible with the reality of producers in that area.

This study was realized to identify the different milk production systems in the Caiuá sandstone area in Northwestern Paraná according to their technological level and analyze their technical and economic indicators.

Material and methods

The study area comprises the Caiuá sandstone region, which in Paraná occupies a large part of the Northwest mesoregion and some municipalities in the West and North mesoregions (Figure 1). The region has a mesothermic humid subtropical climate, denominated Cfa by Köppen climate classification (Köppen & Geiger, 1928), characterized by hot summers, with infrequent frosts, no dry season and no water deficit. The Caiuá sandstone area is approximately 32,000 km², i.e., approximately 16% of the area of the state of Paraná.

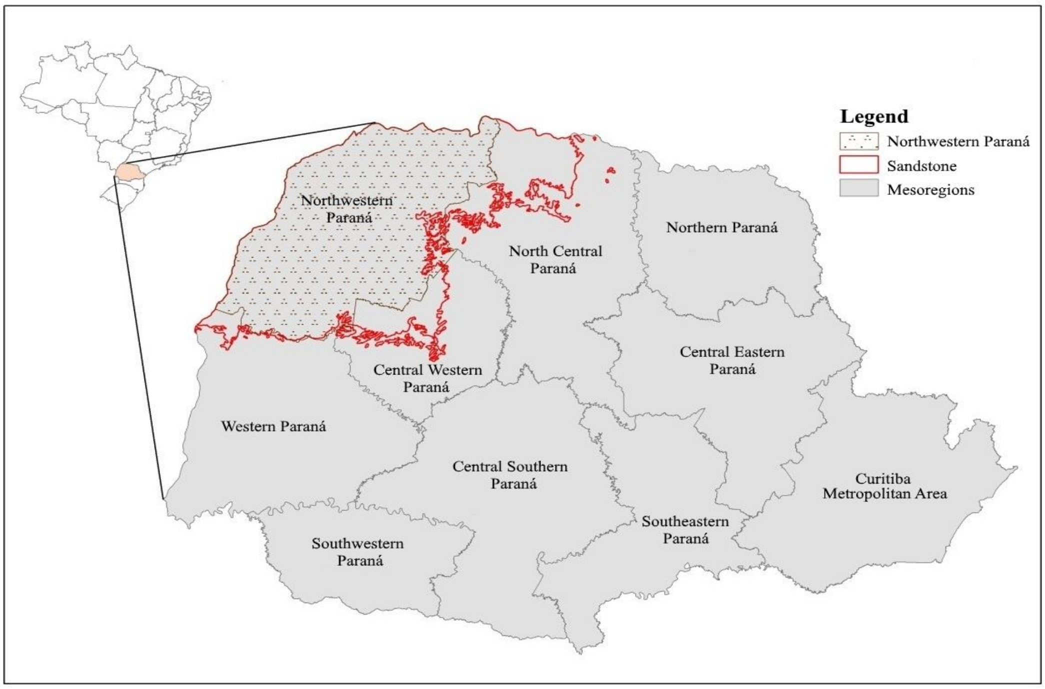

Figure 1. Area covered by the study and by Caiuá sandstone in Northwestern Paraná.

After identifying, characterizing, classifying, and defining the types of agricultural establishments prevalent in each municipality/region of the state of Paraná, based on the 1995/96 Agriculture Census by Doreto, Laurenti & Del Grossi (2001), the Reference Network for Family Agriculture (*Redes de Referência para Agricultura Familiar – REDES*)[1] selected and began to monitor 38 family farms[2], with homogeneous characteristics in terms of milk production system (as described in Table 1), representative of the Caiuá sandstone area in the Northwest Paraná mesoregion. The farms differ according to the degree of intensification of pasture management. The REDES data are the foundation of this study.

After monitoring and analyzing the family farming establishments dedicated to milk production in the region, technical and animal indicators of milk production were obtained. Then, based on the categorization and technologies recommended by the IAPAR, three milk production systems were defined, classified according to pasture management – specifically, low, medium and high technological standards – whose characteristics are described in Table 2.

The analyses of the costs and profitability of milk production were based on the methodology of the Agriculture Federation of Parana State (Federação da Agricultura do Estado do Paraná [FAEP], 2005). The fixed and variable costs of production and the most commonly used dairy farming inputs were estimated. The prices paid and received by milk producers were obtained from the Department of Rural Economy (Departamento de Economia Rural – DERAL), of the Paraná State Department of Agriculture and Supply (Secretaria da Agricultura e Abastecimento do Paraná – SEAB-PR). The analysis period covered the harvest years 2002/2003 to 2013/2014.

Table 1. Common characteristics of milk production systems according to the technological standard.

I	Race	Dairy herd composed mostly of crossbred cows, predominantly 7/8 Dutch blood
II	Useful area	11 ha of useful surface area for animal production
III	Average productivity	15 L cow^{-1} day^{-1}
IV	Pasture system	Rotational stocking, with perennial tropical pasture (PTP) during the summer
V	Feed base	
	Summer	PTP, energy or energy-protein supplementation, according to the production and lactation curve
	Winter	Sugar cane, corrected with urea and ammonium sulfate, with energy-protein supplementation

Table 2. Specific characteristics of each milk production system according to the technological standard.

		Low	Medium	High
I	Pasture management	100 kg of N ha^{-1} $year^{-1}$	200 kg of N ha^{-1} $year^{-1}$	300 kg of N ha^{-1} $year^{-1}$
II	Area with PTP	9.6 ha	8.4 ha	8.2 ha
III	Sugarcane area	1.4 ha	2.6 ha	2.8 ha
IV	Herd composition			
	Cows	20	38	45
	Heifers	6	12	14
	Calves	7	14	16
V	Stocking rate[1]	3 to 4 AU ha^{-1}	6 to 7 AU ha^{-1}	8 to 9 AU ha^{-1}
VI	Average milk production	7.466 L ha^{-1} $year^{-1}$	14.434 L ha^{-1} $year^{-1}$	16.923 L ha^{-1} $year^{-1}$
VII	Labor	1.5 H Eq.	2 H Eq.	2 H Eq.
VIII	PTP productivity	Low	Medium	High
IX	Forage	Giant star, Tanzania and Mombaça	Napier grass, elephant grass, giant star, Tanzania, Mombaça and Tifton-85	Napier grass, elephant grass, giant star, Tanzania, Mombaça and Tifton-85

Notes. [1]Stocking rate of pastures in the rainy season. PTP: perennial tropical pasture. N: nitrogen. AU: animal unit. H Eq.: human equivalent.

The economic indicators analyzed in this study were the following: revenue from milk, revenue from sales of waste and scrap, total operating cost (TOC), actual operating cost (AOC), depreciation, total

[1] The Agricultural Research Institute of Paraná State (Instituto Agronômico do Paraná - IAPAR), in partnership with the Paraná. The Company for Technical Assistance and Rural Extension (Empresa Paranaense de Assistência Técnica e Extensão Rural – EMATER/PR) created the REDES project with the primary objective of assisting rural producers in all regions of the state of Paraná. In the Northwest Paraná mesoregion, mainly in the Caiuá sandstone area, REDES has been operating since 1998, primarily focusing on the development of dairy farming technologies adapted to the region's limited climate and soil conditions.

[2] REDES uses a research methodology adapted to rural extension, supported in farms analyzed and monitored under the systemic approach, which includes analyses of natural resources, plant and animal production, human resources and socioeconomic aspects of family farming establishments (Miranda, Carneiro, Soares Júnior, & Fuentes-Llanillo, 2009). In its different stages, the implementation of REDES involves conducting a preliminary study to characterize the region and classify the farmers, using information from agricultural censuses, which assists in the selection of the production systems to be studied. Once the agricultural establishments have been selected, their productive system is monitored and a diagnosis is made, in order to understand the operation of that system, its bottlenecks and potential, in addition to the farmer's goals, information that will in turn support the stages of planning and interventions on the farm. Based on the monitoring of the farms and the interventions performed in order to improve its production systems—which is done based on the study results—technical and economic references are obtained, which are also useful for other farmers with similar characteristics.

cost (TC), variable cost (VC), fixed cost (FC), gross margin (GM) and income from agricultural operations (IAO). Revenue from milk was calculated based on the amount of milk that each intensified system produced, multiplied by its price in that same period. TC was calculated based on the sum of the VC and FC. VC was composed of the sum of the items (i) fertilization, (ii) energy/protein supplementation, (iii) mineralization, (iv) health, (v) breeding and (vi) return on working capital, not considering taxes and fees. FC was the sum of expenditures on (i) animals, (ii) the site's physical structure, (iii) miscellaneous equipment, (iv) planting of sugarcane and pasture, including soil preparation, and (v) the opportunity cost, composed of return on land, capital invested and labor. TOC was calculated based on the sum of AOC and depreciation. AOC was obtained based on the sum of VC and taxes and fees, less return on working capital. GM corresponds to revenue from sales of milk, waste and scrap, less AOC. IAO is composed of revenue from sales of milk, waste and scrap, less TOC. Economic profit was calculated by subtracting TC from the revenues.

All economic indicators were adjusted by the Extended Consumer Price Index (Índice de Preço ao Consumidor Amplo – IPC-A), the official inflation index in Brazil, to December 2017 values and converted into US dollars.

Results and discussion

Table 3 presents the results of analyzing the profitability of dairy farming in production systems with low, medium and high intensities of pasture management between the years 2002/03 and 2013/14.

The average total revenue of the period in production systems with low, medium and high technological levels was US$ 28,853.27, US$ 56,019.48 and US$ 65,601.88, respectively. For the three systems evaluated, approximately 87% of the total revenue, on average, came from the sale of milk, irrespective of the production system. In the system with a medium technological level, there was an increase in total revenue of 94.42%, compared to the low technological level. Between the systems with medium and high levels, the difference in earnings was 17.11%; between the systems with low and high levels, this difference was 127.36%. Alvim and Botrel (2001) obtained similar results when they found that higher revenues were obtained in systems with a greater intensification of pasture management, although they showed that efficiency decreases with increased dosage of N. In this period, the total revenue of the three technological levels grew at an annual rate of 4.5% per year. This rate remains the same in the three systems studied, as, regardless of the technological level adopted, the herd's productivity is the same; the difference between them is the number of animals. The productivity per area was thus higher in systems with higher technological levels due to the higher concentration of lactating cows per ha.

Figure 2 presents the price history per liter of milk from harvest years 2002/03 to 2013/14. The average real price per liter of milk received by the producers in the period was US$ 0.31. Regarding the price paid to the producer per liter of milk, there were sharp declines in the agricultural years 2005/06 and 2008/09, which may have compromised the producer's revenue. These results demonstrate that in addition to climate and soil constraints, it is necessary to address market seasonality, which compromises the activity's sustainability.

Table 4 presents the costs of producing one liter of milk, in accordance with the technological level adopted, in the Caiuá sandstone region in Northwestern Paraná between the agricultural years 2002/2003 and 2013/2014. As a rule, the system with a low technological level presented higher costs, mainly due to the economies of scale and scope of the other systems.

The variable cost accounted for 69.08, 75.70 and 77.92% of the total cost, in systems with low, medium and high technological levels, respectively, figures close to those found by Lopes et al. (2005) and Lopes et al. (2009) for the municipality of Lavras (MG). The lowest variable cost per liter of milk was found in the system with a medium technological level, at the cost of US$ 0.29. This value was 7.16% lower than that of the low level and 1.15% lower than that of the high level. In an economic feasibility study of different supplementation levels, Silva et al. (2008) obtained similar costs, ranging from US$ 0.27 to US$ 0.32 for the municipality of Campos Gerais (PR).

Table 3. Economic indicators of dairy farming in family production systems in the Caiuá sandstone region in Northwestern Paraná between the agricultural years 2002/03 and 2013/14. in US$.

	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	Average
Low intensification in pasture management													
Total revenue	24.165	25.523	26.615	21.983	24.780	30.757	27.803	29.849	31.687	32.780	33.425	36.872	28.853
Milk	21.702	22.899	24.088	19.495	22.327	27.596	23.872	25.930	27.250	28.150	28.384	31.221	25.243
Waste/scraps	2.464	2.625	2.527	2.487	2.452	3.161	3.930	3.918	4.436	4.631	5.041	5.651	3.610
TOC	26.898	27.920	26.808	23.679	24.284	27.493	28.755	25.947	26.627	27.635	29.573	29.402	27.085
AOC	24.717	25.740	24.627	21.498	22.089	25.298	26.558	23.700	24.387	25.396	27.333	27.162	24.875
Depreciation	2.181	2.181	2.181	2.181	2.195	2.195	2.197	2.247	2.239	2.239	2.239	2.239	2.210
Total cost	36.462	37.030	35.906	32.752	33.295	36.984	38.932	36.173	36.897	38.164	40.582	40.871	37.004
Fixed costs	10.958	10.476	10.572	10.615	10.608	11.038	11.551	11.878	11.911	12.133	12.507	13.056	11.442
Return on land	987	726	957	833	725	742	890	977	975	1.109	1.337	1.734	999
Ret. on cap. invested	4.508	4.330	4.049	3.819	3.601	3.830	3.923	3.835	3.833	3.586	3.549	3.646	3.876
Taxes (ITR)	10	7	10	8	7	7	9	10	10	11	13	17	10
Depreciation	2.181	2.181	2.181	2.181	2.195	2.195	2.197	2.247	2.239	2.239	2.239	2.239	2.210
Return on labor	3.272	3.232	3.376	3.773	4.080	4.265	4.532	4.809	4.854	5.188	5.368	5.419	4.347
Variable cost	25.504	26.554	25.334	22.137	22.687	25.946	27.381	24.294	24.986	26.031	28.075	27.814	25.562
AOC (no taxes)	24.218	25.213	24.073	21.050	21.576	24.663	26.009	23.104	23.760	24.748	26.680	26.444	24.295
Ret. on working cap.	1.286	1.341	1.261	1.087	1.111	1.282	1.372	1.191	1.225	1.282	1.394	1.370	1.267
Gross margin	-552	-216	1.988	484	2.690	5.459	1.198	6.149	7.300	7.385	6.092	9.710	3.974
IAO	-2.733	-2.397	-193	-1.696	495	3.264	-952	3.902	5.060	5.145	3.852	7.470	1.768
Economic profit	-12.297	-11.507	-9.291	-10.769	-8.515	-6.227	-11.129	-6.324	-5.210	-5.383	-7.157	-3.999	-8.151
Medium intensification in pasture management													
Total revenue	46.884	49.521	51.625	42.666	48.071	59.675	53.963	57.969	61.557	63.684	64.957	71.662	56.020
Milk	41.956	44.271	46.570	37.691	43.166	53.352	46.153	50.132	52.684	54.423	54.875	60.361	48.803
Waste/scraps	4.928	5.250	5.054	4.975	4.904	6.323	7.810	7.837	8.873	9.262	10.082	11.301	7.217
TOC	46.769	48.676	46.275	40.438	41.670	47.713	49.801	44.766	46.080	47.977	51.644	51.379	46.932
AOC	44.540	46.447	44.046	38.209	39.427	45.470	47.556	42.418	43.740	45.636	49.304	49.038	44.653
Depreciation	2.229	2.229	2.229	2.229	2.243	2.243	2.245	2.348	2.340	2.340	2.340	2.340	2.280
Total cost	59.806	61.220	58.607	52.737	53.865	60.817	63.999	58.937	60.406	62.596	66.985	67.325	60.608
Fixed costs	13.844	13.299	13.303	13.386	13.372	14.193	14.971	15.465	15.604	15.831	16.349	17.120	14.728
Return on land	987	726	957	833	725	742	890	977	975	1.109	1.337	1.734	999
Ret. on cap. invest.	6.256	6.028	5.607	5.284	4.956	5.515	5.785	5.719	5.807	5.454	5.501	5.802	5.643
Taxes (ITR)	10	7	10	8	7	7	9	10	10	11	13	17	10
Depreciation	2.229	2.229	2.229	2.229	2.243	2.243	2.245	2.348	2.340	2.340	2.340	2.340	2.280
Return on labor	4.363	4.309	4.501	5.031	5.440	5.686	6.042	6.412	6.472	6.917	7.157	7.226	5.796
Variable cost	45.962	47.920	45.304	39.351	40.493	46.624	49.027	43.471	44.802	46.765	50.636	50.205	45.880
AOC (no taxes)	43.575	45.429	42.975	37.343	38.434	44.243	46.494	41.265	42.528	44.385	48.042	47.650	43.530
Ret. on working cap.	2.387	2.492	2.329	2.008	2.059	2.381	2.533	2.206	2.274	2.380	2.595	2.555	2.350
Gross margin	2.344	3.074	7.579	4.457	8.644	14.205	6.407	15.551	17.817	18.048	15.653	22.624	11.367
IAO	115	844	5.350	2.228	6.401	11.962	4.162	13.203	15.477	15.708	13.313	20.284	9.087
Economic profit	-12.923	-11.699	-6.983	-10.071	-5.794	-1.142	-10.035	-968	1.151	1.088	-2.028	4.338	-4.589
High intensification in pasture management													
Total revenue	54.909	58.017	60.477	49.963	56.300	69.890	63.186	67.885	72.104	74.553	76.018	83.921	65.602
Milk	49.190	51.904	54.600	44.189	50.609	62.550	54.111	58.775	61.768	63.806	64.336	70.768	57.217
Waste/scraps	5.718	6.113	5.877	5.773	5.692	7.340	9.075	9.109	10.337	10.747	11.682	13.153	8.385
TOC	54.989	57.341	54.623	47.535	48.959	56.114	58.665	52.637	54.204	56.447	60.781	60.451	55.229
AOC	52.745	55.096	52.379	45.291	46.701	53.856	56.405	50.265	51.840	54.083	58.416	58.087	52.930
Depreciation	2.244	2.244	2.244	2.244	2.258	2.258	2.260	2.372	2.364	2.364	2.364	2.364	2.298
Total cost	68.981	70.840	67.828	60.635	61.900	70.108	73.880	67.746	69.507	72.015	77.139	77.465	69.837
Fixed costs	14.523	13.962	13.913	13.960	13.905	14.850	15.696	16.199	16.373	16.559	17.109	17.959	15.417
Return on land	987	726	957	833	725	742	890	977	975	1.109	1.337	1.734	999
Ret. on cap. invest.	6.919	6.676	6.201	5.844	5.474	6.156	6.494	6.429	6.552	6.158	6.237	6.617	6.313
Taxes (ITR)	10	7	10	8	7	7	9	10	10	11	13	17	10
Depreciation	2.244	2.244	2.244	2.244	2.258	2.258	2.260	2.372	2.364	2.364	2.364	2.364	2.298
Return on labor	4.363	4.309	4.501	5.031	5.440	5.686	6.042	6.412	6.472	6.917	7.157	7.226	5.796
Variable cost	54.458	56.877	53.915	46.675	47.995	55.258	58.184	51.547	53.134	55.456	60.030	59.506	54.420
AOC (no taxes)	51.614	53.903	51.123	44.274	45.537	52.417	55.160	48.913	50.419	52.615	56.937	56.460	51.614
Ret. on working cap.	2.845	2.975	2.792	2.400	2.458	2.840	3.024	2.634	2.715	2.840	3.094	3.046	2.805
Gross margin	2.164	2.921	8.097	4.672	9.599	16.034	6.782	17.620	20.264	20.470	17.601	25.833	12.671
IAO	-80	677	5.854	2.428	7.341	13.776	4.521	15.248	17.900	18.106	15.237	23.470	10.373
Economic profit	-14.073	-12.822	-7.352	-10.672	-5.600	-218	-10.693	139	2.597	2.538	-1.121	6.456	-4.235

Note: Actual operating cost (AOC). Total operating cost (TOC). Income from Agricultural Operations (IAO).

In the fixed cost, there was an increase of 28.72% between the systems low and medium technological levels, whereas there was an increase of 4.68% between the systems with medium and high levels, and an increase of 34.74% between the systems with low and high levels. The difference between the systems with medium and high levels was lower, as the increase in the number of lactating cows (38 compared to 45) is smaller than that between the systems with low and medium technological levels (20 compared to 38). Furthermore, most of the infrastructure investments made in the system with the lowest intensification are the same, thus gaining economies of scale in production. Although the system with a low technological level exhibits the lowest fixed cost, i.e., US$ 11,442.21, the fixed costs were more diluted in the unit cost per liter of milk in the systems with a medium and high level, US$ 0.09 and US$ 0.08, respectively. Regarding the actual operating cost, the highest cost per liter of milk was identified in the system with a low technological level: an average of US$ 0.30. Knowing that the producer is able to achieve economies of scale in the systems with medium or high technological levels, this figure was reduced an average of 7.15% in the medium level and 6.13% in the high level.

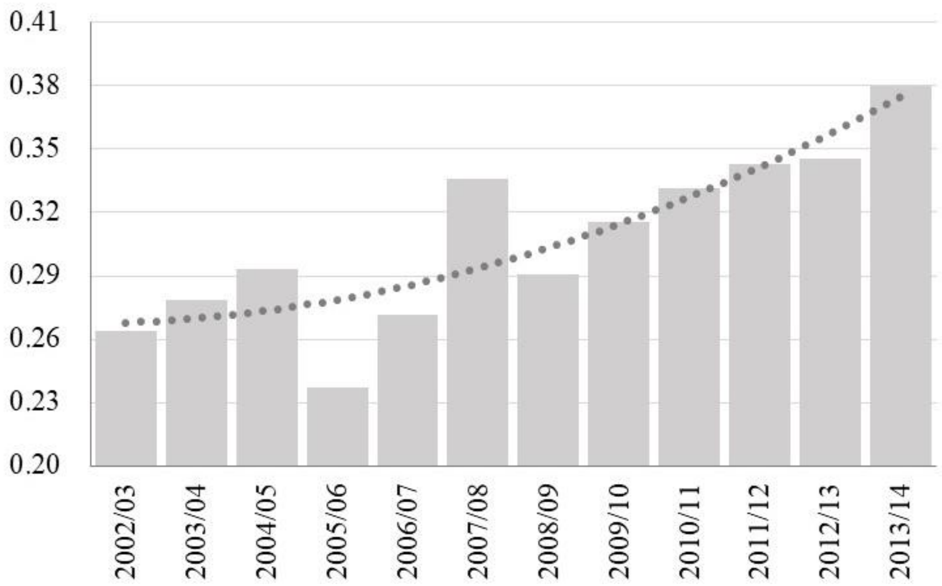

Figure 2. Price per liter of milk from harvest years 2002/03 to 2013/14, US\$ L^{-1}. Note: the values were adjusted to December 2017 values using the IPC-A.

Table 4. Average costs of milk production per liter in the Caiuá sandstone region in Northwestern Paraná between the agricultural years 2002/2003 and 2013/2014, in US$.

	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	Average
Low intensification in pasture management													
Total operating cost	0.33	0.34	0.32	0.29	0.30	0.34	0.35	0.32	0.32	0.34	0.36	0.36	0.33
Actual operating cost	0.30	0.31	0.30	0.26	0.27	0.31	0.32	0.29	0.30	0.31	0.33	0.33	0.30
Total cost	0.44	0.45	0.44	0.40	0.41	0.45	0.47	0.44	0.45	0.46	0.49	0.50	0.45
Variable costs	0.31	0.32	0.31	0.27	0.28	0.32	0.33	0.30	0.30	0.32	0.34	0.34	0.31
Fixed costs	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.14
Medium intensification in pasture management													
Total operating cost	0.30	0.31	0.29	0.25	0.26	0.30	0.31	0.28	0.29	0.30	0.32	0.32	0.29
Actual operating cost	0.28	0.29	0.28	0.24	0.25	0.29	0.30	0.27	0.28	0.29	0.31	0.31	0.28
Total cost	0.38	0.39	0.37	0.33	0.34	0.38	0.40	0.37	0.38	0.39	0.42	0.42	0.38
Variable costs	0.29	0.30	0.28	0.25	0.25	0.30	0.31	0.27	0.28	0.30	0.32	0.32	0.29
Fixed costs	0.09	0.08	0.08	0.08	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.09
High intensification in pasture management													
Total operating cost	0.30	0.31	0.30	0.25	0.26	0.30	0.31	0.28	0.29	0.30	0.32	0.32	0.30
Actual operating cost	0.28	0.30	0.28	0.24	0.25	0.29	0.30	0.27	0.28	0.29	0.31	0.31	0.28
Total cost	0.37	0.38	0.37	0.32	0.33	0.38	0.40	0.37	0.37	0.39	0.41	0.42	0.38
Variable costs	0.29	0.31	0.29	0.25	0.26	0.30	0.31	0.28	0.28	0.30	0.32	0.32	0.29
Fixed costs	0.08	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.08

Regarding the analysis of total operating cost, where the depreciation of machinery, equipment and improvements was also considered, the costs sustained in the period increased by an average of 8.88% for the low level, 5.11% for the medium level and 4.43% for the high technological level. In the studies of Simões, Silva, Oliveira, Cristaldo, and Brito (2009), depreciation was responsible for 13.16% of direct costs in the system with intensive milk production. In Lopes, Santos, Resende, Carvalho, and Cardoso (2011), the depreciation of assets ranged from 3.8% to 19.4% of the total operating cost, and the lower percentage was a reflection of the farm's lack of infrastructure, which may have led to lower milk production. These results denote a certain breadth and heterogeneity of dairy systems, especially in relation to the use of the farms' physical structure.

The total operating cost per liter/milk in the systems with low, medium and high technological levels was US$ 0.33, US$ 0.30 and US$ 0.30, respectively. These values were close to those found by Silva et al. (2008). When the total operating cost was subtracted from the gross revenue from milk, no positive result was obtained for the system with a low technological level. It is thus essential that additional revenue from the sale of waste and scrap be generated, in order to begin operating with a positive income from agricultural operations.

Table 5 presents the items that constitute the actual operating cost and its percentage shares for the three production systems between the agricultural years 2002/03 and 2013/14. The components that have the greatest impact on the actual operating cost are those related to animal feed.

Across the three production systems, the item with the greatest weight in the actual operating cost was energy and protein supplementation, representing an average of 64.02%. In the studies of Segala and Silva (2007), a similar result was found for the municipality of Irani (SC), with feed representing 58.7% of the total, especially during periods of drought. The second-most-represented item in the costs was the fertilization of sugarcane, with an average of 10.2%. The third-largest expenditure was animal health, corresponding to 8.5% of the actual operating cost, a figure approximately 3% greater than that found by Lopes et al. (2011) and Lopes and Santos (2012).

Regarding expenditures on animal breeding, rural electricity, conservation and repairs and technical assistance, the systems presented expenditures on these components that were inversely proportional to the technological level adopted, i.e., as the intensification of pasture management increased, their share of the AOC decreased.

Regarding gross margin, considering the average values of the period evaluated, the system with a low technological level presented the lowest gross margin (US$ 3,973.82). In the system with a medium level, the gross margin was US$ 11,366.95; compared to that of the low level, this value represents an increase of 186.0%. In the system with a high technological level, the gross margin was US$ 12,671.51; compared to that of the medium level, there is a gain of 11.5%, and compared to the low level, this gain is 218.9%. The best gross margin per liter of milk was obtained in the systems with a medium and high technological level, with an average value of US$ 0.07, followed by the low level, with US$ 0.05. As in Lopes et al. (2011), the gross margin economic indicator showed that dairy farming in systems with medium or high intensities of pasture management is sustainable even in the short and medium term.

Table 5. Components of the actual operating cost, of dairy farming in family production systems in the Caiuá sandstone region in Northwestern Paraná between the agricultural years 2002/2003 and 2013/2014.

Item	Intensification in pasture management		
	Low	Medium	High
Energy and protein supplementation	61.27%	65.61%	65.17%
Fertilization of pasture and sugarcane	10.41%	9.42%	10.81%
Health	8.07%	8.68%	8.61%
Transportation of milk	4.05%	4.37%	4.32%
Mineralization	2.23%	2.38%	2.37%
Breeding	2.87%	1.60%	1.35%
Rural electricity	3.48%	1.94%	1.64%
Technical assistance	3.98%	2.76%	2.63%
Taxes and fees	2.33%	2.51%	2.48%
Conservation and repairs	1.30%	0.72%	0.61%

Regarding income from agricultural operations, where expenditures on depreciation are also considered, the system with a medium technological level was the only one that did not present negative values over the period. However, considering the average values of the period evaluated, the system with a high technological level exhibited the best income from agricultural operations (US$ 10,373), with a gain of 586.7% compared to the low level and 114.2% compared to the medium level. The values for the average income from agricultural operations per liter of milk obtained in the systems with low, medium and high technological levels were US$ 0.02, US$ 0.06 and US$ 0.06, respectively. Thus, increasing the technological level can improve income, provided that the marginal cost of the extra milk produced is lower than the price of the milk received (Macdonald et al., 2017).

From an economic point of view, when considering the opportunity cost, i.e., costs of return on land, capital invested, working capital and labor, the system with a low technological level was not economically feasible, even in years where the price of milk was above the average value. The system with a medium level was economically feasible in three years, whereas the system with a high technological level was feasible in four agricultural years, years in which the price paid per liter of milk was higher than US$ 0.33—with the exception of the agricultural years 2007/08 and 2012/13, when the market presented a generalized increase in the prices of this activity's inputs, pressured by the rise of the dollar.

Based on the analysis of economic feasibility, milk production systems confront barriers to being considered economically feasible. Both the price per liter of milk received by the producer and the prices paid for the agricultural inputs influence the final results. However, more important is the fact that in short, even in the Caiuá sandstone area, a region with climate and soil constraints, without considering economic profit, dairy farming can be profitable for family milk producers.

Conclusion

In dairy farming systems operating in the Caiuá sandstone area, in the Northwest Paraná mesoregion, between 2002/03 and 2013/14, without considering economic profit, these systems presented the possibility of profitability for the producers, depending primarily on the price per liter of milk and the inputs inherent in the production. However, when considering economic profit, the systems were not economically feasible.

The technological level influenced the production costs and profitability of the production systems, with a greater intensification of pasture management being correlated with better results for the indicators analyzed.

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