Beef production network in the ecotone of Pantanal-Cerrado biomes

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Abstract

This study analyzes the beef production network (nodes connected by links) in the Pantanal-Cerrado ecotone using cattle transit data (GTA) from 2022–2024, focusing on Guia Lopes da Laguna (MS) as a central hub. Network analysis (Gephi software) revealed a clear directional flow across production phases (reproduction→fattening→slaughter), with Guia Lopes da Laguna serving as the primary convergence point. The expanding network (59 nodes, 95 links by 2024) demonstrates interstate connectivity (GO, MG, MT, SP, RO, BA), highlighting regional integration. Despite data limitations (a single municipality over only two years), key findings include the hub's dominance in slaughter processes and emerging circularity in supply chains. These insights support traceability (e.g., AgriTrace) assisted by Embrapa's BovTrace API, and sustainable beef policies (e.g., PROAPE) by targeting critical production chain issues towards sustainable and certified, high-quality beef production.

Keywords: AgriTrace, Certification; GTA; PROAPE; Traceability.

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1. Introduction

The beef production network in the ecotone of Pantanal and Cerrado biomes represents a critical intersection of economic activity, environmental sustainability, and food security. This study examines the cattle exchange patterns centered around Guia Lopes da Laguna in Mato Grosso do Sul (MS), a major hub in Brazil's beef production network due to the existence of a 30 years old private slaughterhouse named “Global”. The research addresses a significant gap in understanding how cattle movement through different production phases (reproduction, fattening, slaughter) creates complex inter-municipal networks that impact both regional economies and environmental sustainability. The relevance of this study stems from three key factors: 1) Brazil's position as the world's largest beef exporter (Associação Brasileira das Indústrias Exportadoras de Carnes, 2024); 2) increasing global demand for traceable and sustainable beef products (Papa et al., 2024); and 3) the ecological sensitivity of the Pantanal-Cerrado transition zone (Guerra et al., 2025). The Animal Transit Document (GTA) (Brasil, 2025) system provides a unique opportunity to map these networks with precision, offering insights that can inform both commercial strategies and public policies regarding sustainable beef production. Our research specifically investigates: How do the network structures and centrality measures of municipalities in this ecotone region reflect their roles in different phases of beef production; What implications does this have for certification programs like PROAPE (Mato Grosso do Sul, 2025) and sustainable beef initiatives?

2. Methods

The dataset comprises cattle exchanges from 2022 to 2024 of Guia Lopes da Laguna with other municipalities in MS and other states embedded in GTA kindly provided by IAGRO, the Mato Grosso do Sul Agency for Animal and Plant Health Defense. Data has been suitably organized to identify sources and targets in terms of municipalities and their directed links associated with phases of the beef production cycle: reproduction, fattening, slaughter, crowd for auction, and returns from slaughter and auctions. The structured information in datasheets was then digested in Gephi software to calculate weighted degree and betweenness centralities to build a directed network graph. In this case, the nodes were sized according to weighted degree and node font labels according to betweenness centralities.

3. Results and Discussion

The network analysis reveals several important patterns in the beef production system centered around Guia Lopes da Laguna (Figures 1 and 2). The substantial growth in network size from 2022 to 2024 (24 to 59 nodes, 24 to 95 links) indicates increasing connectivity in the regional beef production system, likely due to incentives of PROAPE state policy. The weighted degree and betweenness centrality measures highlight Guia Lopes da Laguna's role as a critical hub, particularly for slaughter processes (represented by red links in Figure 1), as a consequence of the Global company. The data reveals clear directional flows in beef production (reproduction→fattening→slaughter) converging at Guia Lopes da Laguna, while interstate connections demonstrate its regional significance beyond Mato Grosso do Sul, linking multiple states in Brazil's beef production network.

Table 1 presents the number of nodes, links and in- out-degrees for different time spans. The data shows significant network growth in 2024, particularly in fattening (25 nodes) and slaughter-related (22 nodes) connections, suggesting increasing specialization and scale in these phases and positive effects of PROAPE. The increasing "return from slaughter" connections (from 0 in 2022 to 22 in 2024) may indicate growing circularity in the production system, potentially related to the increase in cattle quality demanded by government and consumers of the supply chain.

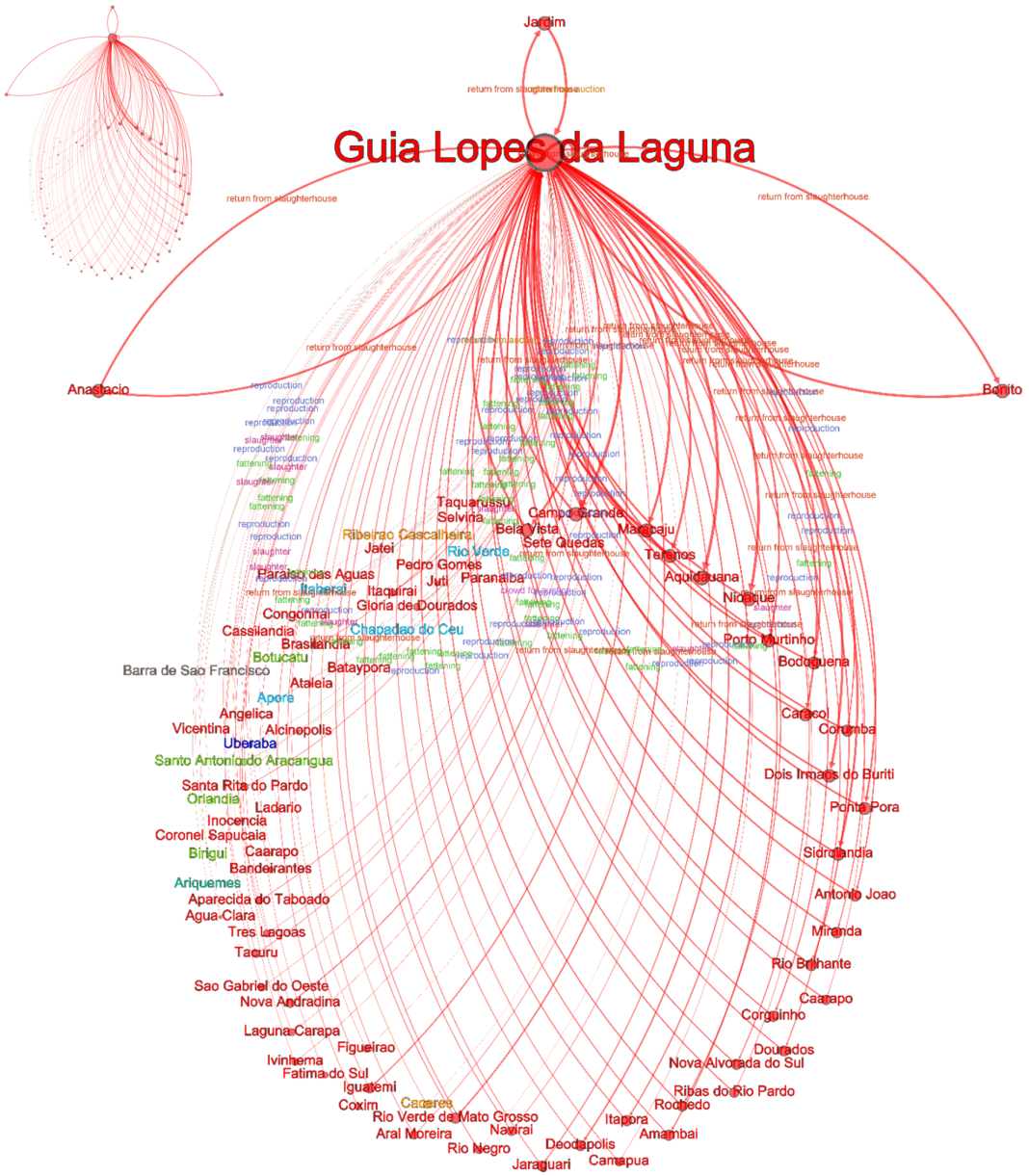

Figure 1. Beef cattle network of municipalities with Guia Lopes da Laguna (MS) as a major hub from GTA data in the period 2022-2024. The inset minor graph depicts only nodes and links. The large graph is the same data with labeled links with different colors representing reproduction (blue), fattening (green), and slaughtering/auctioning processes (red tonnes), and labeled nodes as municipalities in which those in MS are red-colored while remaining municipalities are colored as light blue (GO), dark blue (MG), orange (MT), light green (SP), dark green (RO), and gray (BA).

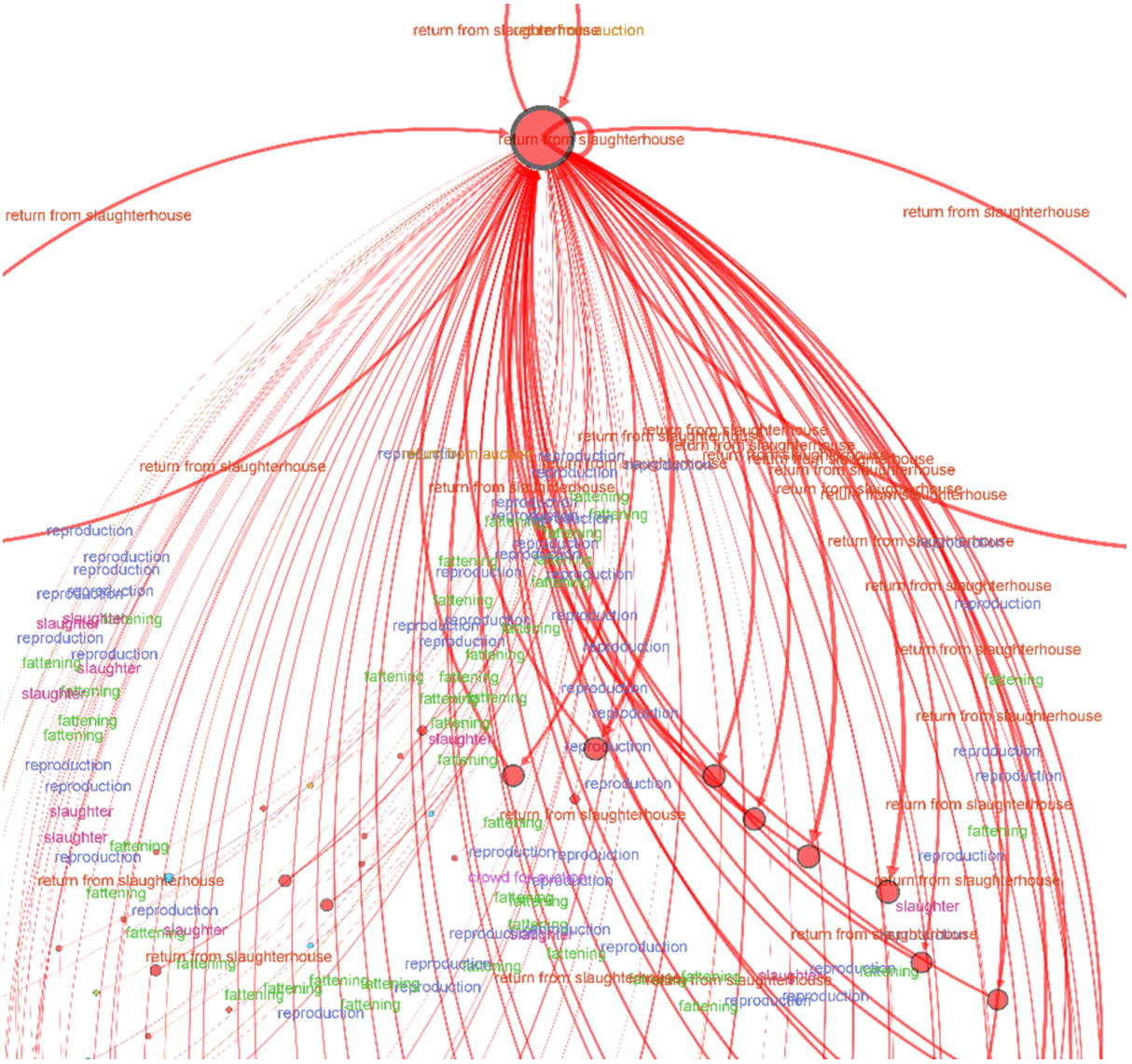

Figure 2. Details of link labels of the graph shown in Figure 1.

The centrality measures suggest that while Guia Lopes da Laguna dominates the network, several other municipalities (particularly in MS) serve as important secondary nodes due to the presence of farms but also slaughterhouses. The National Confederation of Agriculture (CNA) is responsible for maintaining the AgriTrace Platform that gathers official private protocols linked to slaughterhouses, with positive implications for certification and traceability programs. In this sense, Embrapa has delivered the BovTrace

API (application programing interface) in the AgroAPI[136] Platform that enables the records and makes available standardized information on the individual movement of cattle through authorized client systems. These systems can record the movement of animals between producers, as well as between producers and slaughterhouses/markets. The movement can be linked to SISBOV protocol or to private animal production protocols of the CNA.

Table 1. The network properties of beef production associated with Guia Lopes da Laguna.

Number of:	Time in year(s)	Giant network component	Reproduction	Fattening	Slaughter	Return from slaughter	Return from auction	Crowd for auction
Nodes	2022-2024	84	46	40	12	23	3	2
Links	2022-2024	132	49	42	11	27	2	1
Nodes	2022	24	13	11	3	0	0	0
Links	2022	24	12	10	2	0	0	0
In-degree links	2022	6	4	2	2	0	0	0
Out-degree links	2022	18	8	8	0	0	0	0
Nodes	2023	13	6	6	2	2	0	2
links	2023	13	5	5	1	1	0	1
In-degree links	2023	2	2	1	0	0	0	0
Out-degree links	2023	11	3	4	1	1	0	1
Nodes	2024	59	29	25	9	22	3	0
Links	2024	95	32	27	8	26	2	0
In-degree links	2024	2	19	13	6	7	2	0
Out-degree links	2024	93	13	14	2	19	0	0

4. Conclusion

This study provides the first comprehensive network analysis of beef production in the Pantanal-Cerrado ecotone using GTA data, revealing Guia Lopes da Laguna as a dominant hub with extensive connections to municipalities across multiple states. The findings demonstrate how network analysis can identify critical issues for the success of regional training, technology transfer, public policies, traceability and sustainable certification programs in the Brazilian beef production systems.

Acknowledgements

[136] Available at: http://embrapa.br/agroapi.

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