http://dx.doi.org/10.1590/1678-4162-12496

Arq. Bras. Med. Vet. Zootec., v.74, n.2, p.270-280, 2022

Characterization of the cattle movement network in the state of Goiás, Brazil

[*Caracterização da rede de trânsito de bovinos no estado de Goiás, Brasil*]

J. *Azevedo Júnior*[1,2], E.P. *Nascente*[2], R.R. *Nicolino*[3], W.F.P. *Teixeira*[4]*, S.R. *Chagas*[2], V.S. *Jayme*[2], L.M. *Pascoal*[2]

[1]Agência Goiana de Defesa Agropecuária, Goiânia, GO, Brasil
[2]Graduate, Universidade Federal de Goiás, Escola de Veterinária e Zootecnia, Goiânia, GO, Brasil
[3]Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil
[4]Universidade Federal de Goiás, Goiânia, Goiás, GO, Brasil

ABSTRACT

The present study characterized the cattle movement network in the state of Goiás, Brazil, in the period from 2010 to 2016, by identifying the areas of greatest flow and the purposes for which these animals were moved. For this, an analysis of the data referring to 4,697,239 animal transit guides (GTA), specifically for bovines, issued between the years 2010 to 2016 was carried out. Data such as the number of animals transported, origin and destination, as well as purpose of movement (slaughter, finishing, reproduction, post-weaning, auctions, sports, exhibitions, exports, and others) were evaluated. The data were subjected to descriptive analysis, in which the animal movements were divided into quartiles. There was an intense movement of cattle throughout the state, mainly for the purposes of finishing and slaughter. Identifying the areas with the highest flow of animals, such as the northwest and south regions, is an important tool for planning actions and applying preventive measures against the spread of infectious agents through the territory of Goiás.

Keywords: animal movement, epidemiology, infectious diseases, risk areas

RESUMO

No presente estudo, foi caracterizada a rede de trânsito de bovinos no estado de Goiás, Brasil, durante o período de 2010 a 2016, identificando-se as áreas de maior fluxo e as finalidades do trânsito desses animais. Para isso, foi realizada uma análise dos dados referentes a 4.697.239 guias de trânsito animal (GTA), especificamente de bovinos, emitidas entre os anos de 2010 a 2016. Avaliaram-se informações como número de animais transitados, origem e destino, bem como finalidade de movimentação desses animais (abate, engorda, reprodução, recria, leilão, esporte, exposição, exportação, entre outras). Os dados foram submetidos à análise descritiva, optando-se pela divisão da movimentação animal em quartis. Observou-se haver trânsito intenso de bovinos em todo o estado, principalmente com a finalidade de engorda, recria e abate. A identificação das áreas que apresentam maior fluxo de animais, como as regiões noroeste e sul, torna-se uma importante ferramenta no planejamento das ações e na aplicação de medidas preventivas contra a disseminação de agentes infecciosos pelo território goiano.

Palavras-chave: áreas de risco, doenças infecciosas, epidemiologia, movimentação animal

INTRODUCTION

The current computer and technology resources allow the compilation of many pieces of information, providing significant advances in many fields of study (Vespignani, 2009), such as epidemiology. In this respect, the study of the movement dynamics of humans and animals has been applied to analyze individual and population movement systems. This has been especially useful for the understanding of the spread of disease among subpopulations (Rautureau *et al*., 2010), for the elaboration of plans for control and eradication of diseases, and better understanding of the livestock economy of the region.

*Corresponding author: weslenteixeira@hotmail.com
Submitted: July 28, 2021. Accepted: November 25, 2021.

In countries like the United States (Gorsich *et al*., 2016), Uruguay (VanderWaal *et al*., 2016), the Netherlands (Santman-Berends *et al*., 2016) and Spain (Pozo *et al*., 2019), these tools have been used only recently. In Brazil, the movement of cattle has already been characterized in different regions, such as the Northeast (Silva-Júnior *et al*., 2017), the South (Felipe *et al*., 2013 and the North (Aragão *et al*., 2018). The dissemination of important diseases with wide territorial distribution has driven these studies (Amaral *et al*., 2016; Cipullo *et al*., 2016), mainly in states with expressive herds within Brazilian livestock.

Research in this sphere is aimed at collecting and interpreting data on animal movement as well as elucidating the behavior of livestock activity in a given region. This information allows the evaluation of herd size and the identification of origin and destination of the animals, in addition to the purpose for which they are destined in the region (VanderWaal *et al*., 2016; Ferreira *et al*., 2019). In this way, the vulnerable areas and the main risk factors involved in the dissemination of the different infectious and parasitic diseases of cattle can be defined, thereby contributing to and enhancing the performance of animal health surveillance systems (Amaral *et al*., 2016).

In the center-west region of Brazil, the cattle movement network is well described in the *Pantanal* (wetland) area (Araujo *et al*., 2019) and throughout the states of Mato Grosso and Mato Grosso do Sul (Capanema *et al*., 2012). In Goiás, one of the states with the greatest potential in the livestock sector, having produced 22,651,910 head of cattle in 2018 (10.6% of the national herd) (Pesquisa…, 2018), no such detailed characterization has been done thus far.

Having the cattle movement network described for Goiás would help the livestock agencies and institutes to act more precisely to control a disease outbreak, like foot and mouth disease, bovine spongiform encephalopathy or other foreign disease with great importance on cattle; to control and eradicate endemic diseases in some counties, just as rabies (Brazil, 2017) and brucellosis (Rocha *et al*., 2009; Nezu, 2020); and also to have a better understanding of how the livestock economy of the state works, e.g., counties focused on dairy or beef cattle, regions where most of the slaughterhouses are present and the trends of transportation. On this basis, the present study was developed to characterize the cattle movement network in the state of Goiás from 2010 to 2016 by identifying the areas with the highest flow and the purposes for which these animals were moved.

MATERIALS AND METHODS

In this study, data contained in 4,697,239 bovine animal movement licenses (AMP) issued in the state of Goiás between January 2010 and December 2016 were evaluated. It is important to emphasize that this observational period was selected due to the need for state public agencies to assess the rate of movement of animals in the region, a measure proposed by the 2017-2026 Strategic Plan (Brazil, 2019), which aims to withdraw vaccination against foot-and-mouth disease in bovine in the state.

The AMP is an official document regulated by the Ministry of Agriculture, Livestock and Supply that contains information of origin, destination, species, number of animals, age, sex, health conditions, means of transport and the purpose of transport. This information guarantees control of the animal movement and the possibility of conducting epidemiological analyses, considering that all livestock properties in Brazil must be registered with the Official Veterinary Service and their geographical position known.

In addition to the number of AMPs, information on the animals' movement, origin, and destination was evaluated. The purpose of the transport was also investigated and defined as finishing, slaughter, post-weaning, auction, reproduction, exhibitions, sports, exports, stamping out, labor, quarantine, and elite auction. All data were compiled into an Excel spreadsheet that was created using a platform of division by county code of the Brazilian Institute of Geography and Statistics – IBGE (Códigos…, 2020).

To present the spatial distribution of animal movements for the purposes, they were divided into three categories: slaughter, movement between farms (trade activities, except slaughter), agglomeration, and others. For these analyses, Terraview software version 4.2.2 and ArcGis software version 10.3 were used.

Network analysis was carried out with the obtained data to determine the movement patterns of the regions of the state of Goiás: northwest, north, center, south and east. For the analysis of networks in the present study, the counties of origin and destination were used as epidemiological units of interest and represented as "nodes" in the maps, whereas the cattle movement "between nodes" was represented by lines of a network, whose thickness was determined according to the number of animals – thicker lines represented a higher animal flow. The counties were also colored according to a color scale to indicate the dynamic of cattle movement. The color scale had colors blue, green, yellow, orange, and red, in which blue represented the counties with a smaller number of animals sent or received and red represented the counties with higher numbers of animals sent or received. The other colors represented intermediate numbers, from lowest do highest, following the previously presented order.

The data were subjected to descriptive statistical analysis. For this step, the animal movement was segmented into quartiles, namely, 100%, 75%, 50% and 25% of the largest animal movement. These values allowed the identification of the areas with the highest animal flows and the evaluation of the characteristics of cattle producers in the state of Goiás.

RESULTS

During the observational period, 124,951,119 cattle were moved in Goiás (Table 1), distributed through 4,697,239 permits for various purposes, with an average of 26.6 animals per AMP.

Table 1. Number of animals transported for different purposes in the state of Goiás, Brazil, between the years 2010 and 2016

Number of transported animals (Total / %)								
Purpose	2010		2011		2012		2013	
	Total	(%)	Total	(%)	Total	(%)	Total	(%)
Finishing	6,380,441	11.40%	77,127,291	13.70%	7,768,207	13.80%	8,647,271	15.40%
Slaughter	2,986,540	11.90%	3,352,831	13.30%	3,628,743	14.40%	4,390,354	17.40%
Post-weaning	444,106	2.30%	986,786	5.10%	1,757,730	9.20%	2,853,656	14.90%
Auction	1,535,682	11.00%	1,962,552	14.00%	1,903,907	13.70%	1,984,866	14.20%
Reproduction	2,472,548	24.00%	2,871,723	27.90%	1,650,499	16.00%	1,092,864	10.70%
Exhibitions	15,258	15.70%	16,668	17.20%	14,373	14.80%	16,139	16.60%
Sports	7,117	7.70%	12,484	13.60%	11,546	12.60%	15,713	17.10%
Exports	1,022	6.00%	630	3.60%	1,067	6.20%	1,822	10.50%
Stamping out	159	3.00%	236	4.30%	598	11.00%	1,006	18.50%
Labor	108	3.20%	235	7.10%	435	13.10%	339	10.20%
Quarantine	46	1.20%	309	8.20%	17	0.40%	39	1.00%
Elite auction	159	15.60%	187	18.50%	241	23.60%	67	6.50%
Total	13,843,186	11.07%	16,917,370	13.54%	16,737,363	13.40%	19,004,136	15.20%

Number of transported animals (Total / %)								
Purpose	2014		2015		2016		Total period 2010-2016	Growth or decrease 2010-2016*
	Total	(%)	Total	(%)	Total	(%)		
Finishing	8,605,447	15.30%	8,889,848	15.90%	8,086,197	14.50%	56,090,140	21.10%
Slaughter	4,034,447	16.00%	3,531,208	14.00%	3,259,289	13.00%	25,183,412	8.37%
Post-weaning	3,555,932	18.50%	4,611,694	24.00%	4,982,427	26.00%	19,192,331	1121.90%
Auction	2,077,810	14.90%	2,351,790	16.80%	2,155,228	15.40%	13,971,835	28.74%
Reproduction	793,702	7.70%	734,357	7.10%	677,836	6.60%	10,293,529	-364.77%
Exhibitions	12,024	12.40%	12,506	12.90%	10,078	10.40%	97,046	-33.95%
Sports	15,842	17.20%	15,707	17.10%	13,467	14.70%	91,876	47.15%
Exports	2,955	17.10%	4,191	24.30%	5,592	32.30%	17,279	547.16%
Stamping out	1,116	20.60%	884	16.30%	1,426	26.30%	5,425	896.85%
Labor	355	10.70%	876	26.40%	971	29.30%	3,319	899.07%
Quarantine	42	1.10%	119	3.20%	3,196	84.90%	3,768	6947.82%
Elite auction	58	5.70%	165	16.20%	142	13.90%	1,019	-11.98%
Total	19,099,730	15.29%	20,153,345	16.13%	19,195,849	15.37%	124,950,979	-

* Calculated value based on data between the years 2010 and 2016 only.

An increase of 27.88% in the flow of animals was observed between 2010 and 2016, corresponding to 5,352,745 more cattle being moved. Between 2010 and 2016, ten purposes showed growth in number of animals transported, mainly quarantine (6,947.82%),

post-weaning (1,121.9%), stamping out (896.95%) and exports (547.16%). On the other hand, there was a decrease in transport for the purposes of reproduction (364.77%) and exhibitions (-33.95%) (Table 1).

When 100% of all flow of animals in the state were analyzed, 65,095 routes were identified, of which 245 were internal. Within 75% of the total flow, 2,586 routes were found, of which 229 were internal. Nevertheless, movements in some routes were sporadic and with a low flow of animals. Thus, to better identify the areas of greater risk, which are associated with greater movement, we used the results referring to 50% and 25% of the largest flow of animals. For 50% of the flow, 517 routes (44 internal) were identified, with 62,502,794 animals moved; and for 25% of the largest flow, 66 routes (55 internal) were identified, with 31,304,477 animals moved. Based on this characterization, we can infer that the northwest and south regions of the state were considered the major animal receiving or shipping centers that sent or received animals (Fig. 1). In addition, it should be stressed that regardless of the purpose, animal transports occurred mostly within the counties.

Of the 246 counties in the state, 33.7% (83/246) represented three quarters of all cattle movements in the observational period, standing out that only eight of these accounted for 18% of all animals moved. There was dispersion in the animal movements within the state, with 30% of these constituting transport within the county itself and rest inter-county movements. Interstate movements, to a lesser extent, occurred for almost all units of the federation and the Federal District. The state of Santa Catarina was the only one that did not received animals from Goiás.

The main cities of destination and origin of the transported cattle in the state of Goiás and the representation of this transit movement for the main purposes are respectively represented by Table 2 and Fig. 2, 3 and 4. Nova Crixás, São Miguel do Araguaia and Rio Verde showed a higher flow of cattle in the state, both incoming and outgoing, whereas Mineiros, Goiânia and Palmeiras de Goiás received a significant number of cattle. Together with São Luís dos Montes Belos, these counties were the most representative in the movement of animals for the purposes of finishing and post-weaning.

The county of Mozarlândia, located in the northwest region of the state, receives the largest number of cattle for slaughter, followed by Palmeiras and Goiânia, located in the south and center of Goiás, respectively (Table 2). The northwest region, represented by the counties of Nova Crixás and Jussara, is also responsible for the largest number of animals sent for slaughter (Table 2).

Regarding the issuance of movement permits for reproduction, the movement of animals is dispersed when compared with those for other purposes, comprising counties from north to south of the state and even interstate. Meanwhile, considering the other purposes, the flow is mostly concentrated in the central region of the state, with emphasis on the counties of Trindade, Goiânia, Rio Verde and Jataí and interstate movement. In addition, it should be noted that most of the movements occur in neighboring counties, with no significant dispersion of animals in the state.

DISCUSSION

This is the first detailed study of characterization of the cattle movement network in Goiás. The current results highlight the representativeness of the state in this livestock segment, with intense movement in different regions and purposes observed over the studied years. These results are aligned with the fact that Goiás is currently the state with the second largest bovine herd in the country, with approximately 22.6 million head (Pesquisa…, 2018).

Most of the cattle herd is concentrated in the northwest and south regions of the state of Goiás, consisting of approximately 4.9 and 8.1 million animals, respectively. The counties with the highest flow of animals are precisely located in these regions: Nova Crixás, São Miguel do Araguaia, Rio Verde, Jussara, Mineiros and Porangatu, which, together, total more than 2.7 million head (Pesquisa…, 2018). These are noteworthy areas in the beef cattle sector, since most of the animals are transported for the purposes of finishing, post-weaning, or slaughter.

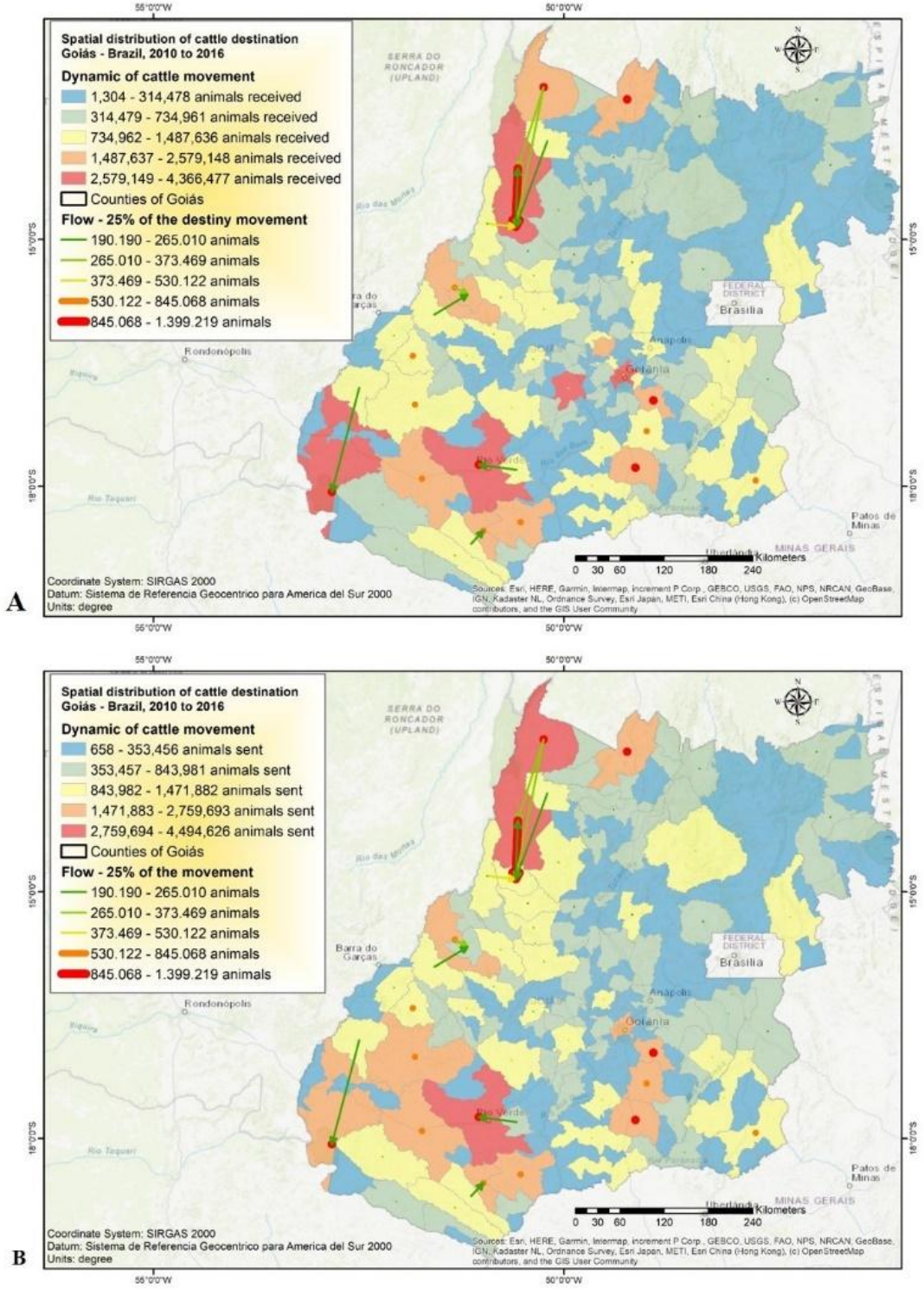

Figure 1. Spatial distribution of cattle movements in the state of Goiás, from 2010 to 2016, indicating the counties of destination (a) and origin (b) of the moved animals. Data referring to 25% of the largest animal flows.

Table 2. Main counties responsible for sending and receiving cattle for the purposes of greatest importance in the movement of animals in Goiás, Brazil.

Purpose	Counties that most send	Number of animals	Counties that most receive	Number of animals
Finishing	São Miguel do Araguaia	2,186,347	Nova Crixás	2,782,516
	Nova Crixás	2,126,652	São Miguel do Araguaia	1,896,597
	Rio Verde	1,666,419	Rio Verde	1,384,533
Slaughter	Nova Crixás	1,651,124	Mozarlândia	3,302,179
	Jussara	680,947	Palmeiras	2,741,592
	Rio Verde	660,536	Goiânia	1,980,279
Post-weaning	São Luís dos Montes Belos	652,575	Bela Vista de Goiás	506,877
	Bela Vista de Goiás	647,877	Nova Crixás	461,538
	Piracanjuba	586,685	Jussara	457,275
Auction	Bela Vista de Goiás	650,039	Goiânia	1,101,548
	Rio Verde	496,540	Rio Verde	877,736
	Piracanjuba	400,136	Bela Vista de Goiás	859,978
Reproduction	Porangatu	597,266	Porangatu	460,327
	Nova Crixás	369,160	Nova Crixás	368,920
	Jussara	203,882	Piranhas	312,807
Other purposes	Trindade	11,986	Goiânia	19,392
	Rio Verde	9,911	Rio Verde	9,260
	Jataí	8,142	Jataí	8,544

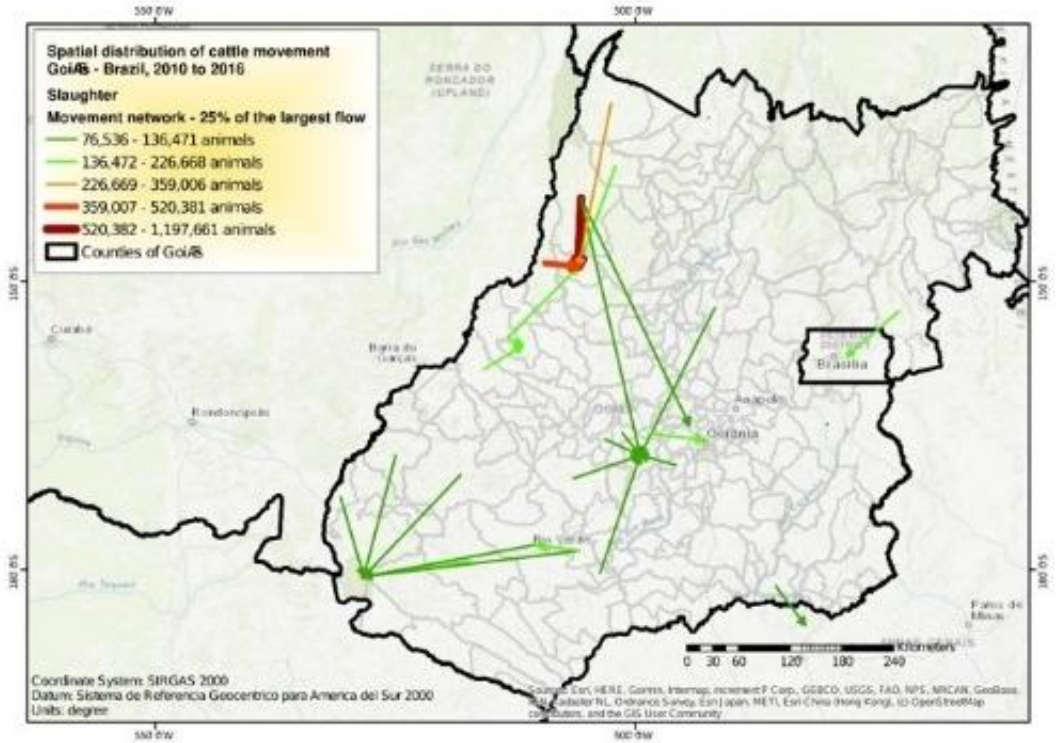

Figure 2. Spatial distribution of cattle movements in Goiás, Brazil (2010-2016) for the purposes of slaughter. Data referring to 25% of the largest animal flows.

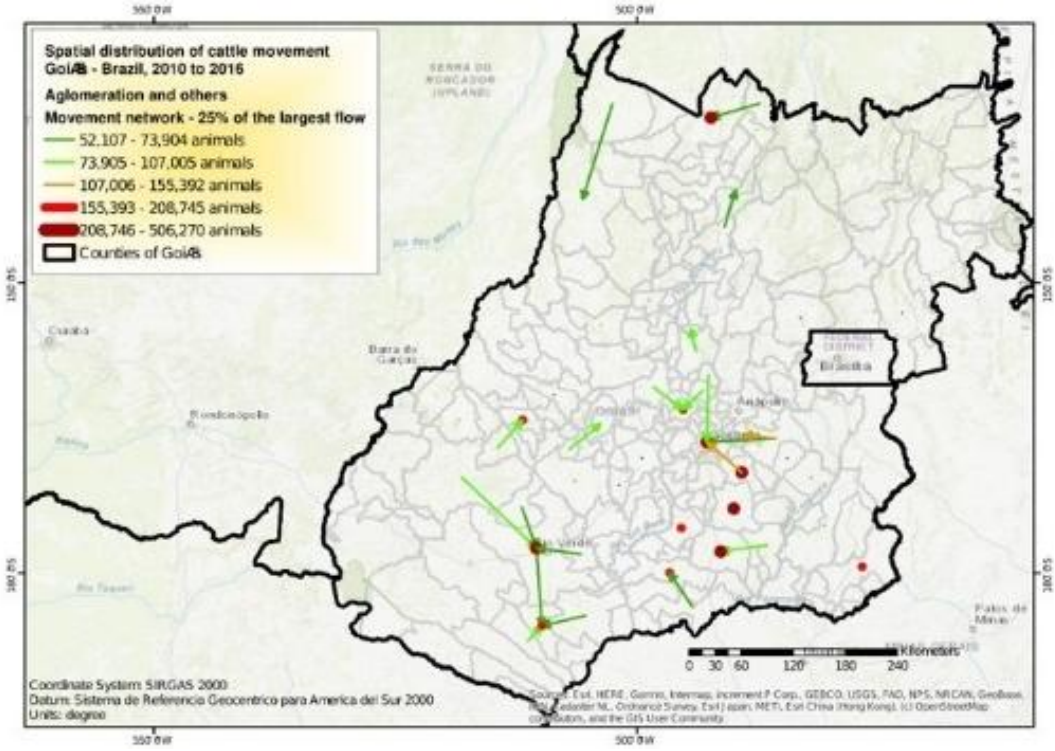

Figure 3. Spatial distribution of cattle movements in Goiás, Brazil (2010-2016) for the purposes of agglomeration activities and others. Data referring to 25% of the largest animal flows.

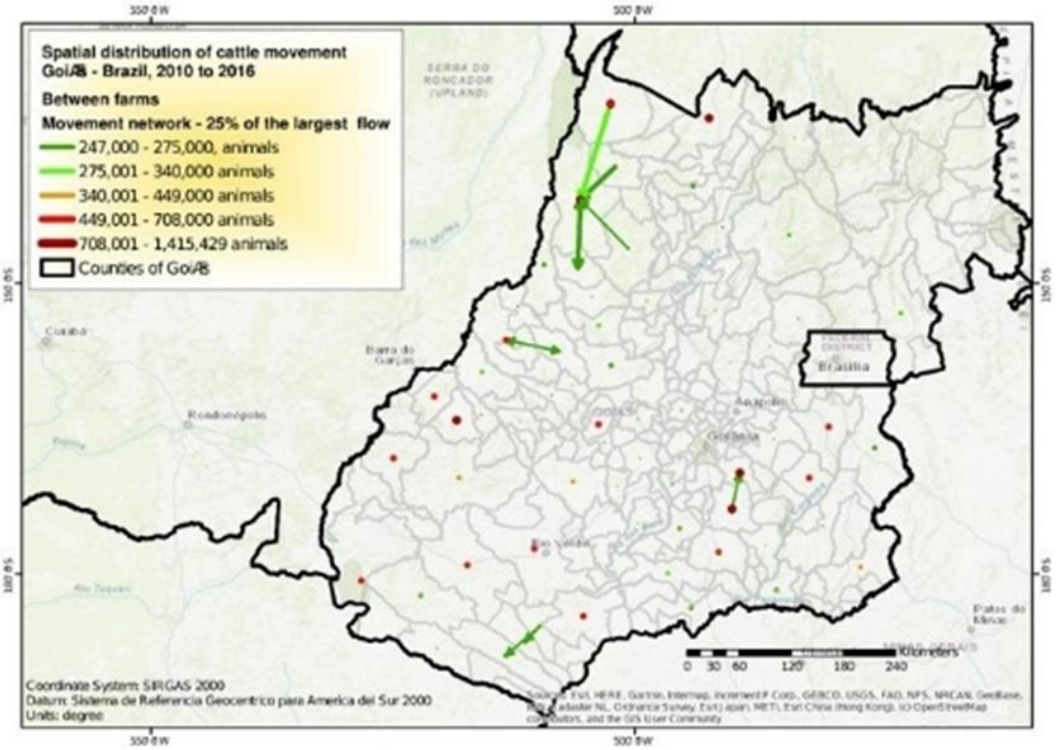

Figure 4. Spatial distribution of cattle movements in Goiás, Brazil (2010-2016) for the purpose of movements between farms. Data referring to 25% of the largest animal flows.

The greatest flow of cattle movements was within the state, a scenario like that identified in the transport of cattle in the state of Mato Grosso (Silva-Júnior *et al*., 2017; Negreiros *et al*., 2018). The occurrence of internal transport suggests a short- or medium-distance movement pattern, where the spatial proximity between farms or establishments that form the cattle trade network constitutes an essential factor for the movement of these animals (Negreiros *et al*., 2018).

Even at a lower frequency, interstate transport was present for almost all units of the federation and the Federal District, except in the state of Santa Catarina. This can be explained by the fact that Santa Catarina holds the health status of an area free from foot-and-mouth disease without vaccination, where the entry of animals vaccinated against the disease is prohibited (Brasil, 2000). The same is not true for Goiás, where the vaccination of cattle is still mandatory despite being considered an area free from foot-and-mouth disease.

Movements for the purpose of finishing and post-weaning constituted approximately 60.25% of all transports reported in the study. These results differ with those found in the state of Pernambuco (Silva-Júnior *et al*., 2017) but are similar to those observed in the states of Mato Grosso do Sul (Grisi-Filho *et al*., 2013) and Pará (Aragão *et al*., 2018). Such differences are mainly because production systems in these areas have different scales, since the Center-West – where Mato Grosso do Sul and Goiás are located - and the North where Pará is located - have high number of large farms, which are important producers of beef in domestic and international trade; thus, cattle are concentrated on these large farms (McManus *et al*., 2016; Sá *et al*., 2018). On the Northeast region of Brazil, which includes the state of Pernambuco, the majority of the livestock production (e.g. cattle, pigs, goats) is in small scale, and the animals are sold on local markets; for this reason, Pernambuco had 52.57% of the cattle moved in or out livestock markets (Silva-Júnior *et al*., 2017).The counties with the highest volume of cattle transported for the purpose of post-weaning are located precisely between the main beef cattle areas (Ferreira *et al*., 2019), which is evidenced by the fact that Nova Crixás and Jussara are two of the main counties to receive these animals. Bela Vista de Goiás sends and receives the largest number of cattle transported for this purpose, which can be characterized by intense intra-county movement. Moreover, this county is in a region with significant participation in the livestock activity in Goiás, having an agro-industrial chain and an economic complex that underwent major changes in the observational period of this study, especially in dairy cattle farming and breeding stock (Castro *et al*., 2014; Ferreira *et al*., 2019).

Usually, the finishing and slaughter chains are directly correlated, since the counties that stood out with the slaughter purpose contain large slaughterhouses, and the counties that most destined animals for slaughter are those with the largest cattle herd (Pesquisa…, 2018). The present study shows this is applied to the State of Goiás as well. Nova Crixás, Jussara and Rio Verde, the counties that send more cattle with the slaughter purpose, are the 1st, 5th and 8th counties on the ranking of cattle production of Goiás (SEAPA, 2020). And Mozarlândia, Palmeiras and Goiânia, the counties that most receive cattle for slaughter purpose, have multinational meat processing companies, e.g. JBS Foods and Minerva Foods. In this regard, it is important to consider that the transport of animals represents a low risk in terms of disease spreading (McGrath *et al*., 2018), as the animals are transported from the place of origin directly to the slaughterhouse (Hardstaff *et al*., 2015).

Properties with large herds have a higher risk of introducing diseases, mainly because they purchase a high number of animals (Bessell *et al*., 2012). However, the chain of contact for the dissemination of pathogens should be considered, e.g., the cattle market, which involves auctions and exhibition fairs. We observed that these agglomeration activities were lower (exhibitions = 97,046 animals; and elite auctions = 1,019 animals from 2010 to 2016) or slightly higher (auction = 13,971,835 animals from 2010 to 2016) when compared with the other purposes (e.g., movement for finishing purpose, with 56,090,140 animals moved from 2010 to 2016). The lower movement of animals for these purposes is interpreted as a decreased potential risk of spread of diseases.

The significant increase in the number of animals transported for the purpose of quarantine (6947.82% between 2010 and 2016) and stamping out (896.85% between 2010 and 2016)

further supports this information, clearly demonstrating the intensification of actions promoted by the state's animal health inspection agency (Agrodefesa). This fact is also suggested to reflect the increased awareness of veterinarians in the process of diagnosis and notification of mandatory diseases to the inspection agencies.

Goiás showed a significant increase in the export of cattle during the evaluated period (547.16%), differing from the national scenario. According to the Ministry of Industry, Foreign Trade and Services (MDIC), between the years 2010 and 2016, the Brazilian market showed a significant decrease (-301.88%) in the number of exported cattle. The greater export in Goiás may be related to the increase in the number of farms included in the Trace List, making it currently one of the main states suitable for export, together with Mato Grosso and Mato Grosso do Sul. This list includes all Brazilian rural establishments certified to export to the European Union, since they are subject to strict health requirements (Brasil, 2020).

The number of animals transported for reproduction purposes was significantly lower when compared with those moved for other purposes. This can be attributed to the rise of biotechnologies accessible to small and large cattle farmers in the state, such as the use of fixed-time artificial insemination. A fact that reinforces this idea is the significant increase in the sale of bovine semen in Brazil when we compare 2010 (six million doses) and 2016 (11.7 million doses) (Relatório…, 2010; Index…, 2019). It is known that, in addition to providing better productive and economic rates, the use of these technologies reduces the risk of direct transmission of infectious diseases of reproductive nature.

Identifying areas with a greater flow of animals is an important tool, from an epidemiological point of view. It allows better planning of actions and application of preventive measures against the spread of infectious agents and better understanding of the livestock activity in the state. Through the data exposed in this study, epidemiological models can be created to predict disease spread in places with greater movement. As a result, areas with greater animal movements become more dependent on epidemiological surveillance actions, making it possible to define the areas that involve primary cases and thus determine the initial source of infection (Felipe *et al*., 2013).

CONCLUSIONS

In this study, it was observed that the Northwest and South regions of the state of Goías presented more intense movement of cattle, with most transport related to finishing, post-weaning, and slaughtering purposes. It was also possible to identify patterns and trends on cattle movement – increase in the transport with purpose of quarantine, post-weaning, stamping out and exports, and reduction of transport with purpose of reproduction and exhibitions.

ACKNOWLEDGMENTS

Thanks are due to the Agricultural Defense Agency of Goiás (Agrodefesa) and fund for the development of cattle ranching in Goiás (Fundepec Goiás).

REFERENCES

AMARAL, T.B.; GOND, V.; TRAN, A. Mapping the likelihood of foot-and-mouth disease introduction along the border between brazil and paraguay. *Pesqui. Agropecu. Bras.*, v.51, p.661-670, 2016.

ARAGÃO, S.; PONTES, A.; GOUVEIA, L. A. *et al*. The visualization of cattle movement data in the state of Pará in 2016 through networks of animal transit graphs and guides. *Adv. Sci. Technol. Eng. Syst*., v.3, p.92-96, 2018.

ARAUJO, A.G.J.; TEIXEIRA, D.L.S.; GRILO, L.M. *et al*. Hydrological dynamic and rural mobility: Considerations on the cattle transit the south pantanal in years of extreme events: the drought of 2010 and the flood of 2014. *Raega Espaço Geogr. Anál*., v.46, p.140, 2019.

BESSELL, P.R.; ORTON, R.; WHITE, P.C.L.; HUTCHINGS, M.R.; KAO, R.R. Risk factors for bovine tuberculosis at the national level in Great Britain. BMC *Vet. Res*., v.8, p.51, 2012.

BRASIL. Agrodefesa. Instrução Normativa Nº 02/2017, de 15 de março de 2017. Available in: http://www.sgc.goias.gov.br/upload/arquivos/2018-06/in_-02-2017---estabelece-regiOes-de-alto-e-baixo-risco-para-raiva-dos-herbIvoros_compressed.pdf. Accessed in: 26 Oct. 2021.

BRASIL. Ministério da Agricultura Pecuária e Abastecimento. Portaria da Secretaria de Defesa Agropecuária nº 153, de 27 de abril de 2000. *Diário Oficial da União*. Brasília, DF, 28 de abril, 2000. Seção 1.

BRASIL, Ministério da Agricultura Pecuária e Abastecimento. Programa nacional de erradicação e prevenção da febre aftosa/ - plano estratégico 2017-2026, 2019 Available in: https://www.gov.br/agricultura/pt-br/assuntos/sanidade-animal-e-vegetal/saude-animal/programas-de-saude-animal/febre-aftosa/plano-estrategico-pnefa-2017-2026. Accessed in: 11 Oct. 2020.

BRASIL, Ministério da Agricultura Pecuária e Abastecimento. Rastreabilidade animal: lista de estabelecimentos rurais aprovados (ERAS) aptos a exportar à União Europeia, 2020. Available in: https://www.gov.br/agricultura/pt-br/assuntos/sanidade-animal-e-vegetal/saude-animal/rastreabilidade-animal. Accessed in: 11 Oct. 2020.

CASTRO, M.; LOPES, J.; SOUZA, R.; SOUZA, C.; NASCIMENTO, A. Cadeia produtiva do leite em Goiás: uma análise para o território Estrada de Ferro. *Conjuntura Econ. Goiana*, v.30, p.83-98, 2014.

CAPANEMA, R.; HADDAD, J.; FELIPE, P. Trânsito de bovinos nos estados do Mato Grosso e Mato Grosso do Sul, Brasil. *Arq. Bras. Med. Vet. Zootec*., v.64, p.253-262, 2012.

CIPULLO, R.; GRISI-FILHO, J.; DIAS, R.; FERREIRA, F. *et al*. Cattle movement network, herd size, and bovine brucellosis in the State of Mato Grosso, Brazil. *Semin. Ciênc. Agrár*., v.37, p.3777-3792, 2016.

CÓDIGOS dos municípios. Riode Janeiro: IBGE, 2020. Available in: https://www.ibge.gov.br/explica/codigos-dos-municipios.php. Accessed in: 26 Oct. 2021.

FELIPE, P.; NICOLINO, R.; CAPANEMA, R.; HADDAD, J. Characterization of cattle transit in the state of Paraná and Santa Catarina, Brazil, 2008. *Arq. Bras. Med. Vet. Zootec*., v.65, p.659-668, 2013.

FERREIRA, G.; MIZIARA, F.; COUTO, V. Pecuária em Goiás: análise da distribuição espacial e produtiva. *Rev. Eletron. Prodema*, v.13, p.21-39, 2019.

GORSICH, E.L.A.; BUHNERKEMPE, M.; GREAR, D. *et al*. Mapping U.S. cattle shipment networks: Spatial and temporal patterns of trade communities from 2009 to 2011. *Prev. Vet. Med.*, v.134, p.82-91, 2016.

GRISI-FILHO, J.; AMAKU, M.; FERREIRA, F. *et al*. Detecting livestock production zones. *Prev. Vet. Med*., v.110, p.304-311, 2013.

HARDSTAFF, J.; HÄSLER, B.; RUSHTON, J. Livestock trade networks for guiding animal health surveillance. *BMC Vet. Res*., v.11, p.82, 2015.

INDEX ASBIA 2019 Associação Brasileira de Inseminação Artificial, 2019. Available in: http://www.asbia.org.br/certificados/index/. Accessed in: 15 Oct. 2020.

MCGRATH, G.; TRATALOS, J.; MORE, S. A visual representation of cattle movement in Ireland during 2016. *Ir. Vet. J*., v.71, p.18, 2018.

MCMANUS, C.; BARCELLOS, J.; FORMENTON, B. *et al*. Dynamics of cattle production in Brazil. *PLoS One*, v.11, p.e0147138, 2016.

NEGREIROS, R.; GRISI-FILHO, J.; DIAS, R. *et al*. Cattle trade between and within biomes in the state of Mato Grosso, Brazil. *Pesqui. Vet. Bras*., v.38, p.2023-2028, 2018.

NEZU, I.H. *Prevalência e fatores de risco da brucelose bovina em Goiás*. 2020. 51f., Dissertação (Mestrado em Saúde Animal) - Universidade de Brasília, Brasília, DF.

PESQUISA da pecuária municipal 2018. Rio de Janeiro: IBGE, 2018. Available in: https://biblioteca.ibge.gov.br/visualizacao/periodicos/84/ppm_2018_v46_br_informativo.pdf. Accessed in: 10 Oct. 2020.

POZO, P.; VANDERWAAL, K.; GRAU, A. *et al*. Analysis of the cattle movement network and its association with the risk of bovine tuberculosis at the farm level in Castilla y Leon, Spain. *Transbound. Emerg. Dis*., v.66, p.327-340, 2019.

RAUTUREAU, S.; DUFOUR, B.; DURAND, B. Vulnerability of animal trade networks to the spread of infectious diseases: a methodological approach applied to evaluation and emergency control strategies in cattle, France, 2005. *Transbound. Emerg. Dis*., v.58, p.110-120, 2010.

RELATÓRIO estatístico de importação, exportação e comercialização do sêmen. Associação Brasileira de Inseminação Artificial, 2010. Available in: http://www.asbia.org.br/certificados/relatorios/. Accessed in: 15 Oct. 2020.

ROCHA, W.V.; GONÇALVES, V.S.P.; COELHO, C.G.N.F.L. *et al*. Epidemiological status of bovine brucellosis in the State of Goiás, Brazil. *Arq. Bras. Med. Vet. Zootec*., v.61, p.27-34, 2009.

SÁ, M.; SÁ, C.; NICOLINO, R. *et al*. Data on network of live cattle exports from Brazil. *Data Brief*, v.19, p.1963-1969, 2018.

SANTMAN-BERENDS, I.; BROUWER-MIDDELESCH, H.; VAN WUIJCKHUISE, L.; BONT-SMOLENAARS, A.; VAN SCHAIK, G. Surveillance of cattle health in the Netherlands: Monitoring trends and developments using routinely collected cattle census data. *Prev. Vet. Med*., v.134, p.103-112, 2016.

SEAPA, Secretaria de Estado de Agricultura, Pecuária e Abastecimento. Radiografia do agro, 2020. Available in: https://www.agricultura.go.gov.br/files/agro-em-goias/portugues-radiografia-2021.pdf. Accessed in 26 out 2021

SILVA-JÚNIOR, J.; ALMEIDA, E.; CORRÊA, F. *et al*. Livestock markets play an important role in the cattle movement network in Pernambuco, Brazil. *Braz. J. Vet. Res. Anim. Sci*., v.54, p.225-237, 2017.

VANDERWAAL, K.; PICASSO, C.; ENNS, E. *et al*. Network analysis of cattle movements in Uruguay: Quantifying heterogeneity for risk-based disease surveillance and control. *Prev. Vet. Med*., v.123, p.12-22, 2016.

VESPIGNANI, A. Predicting the behavior of techno-social systems. *Science*, v.325, p.425-428, 2009.