

Epidemiological risk in the movement of cattle in the regions of critical control points for foot-and-mouth disease in the state of Mato Grosso do Sul

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Abstract— *Cattle ranching in the state of Mato Grosso do Sul has been a supporter of the state's agribusiness, which has one of the largest cattle herds in the country, and has in its extensive breeding system a high genetic herd and the animals have access to an excellent pasture in the face of good quality of the fertile lands of the state. This activity generates directly and indirectly approximately 38,317,000 jobs and moves 24 billion reais annually, and this financial movement has increased by 18.2% in 2021 compared to the previous year (DETEC/Famasul System, 2021), contributing to the state's GDP of R\$ 23.5 billion, with an expected growth of 3.5% in 2021 (Tavares, 2021). The Agency for Animal and Vegetable Agricultural Defense - IAGRO has developed a work recognized nationally and internationally. In view of the state having approximately 1,500 kilometers of border, strict control of critical animal movement points in these regions is necessary. To date, 38,526 Animal Transit Guides - GTAs have been issued totaling 1,419,364 cattle and buffaloes moved in these regions. Thus, IAGRO performs continuous and uninterrupted work of sanitary surveillance in these regions, with actions of irregular traffic inhibition and regular traffic control. In 2021, in these regions, 125 searches were conducted for absentees, 362 vaccinations accompanied by the official service and 45 records of infractions for non-vaccination and 34 for lack of registration of*

the vaccine. (IAGRO,2021). All this health surveillance work aims to maintain the protection of the entire herd of the state of Mato Grosso do Sul resulting that for more than 15 years without record of aftosa focus in the state, we maintain a vaccination coverage above 99.2% to more than 6 years and the state pleads for the status of aphthous-free area without vaccination, demand from IAGRO and the entire production chain of the state. We will remain firm, convinced that work must continue and improve with health defense actions, health education, technical staff training and health surveillance throughout the state, with emphasis on the entire international and interstate border region.

I. INTRODUCTION

With the high increase in the consumption of protein of animal origin, due to the population growth of the world, and having Brazil as one of the largest producers and exporters of beef, and Mato Grosso do Sul being one of the main federative entities, responsible for the export of meat to several countries, which increases the revenue of the state and the country, generating numerous direct and indirect jobs, it is of paramount importance to control diseases among them Foot-and-mouth disease, which is a health barrier for international trade, causing high expenses for its control and eradication, huge losses in cases of outbreak [1] and due to the fall in herd productivity, in addition to economic losses and meat importing markets and indemnification when necessary animal sacrifice [2].

Given the importance of the eradication of foot-and-mouth disease, with regard to the prevention of animal health and national socioeconomic development, we perceive the need for analysis and evaluation of the epidemiological risk of this disease in the country.

Animal transit and the movement flow of cattle have always been recognized as predominant factors for the spread and occurrence of diseases throughout Brazil, as described in a study between 1960 and 2002 and reported by Felipe et. al. (2010). In Minas Gerais, from 1992 to 1994, 69% of the properties affected with foot-and-mouth disease had the introduction of animals. This process of cattle entry made the properties more vulnerable to the introduction of the virus, attributing to cattle transit a primary role in the spread of diseases. Thus, to understand the risks of diseases, it is necessary to know animal movement, which must be complemented with a global surveillance system and fostered by traceability tools [3].

Thus, this study aims to characterize the epidemiological risks in the movement of cattle in regions

of critical control points, for foot-and-mouth disease in the state of Mato Grosso do Sul.

a) The geographical characterization of the state of Mato Grosso of Sul

Located in the south of the Midwest Region, it is limited to five states: North - Mato Grosso; Northeast - Goiás and Minas Gerais; East - São Paulo; Southeast - Paraná and two countries: Bolivia to the west and Paraguay to the South and Southwest.

According to data from IBGE and the Government's Institutional Page, Mato Grosso do Sul has the following characteristics: divided . The largest urban concentrations are in the Center - Campo Grande, Centro-Sul - Dourados, East - Três Lagoas and Noroeste - Corumbá. It occupies an area of 357.145.532 km², with a population of 2.839.188 inhabitants as of July 1, 2021- the 21st most populous state in Brazil.

The Pantanal occupies the western end of the state, to the east and southeast are the mountains of Bodoquena, Maracajú and Amambai, forming the Plateaus and to the northwest are the Plains. The main rivers are Paraguay, Paraná, Paranaíba, Miranda, Taquari, Negro, Apa, Dourado and Correntes [4].

Also according to recent data from IBGE, the main economic activities are beef and dairy cattle, soybean, corn, sugarcane, cotton and rice crops, the pulp industry and iron, manganese and limestone mining.

The north of Mato Grosso feared the economic impact of the separation of the south, the separatist movement comes from the first decades of the twentieth century and on October 11, 1977, the dismemberment of Mato Grosso do Sul took place. On January 1, 1979, President Ernesto Geisel elevated MS to the category of State [5].

Mato Grosso do Sul is formed by two large regional complexes: Plateau in the sense NNE-SSE - a little bumpy topography that contributed to the expansion of modern commercial cultures, technical and sensitive to innovations, characterizing it as an important set of the territorial division of labor and the Pantanal in the SENSE NO-SO - biome whose remarkable presence of flooded areas, firm soil and transition areas compose a natural mosaic whose abiotic and biotic diversity, leads to the rational use of space. It is worth mentioning that the presence of livestock activity is felt in both macro-regional groups [6].

The process of storage and spatial organization of livestock production and the institution of the South-Mato Grosso identity can be understood from eight intense moments [7], namely, I - related to the genesis of mining activity in the eighteenth century; II - corresponds to the moment of land storage after the Paraguayan War in the 19th century; III - constituted by the reflections of the monopoly of the Matte Larangeira Company, between the end of the 19th century and the beginning of the 20th century; IV - marked by the expansion of foreign capitals (charqueadas) and the international market, before and after the First World War; V - closely related to the expansion of the cooled meat market, the implementation of refrigerators in the state of São Paulo and the intensification of rail transport through the Northwest of Brazil, between the first and second half of the twentieth century; VI - has connection with state policies, more precisely the march to the West and the expansion of agricultural frontiers, marking the phase of expansion of new crops through the cerrado; VII - the crisis of the 1980s denotes an internal re-organization of production; VIII - characterized by the opening and consolidation of markets accompanied by innovation strategies in the face of the demands of international competitiveness.

The peculiar cattle ranching of MS had its origin marked by the different fronts of settlement, since the seventeenth century, going through different processes of organization, allowing it to gradually acquire a status of relevance in the socio-spatial formation of the state, not constituting only a reflection of other formations - minas gerais, paulista or gaúcho [7].

Also according to Bertholi (2006), the non-Indian occupation of the South-Mato Grosso space, considering the multiple determinations regarding the motivation of the various groups that entered the territory and constituted the production relations, it is worth mentioning three: the first conducted by the natural veins of the Tietê, Paraná, Pardo,

Taquari and Paraguay rivers, the second as a strategy to guarantee land ownership by the Brazilian interior, of strategic-military bias, of the foundation of fortifications in the border areas and finally, of that under the political determination of granting glebes to influential groups. All these motivations contributed to insert the former South of Mato Grosso into the dynamics of capitalist relations of production, allowing the places to overcome the status of *paradouros* and definitively establish a relationship with the territorial division of labor [7].

This whole process of occupation, conducted or through the veins of the rivers that cut through the territory and join the Plateau to the Pantanal, or by the interests of the imperial government in securing the ownership of the lands in the face of the Spanish offensive, meant the arrival of new social formations and the definitive establishment of relations of southern Mato Grosso with the dominant and universal modes of production [7].

The banks of the rivers served primarily as a resting place for the Monsoon, especially those where the cities of Camapuã and Coxim were later founded. Others, such as Corumbá, Aquidauana and Aparecida do Taboado enabled the development of local commerce thanks to the privileged geographical position, in the path of the platinum market, on the way of the market with Campo Grande and on the way with the mining market, respectively. Unlike Amambaí and Bela Vista who assumed a character of *Entrepósito de Gado*, as well as those who were in the territory of Matte Larangeira served as *Entrepósito de Erva*, as Ponta Porã and Caarapó [7].

“In this dynamic, highlighted by Campo Grande, located between the areas of Vacaria and the main marketing routes, it connected the markets of the major Brazilian centers to the platinum and the most remote areas of the North (via the port of Corumbá), thus becoming the most dynamic center of the state, already at the beginning of the twentieth century”.[7]

According to updated data from AGESUL - State Agency for Project Management, highways and roads in Mato Grosso are divided as: Federal: 3.012.4 kilometers on 12 paved highways; State: 14.586.60 kilometers, of which: 1,915.4 planned, 8,548.3 unpaved and 4,122.9 paved. Municipal highways are composed of 45,176.8 kilometers of roads in natural bed.

b) Cattle ranching and buffalo in the state of Mato Grosso do Sul

The state of Mato Grosso do Sul was divided into four mesoregions and 11 microregions (Fig. 1) based on multithematic socioeconomic and geopolitical characteristics [8], which can facilitate the understanding of the spatial distribution of agricultural production chains and livestock.

According to data provided by IBGE (2020) the state has a staff of 19,027,086 cattle and 16,369 buffaloes. The livestock production of beef cattle is more expressive, with slaughter of approximately 3,389,421 heads, representing 11.34% of the national slaughter of cattle (BRASIL, 2020). The 10 municipalities with the highest cattle count are: Corumbá (1,927,002 heads), Ribas do Rio Pardo (1,085,497 heads), Aquidauana (794,825 heads), Porto Murtinho (647,006 heads), Santa Rita do Pardo (544,691 heads), Rio Verde do MT (533,366 heads), Campo Grande (520,524 heads), Três Lagoas (500,672 heads), Água Clara (485,095 heads) and Brasilândia which presented 463,033 head of cattle [9] [10]

The municipalities with the highest cattle are concentrated in the mesoregion of Baixo Pantanal and Três Lagoas, where extensive breeding systems are traditionally developed for the production and commercialization of beef calves for breeding and fattening in areas with availability of food in quantity and of superior quality [11]. It is emphasized that the mesoregion of Três Lagoas has replaced livestock activity with pulp and paper production, which probably determines changes in land use and occupation in this region.

According to Hott et al. (2021) the state's dairy production in 2019 was equivalent to 0.81% of the national production. In 2020, 162,783 cows were milked and dM milk production was estimated at 295,940,000 liters. Among the 10 municipalities, with the highest number of cows milking, are Paranaíba (14,299 heads), Itaquiraí (11,446 heads), Nova Andradina (10,649 heads), Sidrolândia (9,627 heads), Terenos (8.4 11 heads), Iguatemi (6,295 heads), Camapuã (6,190 heads), Ponta Porã (6,158 heads), Aparecida do Taboado (6,004 heads) and Innocence, with 5,031 cows milked during this period [12][13].

Mato Grosso do Sul has eight dairy basins: the Southern Cone, Nova Andradina, Glória de Dourados, Dourados, Aquidauana, Campo Grande, Centro-Norte and the Bolsão basin. The characteristics of the production chain include low level of information and training, low

productivity and small production volumes, financial economic insufficiency and low membership in associativism and cooperativism. In the MS more than 50% of milk is produced in properties with less than 50 hectares, by family farming [14].

The particularities of livestock activity directly interfere in the dynamics of events related to health problems, including in relation to AF. Thus, the strategy of establishing livestock circuits as a complementary concept to the biological focus given to the concept of AF ecosystem (host-environment agent) was important from 1992, because a new stage intended to invest in the eradication of the disease and, for this, the involvement of the entire production chain would be fundamental. The delimitation and definition of livestock circuits (Fig. 2) was carried out after a comprehensive evaluation of these characteristics and with the participation of representatives from different sectors, considering four types of activity: extractive livestock, mixed livestock for meat, livestock for milk processing and market activity [15].

In this context, studies on the distribution of herds, land structure and the transit of these animals, for different purposes, can clarify more particularly how agricultural circuits work.

Evaluating aspects of land use within the dynamics of production chains of different species and their role in the implementation of different strategies for control and eradication of AF are fundamental for the success of PNEFA in the MS [16], especially in view of the distribution of small properties, location in settlements and indigenous areas (Fig. 3), cultural, socioeconomic, breeding practices and movement among small producers.

The stratification and analysis of the characteristics within the different livestock circuits can contribute to the success in the eradication of AF in the state, corroborating Moraes et al. (2017) that described technological innovations, institutional organization, shared responsibility and increased epidemiological surveillance as fundamental conditions for this to occur [17].

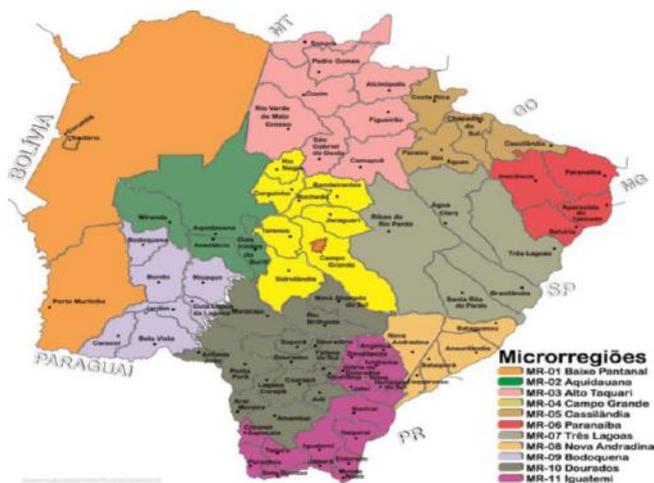


Fig. 1: Mesoregions and microregions of the state of Mato Grosso do Sul. Source: [8]



Fig. 2: Brazilian livestock circuits, defined for strategies of actions to control and eradicate foot-and-mouth disease. Source: Moraes et al. (2017).

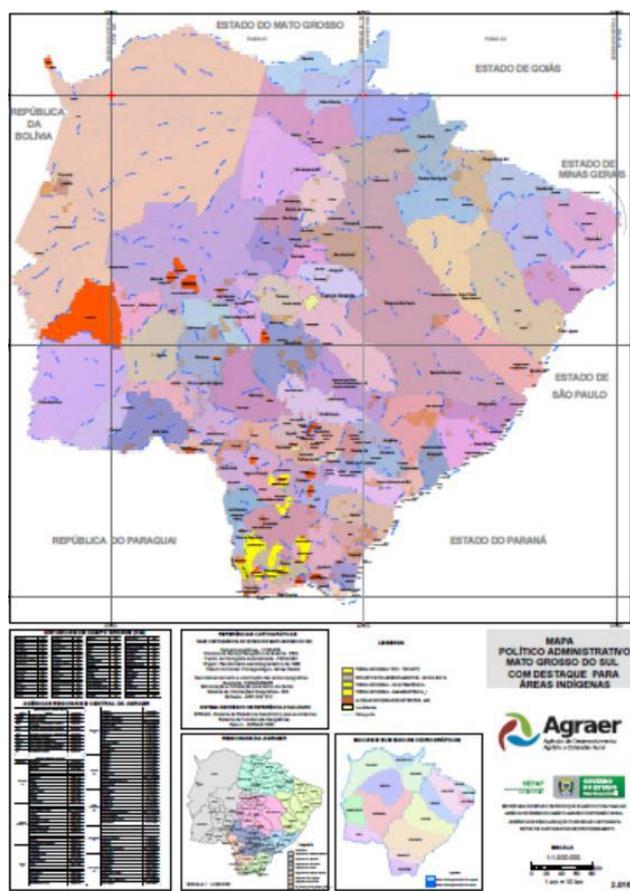


Fig. 3: Administrative political map of the state of Mato Grosso do Sul, with emphasis on indigenous areas and rural settlement projects. Source: AGRAER (2021).

c) The importance of agricultural activity in the state of Mato Grosso do Sul

The primary sector is the main economic activity of Mato Grosso do Sul, and livestock activity occupies a prominent position in this scenario, which causes a large volume of beef exports from the state to all continents. Given this context, this activity has a great impact on the state's trade balance, which makes this activity very competitive and technical [17].

Mato Grosso do Sul, according to updated data from the State Agency for Animal and Plant Sanitary Defense (IAGRO), has a cattle herd of 17.7 million, and with the highest concentration in the municipalities of Corumbá with 1.8 million, Ribas do Rio Pardo with 940,000 and Aquidauana with 779,000, and the state has the 5th largest herd in the country [18].

In 2020, a total of 3,347,680 cattle [18] were slaughtered in the municipal, state and federal inspection services, which moved US\$778,246 million and

210,642,000 tons of beef [19] were exported. Hong Kong stands out with 23.92% of the countries that imported beef the most in the state of Mato Grosso do Sul, followed by China with 16.25% [20].

Cattle ranching in the state of Mato Grosso do Sul directly and indirectly generates approximately 38,317,000 jobs and moves 24 billion reais annually, and this financial movement has increased by 18.2% in 2021 compared to the previous year [21], contributing to the state's GDP of R\$ 23.5 billion, expected to grow by 3.5% in 2021 [22].

d) Foot-and-mouth disease virus in Brazil, the midwest and Mato Grosso do Sul

The first description of cases of foot-and-mouth disease (AF) was made by Giorlano Fracastorius, in 1514, in the verona region of Italy [23]. In South America, the occurrence of AF was documented in 1870, almost simultaneously in the Province of Buenos Aires (Argentina), in the central region of Chile and Uruguay [24]. It is suggested that the occurrence of foci occurred through the trade of animals from Europe (endemic region) [25], mainly through the import of breeding cattle to meet the growing demand for production linked to the development of the refrigeration segment [26].

Chile detected its first outbreaks in 1871 and the FA spread to Brazilian states in the 20th century, in addition to other countries such as Paraguay and Peru (1910), Bolivia (1912), Venezuela (1950), Colombia (1950/1951) and Ecuador in 1956 [25]. In this context, South America was characterized as an endemic area for this disease.

It assumes that the Southern region of Brazil has been affected due to the outbreaks recorded in the Southern Cone region of America, however, the first officially recognized case in the country occurred in 1895 in the city of Uberaba in Minas Gerais and the following year, in 1896, in the state of Rio Grande do Sul and again in the Region of triângulo Mineiro, import of animals from Europe [15][24].

Several decades passed after the first records of AF, until an intervention was initiated for its control in Brazil [24].

In the 1960s, the first program to combat foot-and-mouth disease involving Banco do Brasil credit lines was developed and, simultaneously, the introduction of infrastructure in laboratories, training of people, awareness of producers, production of vaccine, notification of outbreaks and diagnosis of the disease was established [26].

In the 1970s, the intensification of surveillance resulted in higher reports of outbreaks and epidemiological studies identified risk areas and correlated the regions of AF occurrence with the movement of animals. The investment in vaccine quality control was paramount for the success of health programs [2], since at that time, outbreaks occurred in herds with low immune coverage due to the use of vaccines with low immunogenic quality. In 1976, 48% of the outbreaks recorded were an epidemic outbreak in Rio Grande do Sul by the type "A" virus, going to the states of Bahia, Minas Gerais and São Paulo, representing the total of 70% of the outbreaks recorded in Brazil. In 1980 the "O" virus was responsible for a new outbreak in Rio Grande do Sul [24].

Since 1980, studies have shown that the disease was influenced by the movement of cattle and the characteristics of the regions [2] and, then, a sharp drop in the number of outbreaks was observed as a result of the strengthening of the control activities of the Official Veterinary Service (SVO), vaccination campaigns with greater availability and quality of the vaccine, which, since 1978, it has been submitted to production for evaluation by the Ministry of Agriculture, and the consolidation of programs to combat foot-and-mouth disease in the Southern Region of the country (region with the highest number of cases of the disease) (MORAES, 2018). The implementation of the Hemispheric Plan for the Eradication of Foot-and-Mouth Disease (PHEFA) in 1987, added to what had been carried out, resulted in a significant decrease in the number of foci, maintaining this trend until 1991 [27].

The upsurge in outbreaks from 1992 to 1994 was a reflection of improvements in notification by state veterinary services (ES) and in the intensification of cattle marketing and transit, stimulated by financial speculation. However, the SVO interfered intelligently, restricting the transit of animals, and the situation normalized in 1995 [24].

In the 1990s, the important aspects of cattle production chains were addressed in studies and the transit of animals was characterized as one of the largest disseminators of the disease, which was fundamental to understand the spatial distribution of AF and its relationship with agricultural activity. The types of ecosystems of the disease determined by these studies were essential for the determination of livestock circuits and the creation of different public policies [15]. The modernization of refrigeration industries to places closer to cattle breeding, avoiding the displacement of animals over

long distances, and the exclusive use of the vaccine with oily adjuvant throughout Brazil, were important factors for the eradication of the disease [9].

In 1998, Rio Grande do Sul and Santa Catarina were internationally recognized as an AF-free zone with vaccination. However, that same year, outbreaks were recorded in Mato Grosso do Sul, in the municipality of Porto Murtinho and, the following year, in Naviraí, both located in the international border region [24]. According to Amaral et al. (2016) [28], vulnerability to the entry of foot-and-mouth disease in this region bordering Paraguay is associated with the introduction of animals into the properties, distance from properties to the border and small properties of rural settlements.

Souza (1999) [30] gave a description of the actions to attend the outbreak of Porto Murtinho and Naviraí, MS. The notification of Porto Murtinho was made in February 1998 and the occurrence was finalized in May, were two outbreaks detected in properties distant 45 km, belonging to the same tenant. The vulnerability of the Pantanal Sul region had already been signaled by Moraes et al (1997) [30] as a result of serological analyses and interviews with producers in municipalities in the region, although vaccination coverage was satisfactory and serum positivity was low, it is noteworthy that the municipalities of Aquidauana and Porto Murtinho had the highest frequencies of serum positivity for the stratum evaluated in the years 1995 and 1996.

In January 1999, the suspicion of vesicular disease was reported in the municipality of Naviraí and care measures were immediately applied to the first focus and the second focus was identified the following day. On January 30, 1999, the two properties were cleaned and disinfected and the sanitary void was started [29].

Reintroductions of foot-and-mouth disease in Rio Grande do Sul were reported in 2000 and 2001 as a consequence of later confirmed animal health problems in the province of Formosa, Argentina, on the border with Paraguay, involving viral types A and O (BRASIL, 2021) (MORAES, 2018). In August 2000, the first notification occurred in the municipality of Joia-RS, and the disease spread to three other municipalities (Eugênio de Castro, Augusto Pestana and São Miguel das Missões). The total of 22 foci distributed in the four municipalities was recorded and there was the sanitation of 142 properties considered as contact, with the sacrifice of 8,185 cattle, 772 sheep, 04 goats and 2,106 pigs as reported by Gocks (2012).

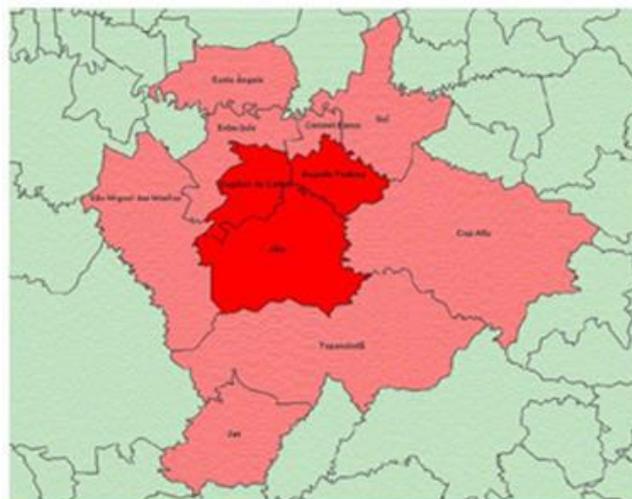


Fig. 4: Restricted area defined at the beginning of health emergency actions in RS in 2000. Source: Brazil (2020).

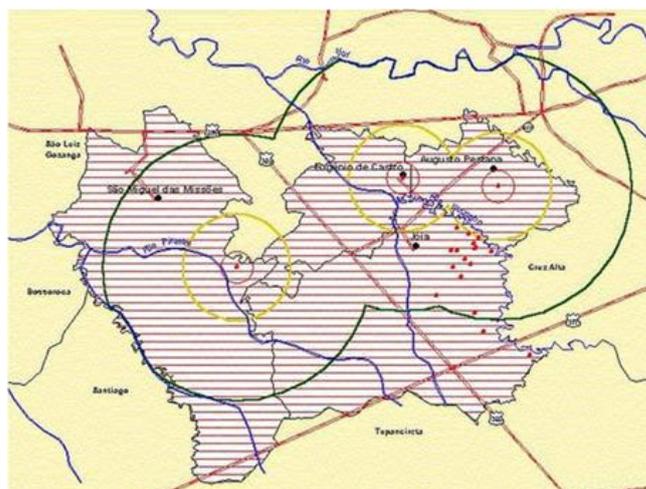


Fig. 5: Geographical representation of the areas of epidemiological risk established around the outbreaks located in the municipalities of Augusto Pestana, Eugênio de Castro and São Miguel das Missões - RS, 2000. Source: Brazil (2020).

In May 2001 a new case was confirmed in Santana do Livramento-RS due to indirect movements in the triple border region. The epidemiological link was identified through laboratory confirmation of type A virus with antigenic characteristics similar to those in Argentina and Uruguay. From May to July 2001, 30 foci of AF in RS were reported as described by Gocks (2012), 01 in Santana do Livramento, 05 in Alegrete, 03 in Quaraí, 02 in Dom Pedrito, 01 in Jarí and 18 in Rio Grande. 11,761 cattle, 5,039 sheep and 05 pigs, which were exposed or showed signs of the disease, were sacrificed and activities ended in October of the same year.

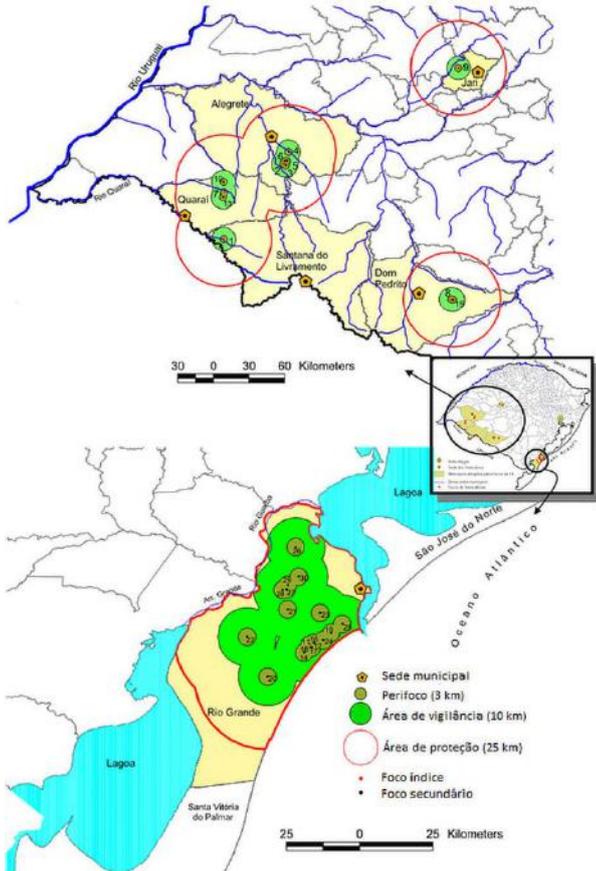


Fig. 6: Geographical location of foot-and-mouth disease foci, with emphasis on emergency areas in RS, 2001. Source: Brazil (2020).

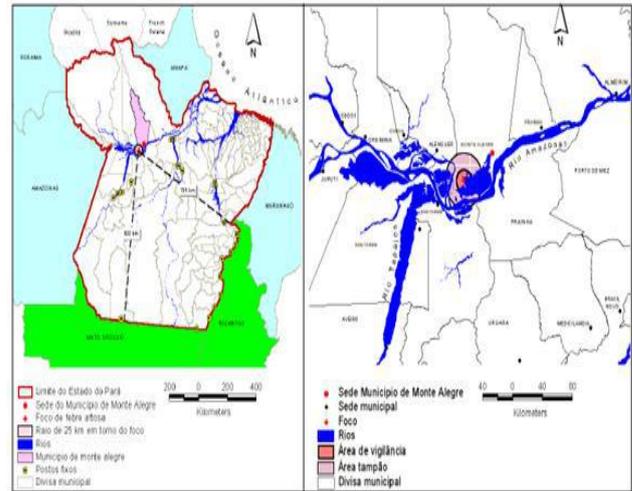


Fig. 7: Location of the foot-and-mouth disease outbreak and safety area in the municipality of Monte Alegre, Pará, Brazil. Source: Panaftosa (2005).

In September of the same year, the positive diagnosis of foot-and-mouth disease, virus C, was confirmed in epithelium samples of cattle located in the municipality of Careiro da Várzea, Amazonas. Clinical signs compatible with the disease were identified by the Amazon Animal Health Defense Service in 04 cattle from 12 to 24 months of age. In the property involved there were 34 cattle, 15 sheep and 01 pigs, and in 2003 and 2004 vaccinations against foot-and-mouth disease had not been recorded (PANAFTOSA, 2005).

These impactful data reinforce the complexity of health defense work and the importance of health education that can positively interfere in the intensification of passive surveillance, in the agility of notifications and control procedures performed by the SVO, which must present interaction with the productive sector, among other aspects, in to be efficient (GOCKS, 2012).

In 2004, occurrences of foot-and-mouth disease were recorded in the state of Pará with a focus of type O virus in the municipality of Monte Alegre and four outbreaks of type C virus in the state of Amazonas. The focus on Monte Alegre-PA was recorded during a suspicious care by the Official Veterinary Service, in a bovine with a discrete clinical sign in only one paw (BRASIL, 2009). In eliminating the focus, inspection and surveillance work was carried out involving 453 herds, a total of 14,462 cattle, 2,393 buffaloes, 1,221 pigs and 142 small ruminants inspected with the sacrifice and destruction of the 130 susceptible animals found in the focus and 31 contacts.



Fig. 8: Geographical location of foot-and-mouth disease outbreak in Careiro da Várzea, Amazonas, Brazil. Source: Panaftosa (2005).



Fig. 9: Satellite image of the detection zone of c virus cases in Amazonas, Brazil. Source: Panaftosa (2005).

The last cases of AF in Brazil were recorded in Mato Grosso do Sul and Paraná, in the years 2005 and 2006, as described by Moraes (2018). In September 2005 a new epidemic caused by serotype O affected the municipalities of Eldorado, Japorã and Mundo Novo, located in the southern border region of Mato Grosso do Sul. A total of 33 foci were detected over a two-month period, and 660 cases (cattle) were reported to OIE and 26,553 cattle, 566 pigs and 626 sheep and goats were sacrificed. In Paraná, 07 outbreaks with 20 bovine cases were reported in five municipalities: Bela Vista do Paraíso, Grandes Rios, Loanda, Maringá and São Sebastião da Amoreira. Between December 2005 and February 2006, 6,781 cattle were sacrificed until the resolution of the foci (PNEFA, 2008a; PNEFA, 2008b; NEGREIROS et al., 2009; OIE-WAHIS, 2021).



Fig. 10: Representation of the municipalities involved in the outbreak of foot-and-mouth disease in Mato Grosso do Sul, in 2005. Source: PNEFA (2008b).

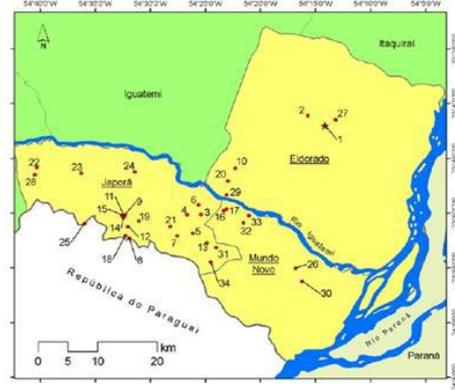


Fig. 11: Location of the foci recorded in Mato Grosso do Sul, 2005 and 2006 (the identification number of the foci corresponds to the detection sequence). Source: Brazil (2020).

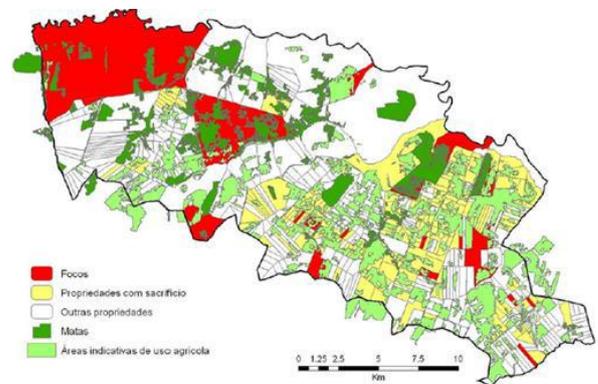


Fig. 12: Map of the Municipality of Japorã, MS, 2005 (highlight for properties notified as focus and cattle sacrificed and for properties not declared as foci but with cattle sacrificed due to bonding with foci, 2005 and 2006). Source: Brazil (2020).

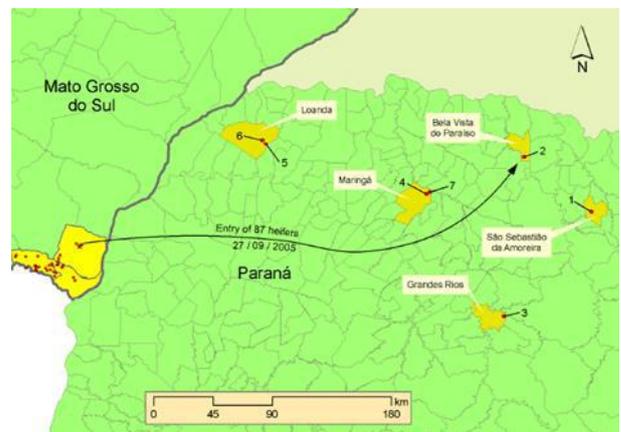


Fig. 13: Geographical representation of the foci registered in Paraná. Source: PNEFA (2008a).

According to the context presented by Brazil (2020), in the last ten years South America includes most of the

herds located in a free country or zone with or without vaccination, including with countries achieving the recognition of foot-and-mouth disease free without vaccination, in whole or in part.

e) **State Agency for Animal and Plant Sanitary Defense - IAGRO**

The State Agency for Animal and Plant Sanitary Defense (IAGRO), is an municipality with forum and headquarters in the Capital of the State of Mato Grosso do Sul with legal personality of public law, technical, administrative and financial autonomy, own assets, and period of indefinite duration, in accordance with the law, was created by item I of Art. 6 of Decree-Law No. 9, of January 1, 1979 (MATO GROSSO DO SUL, 1979), under the name of Department of Agricultural Inspection and Defense of Mato Grosso do Sul (IAGRO), and its name changed to the State Agency for Animal and Plant Sanitary Defense by point "a" of item III of article 83 of State Law No. 2,152, of October 26, 2000 (MATO GROSSO DO SUL, 2000). IAGRO is bound by the State Secretariat of Environment, Economic Development, Production and Family Agriculture (SEMAGRO) and supervised by it, pursuant to Law No. 4,640 of December 24, 2014, and its amendments (MATO GROSSO DO SUL, 2014).

IAGRO is invested by an agricultural defense authority of the State of Mato Grosso do Sul and is responsible for ensuring the supply of quality animal and plant products to the population, through defense and agricultural inspection, operating in the promotion of public health, preservation of the environment and ensuring access to agricultural products to consumer markets. The agency is also responsible for complying with the operational obligations delegated by the Executive Branch, which deals with legislation related to the protection of animal and plant health and the control and inspection of agricultural products, goods and services, processes and technologies achieved by the agricultural health care system, being assured the other prerogatives necessary for the proper exercise of its duties (MATO GROSSO DO SUL, 2020).

IAGRO's basic organizational structure for the performance of its duties is divided hierarchically into a Superior Collegiate Decision-Making Body represented by the Board of Directors, which is responsible for the main resolutions and strategic decisions of the municipality, the Superior Management Board represented by the Board of Directors of the Presidency, which is composed of the Chief Executive Officer and the Deputy Director, and its responsibilities are to manage the resources and general

operations, acting as the central point of communication between the operational and the board of directors, and it is up to the Chief Executive Officer to determine the strategic direction and ensure that the objectives are implemented through functional steps. Below the Superior Management Body is the Collegiate Body of Senior Management represented by the Board of Directors, which is composed of the Chief Executive Officer, Deputy Director and Managers who approve IAGRO's annual work plan. Directly linked to the Superior Management Body are the Superior and Direct Advisory Bodies represented by the Quality Management System Coordination; Coordination of Development and Strategic Management: Legal Attorney and Intelligence Coordination. Following the hierarchy below are the Superior Management Bodies and subordinate units being the managements with end activity the Management of Inspection and Animal Sanitary Defense composed of the Division of Animal Sanitary Defense and the Division of Inspection of Animal Products, Management of Inspection and Plant Sanitary Defense composed by the Division of Plant Sanitary Defense, Division of Agricultural Products and Materials and Division of Inspection and Classification of Products of Plant Origin, Laboratory Management composed of the Division of Laboratory of Animal Disease Diagnostics and Food Analysis, Division of Laboratories of Analysis of Official Seeds and Laboratory Division of Laboratory of Soil Analysis and Agricultural Corrective, Management of Control and Operations composed Division of Epidemiology, Division of Sanitary Education, Division of Execution of Infraction and Fine And Agricultural Traffic Division and management with activity through Administration and Finance Management composed of the Administration Division, Accounting, Budget and Finance Division, Human Resources Division, Information Technology Division and Transport Division. Finally, there are the Operational Execution Units represented by the Regional Units and Local Units (MATO GROSSO DO SUL, 2020).

f) **Critical control points for reintroduction of foot-and-mouth disease virus by animal health defense in the state of Mato Grosso do Sul**

In the context of the epidemiology of foot-and-mouth disease and analyzing the characteristics of the virus in the environment, it is estimated that the movement of animals creates an important risk of spreading the disease. The commercial movement of cattle enables the virus to remain in the environment and production structures can favor conditions for the maintenance of viral circulation, characterizing these areas as endemic areas that become

"suppliers" or providers of viruses to other regions (HUGE, 2011). Thus, animal traffic is one of the critical control points of Foot-and-mouth Disease in Mato Grosso do Sul, and should be closely monitored.

People also represent an important factor of analysis in the epidemiology of Foot-and-mouth disease, because when they come into contact with infected animals they are exposed to large amounts of viruses, the volumes of air sampled in a period of 30 minutes in a facility with infected animals have values such as 10 million infecting units. People in these conditions can be an efficient mechanical vector of foot-and-mouth disease virus and therefore anyone who has had contact with infected or potentially infected animals or carcasses should take strict biosafety measures to prevent the spread of the virus (HUGE, 2011).

A really important point to be addressed in the epidemiology of the disease is that the real importance of human action in the foci of Foot-and-Mouth Disease consists in the involvement of people in the mechanical transmission of the virus, predisposing to the dissemination of this agent to susceptible animals, either by contaminated clothing, footwear or hands, or even in the upper respiratory tract, since the virus exhibits resistance characteristics and remaining in the environment for weeks (HUGE, 2011).

The geographical distribution of the last outbreaks of the disease demonstrated that all events have occurred in border areas, which, together with the characteristic of non-aerial dissemination of Foot-and-Mouth Disease, marks the importance of the work of partnerships between neighboring countries in these areas. As a priority, mercosur has established the implementation of combined health actions in the border regions between the countries of Argentina, Bolivia, Brazil and Paraguay, promoting the continuity of national programs for the eradication of AF and other regional actions and strategies capable of identifying possible primary sources of infection, with the aim of minimizing the risks of the introduction and dissemination of the virus in the region (HUGE, 2011).

The State of Mato Grosso do Sul, for its immense dry border with two countries, being Paraguay and Bolivia, and taking into account the variation of values of the bovine atone between the two and the MS, which is often much lower in relation to the price practiced in the state, according to Canal Rural (2021), the price of the ox atroe in Mato Grosso do Sul is R\$ 270.00, while in neighboring countries the price difference reached 10 dollars per arroba

(Revista Globo Rural, 2021), a variation that encourages producers to risk smuggling animals without any documentation and sanitary attestations, thinking only of the profit obtained from this trade, becoming in this way the most critical control point for the reintroduction of the disease across our border, which has numerous vicinal roads connecting them.

Another important critical point of control are the events of animal agglomerations, such as auctions, exhibitions, lace parties, etc. only in the year 2021 from January to September, 524 events with animal agglomeration were held, and a total of 475,986 goats transited throughout the state to participate in these events, in addition to 160 sheep and 17 goats [18] (IAGRO,2021). In these points, the transit of animals from various units of the federation and several municipalities within the state are common, which promotes a high contact between the various species of susceptible animals, such as Cattle, Buffaloes, Goats and sheep, which greatly increases the spread of all types of diseases, including Foot-and-mouth disease.

This study has as main objective the characterization of epidemiological risks for the reintroduction of foot-and-mouth disease virus in Mato Grosso do Sul, evaluating critical control points, especially in relation to the movement of cattle in the border regions with Paraguay and Bolivia.

II. MATERIALS AND METHODS

a) Research Design

This work regarding its research nature has a qualitative and quantitative approach since it will require statistical methods and techniques through data collection of IAGRO systems (PRODANOV and FREITAS, 2013).

The research was carried out through a bibliographic study endorsed in this article, we used data from the IAGRO of transit and movement of animals from the risk region and critical control points, mainly from the international border region, as well as actions developed in the areas of study.

Highlighted by a research in the exploratory and explanatory form, which provided a greater proximity to the problem, and identified the factors that determine or contribute to the occurrence of the facts (GIL, 2008).

b) IAGRO data collection

Data were collected from the e-Saniagro system, the system responsible for all control of animal stock, registration of producers and properties, control of all animal movements through e-GTAs, agricultural events, veterinary prescriptions for brucellosis vaccination, control of stock of vaccines in resales, controls all Infraction Records and fines drawn up by the Agency's inspectors, in addition to all financial transactions related to the fees and fines imposed. All verification of the data present in this database is analyzed by a BI (Business Intelligence) system that generates reports of movements, controls and irregularities that generate demands for traffic and property inspection teams. All producers in the state have access to this system where they make the declaration of vaccination of animals, issue Animal Transit Guides - GTA and perform the adjustment of stock of animals of their property.

c) Cattle movement network and heat map

The networks of cattle movements are generated from analyses made by the BI System in our e-Saniagro database, taking into account all gtas (Animal Traffic Guides) emissions in the state, characterizing the properties of origin and destination.

The heat map took into account the entire balance of animals and the geographical coordinates of all producers and health records registered in our e-Saniagro System.

III. RESULTS AND DISCUSSION

In 2021, 334,578 Animal Transit Guides (GTAs) were issued in Mato Grosso do Sul, by IAGRO throughout the state, characterizing the municipalities that moved cattle and buffaloes the most were: Corumbá, Campo Grande, Ribas do Rio Pardo, Paranaíba, Aquidauana, Rio Verde de Mato Grosso, Coxim and Porto Murtinho, [18](IAGRO,2021) as shown in the animal movement map below.

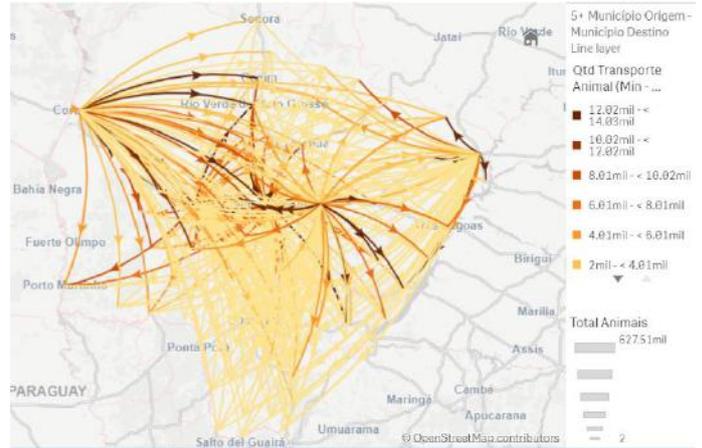
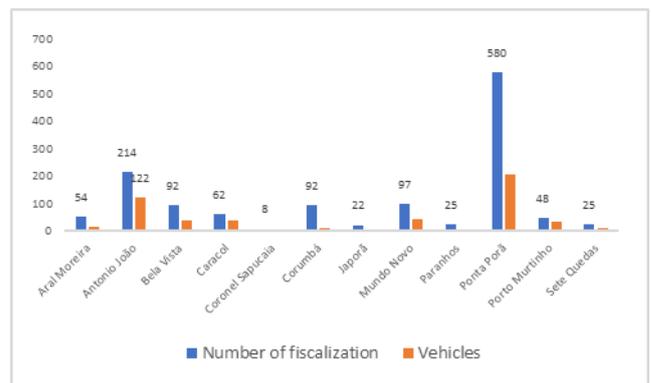


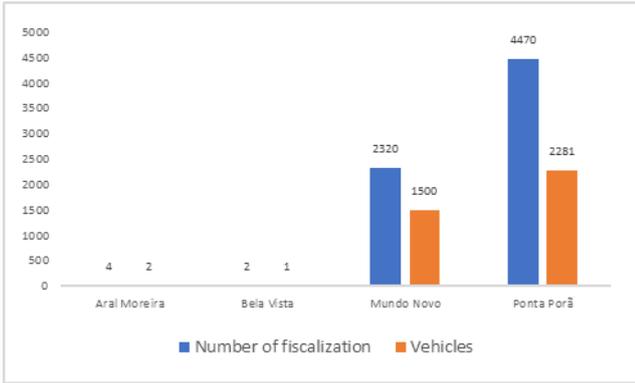
Fig. 14: Cattle movement in the state of Mato Grosso do Sul in 2021. [18]

a) Traffic control in border regions.

The traffic control of animals, their products and by-products carried out in the border region with neighboring countries is carried out from a monthly report issued by the e-Saniagro system, which identifies properties with suspicious movements, generating a list of places with high probability of irregular traffic. From this report, the steering wheel inspection teams are designated for the border regions, generating numerous inspections and infractions, and even sanitary slaughters of cattle and equidae that had no origin. According to the chart below, in 2021 alone, 1,319 steering wheel inspections and 6,796 inspections were carried out at fixed posts in the border region, covering a number of 4,312 vehicles.

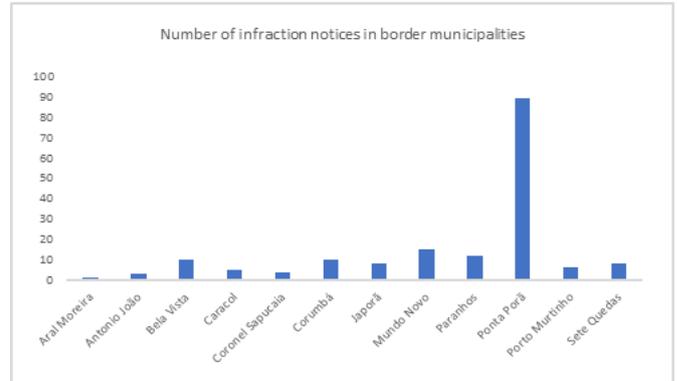


Graph 01: Number of inspections and vehicles approached by border municipality by steering wheel inspection teams in 2021 (IAGRO,2021)



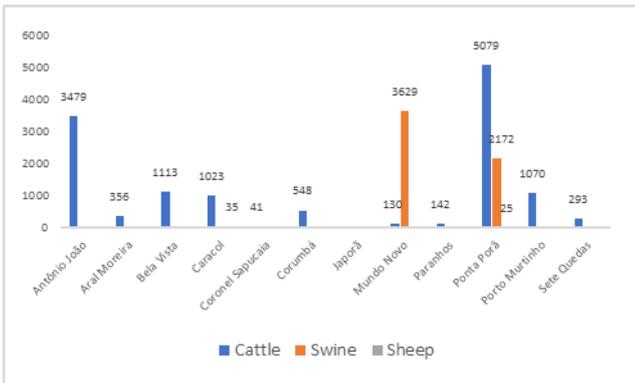
Graph 02: Number of Vehicles and inspections at fixed stations in the international border regions in 2021. (IAGRO,2021)

all 12 municipalities of the international border, only in the year 2021, divided according to graph 05.



Graph 05: Number of Infraction Notices per border municipality drawn up by inspection teams in 2021 [18].

In these inspections, 71,611 bovínidos, 152,822 pigs and 473 sheep were surveyed (Graph 03 and Graph 04).

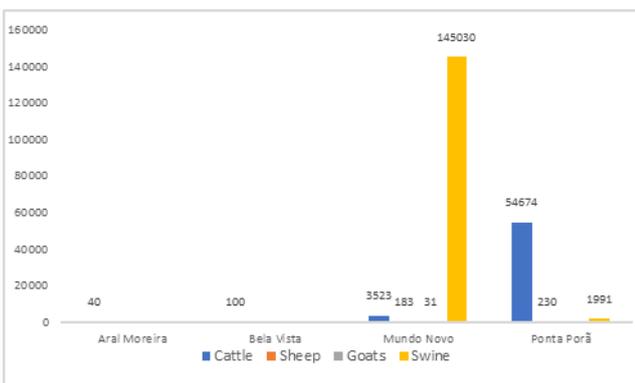


Graph 03: Number of animals inspected by the steering teams at the border by species in 2021 [18].

IAGRO currently has 4 vessels that are used in the control of animal transit in rivers, mainly in the borders and regions of the Pantanal, the vessels allow in each one that the actions are carried out by up to 6 servers, which allows the performance of irregular traffic control actions of cattle in these regions, the servers that act in river inspections, receive periodic training with the Brazilian Navy [18].

b) Traffic control in interstate currency regions.

The traffic control carried out in the borders of the state of Mato Grosso do Sul, with the neighboring states being, Mato Grosso, Goiás, Minas Gerais, São Paulo and Paraná, take place in fixed inspection posts and teams of Volantes, where the posts serve as a support point for the teams that carry out the inspection throughout the entire length of the border with the neighboring states. All the survey of the movements were made from the existing data in the e-saniagro system, related to the emission of GTAs (Animal Traffic Guides), indexing the networks of movements and possible irregularities, which bases the destination of the steering wheels and the places of operation, as graph 06 attached below, where the amounts of inspections are available, the number of vehicles covered.

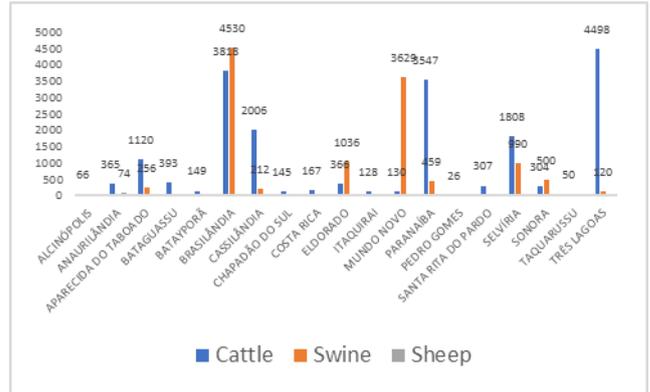


Graph 04: Number of animals inspected at fixed posts in border municipalities per species in 2021 [18].

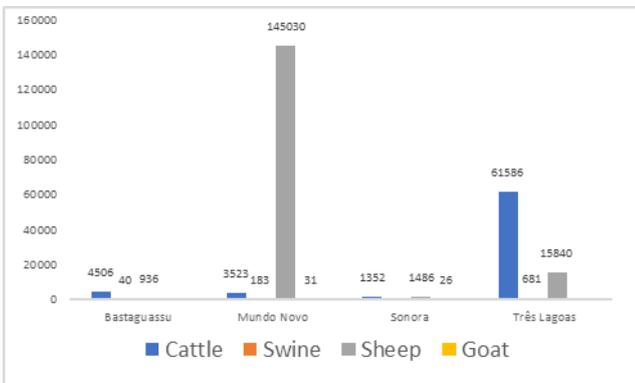
All these inspections of vehicles carrying animals generated a quantity of 171 Infraction and Fine Notices in



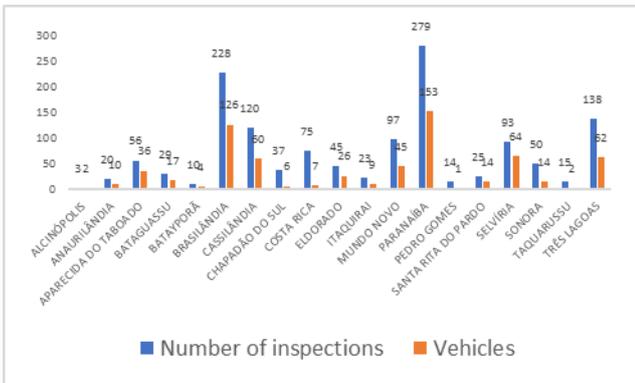
Graph 06: Number of inspections and vehicles surveyed at interstate currency stations in 2021 [18].



Graph 09: Number of animals surveyed by steering wheel inspection teams in municipalities of interstate currency in 2021 [18].



Graph 07: Number of animals surveyed at fixed interstate currency stations in 2021 [18].



Graph 08: Number of inspections and vehicles inspected in municipalities of interstate currency by steering wheel inspection teams in 2021 [18].

c) Cattle population in border regions.

The border region of the state of Mato Grosso do Sul with neighboring countries currently has 3,394,910 cattle and 6,380 buffaloes divided into 12 municipalities, according to data extracted from the e-Saniagro System. The map below characterizes the main sites with bovídios, where red indicates the highest concentration and blue the lowest concentration. According to Figure 06.

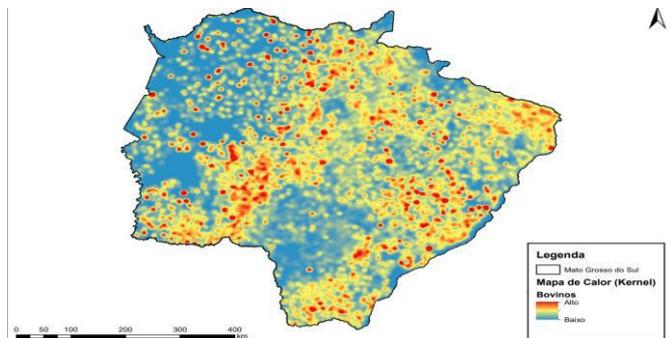


Fig. 15: Cattle Heat Map in Mato Grosso of Sul state [18].

Based on the heat map, we were able to identify the municipalities with the highest number of animals per area, being an important indicator, because if we consider only the data of the amount of animals per municipality, we would not place the municipality of Japorã as a place with a large concentration of goats in the State.

This data is very important for the decision-making of the destinations of the fly-wheel inspections, based on animal movements and in the places with the highest concentration of cattle in the state.

d) Maps of bovine movement networks

Based on the information contained in our e-saniagro systems and analyzed by BI (Business Intelligence), were issued from January 1, 2021 to the present day, 38,526 Animal Transit Guides (GTA), having as origin the border municipalities of Mato Grosso do Sul with neighboring countries, being Corumbá as the largest emitter with 12,859 GTAs followed by Porto Murtinho with 5,854 GTAs and Bela Vista with 5,691 GTAs, transiting with 644,880, 235,510 and 156,970 bovídeos respectively, with main destinations the municipalities of Campo Grande, Rio Verde de Mato Grosso and Aquidauana, as shown in Figure 07 of movement below.

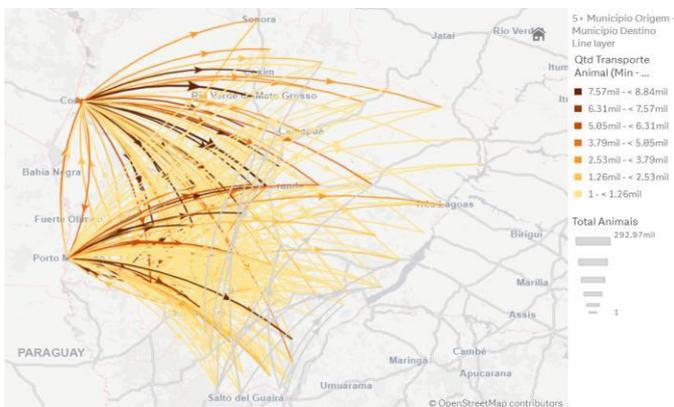
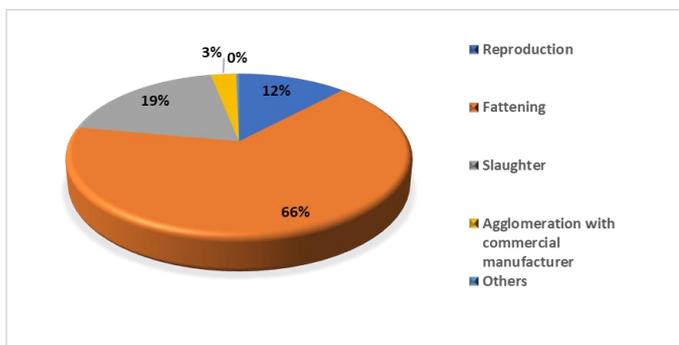


Fig. 16: Movements with origin in municipalities with international border. (IAGRO,2021)

Taking into account the purpose of the movement, the 12 municipalities of the border moved to fatten 934,650 animals, the second as slaughter being the total of 269,400 bovídeos and the third with Reproduction, moving 170,670 heads. graph 10 below.



Graph 10: Purpose of movements of border municipalities [18].

If we consider only the animals that leave the municipalities of the border to establishments for the purpose of agglomeration, we have a quantity of 1,031 GTAs, covering a quantity of 39,880 bovídeos, being again the municipality of Corumbá the largest emitter with 33,740 animals, followed by Porto Murtinho and Ponta Porã, with 2,580 and 1,520 animals respectively. As shown in Figure 08 of movement below.

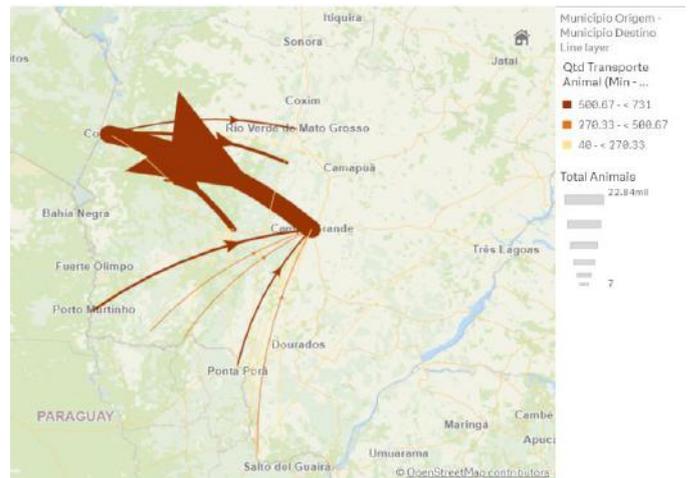


Fig. 17 - Movements with origin in the international border and destination agglomeration events [18].

The municipalities that receive these animals the most for events with agglomeration in 2021 are, Campo Grande, followed by Aquidauana and Rio Negro, totaling 37,907 bovídeos only for these 3 municipalities.

If we consider that the movement of bovídeos in the state is a risk for the reintroduction of diseases, followed by the international frontier and agglomeration events, we can consider this network of movement of animals as the most risky for Foot-and-mouth disease in the State of Mato Grosso do Sul, being very important the control of this traffic to mitigate the health risks arising from this traffic.

Having this analysis as a basis, constant inspections are carried out in the border region, where the steering wheel inspection teams have fixed posts as a support base and move throughout the international border, where we carry out the verification of animals transported regularly, that is, with all the necessary sanitary documentation, and irregular movements, which trigger numerous other health control actions, as herd counts and even sanitary slaughter.

The map below shows the points where steering wheel and fixed posts were carried out throughout the state of Mato Grosso do Sul only in the period from August 1,

2021 to October 18, 2021, where 5258 inspections were carried out.

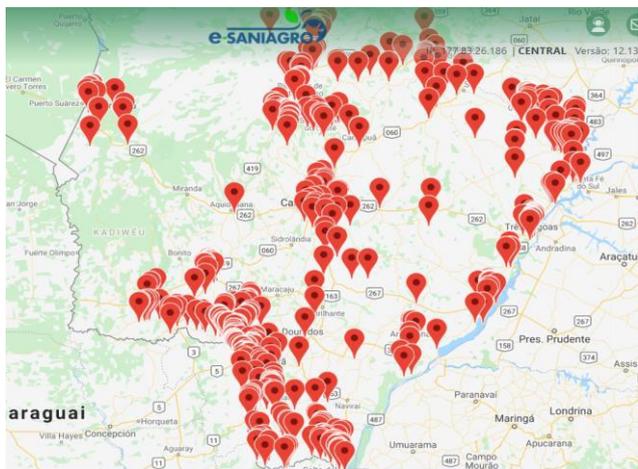
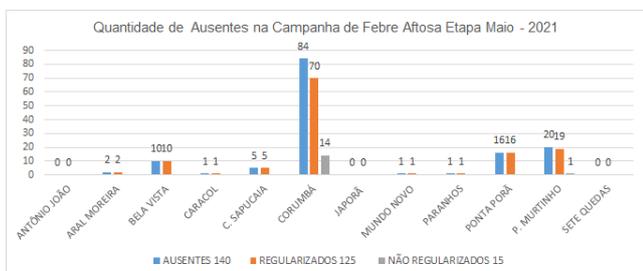


Fig. 18: Traffic inspections occurred in the state in the period from 01/08/21 to 18/10/21 totaling 5273 Inspection Reports [18].

e) Regularization of properties absent from foot-and-mouth disease vaccination

According to updated data from the last vaccination campaign against foot-and-mouth disease in May 2021, the 12 municipalities with international border had an amount of 140 properties absent from vaccination, according to graph 07.



Graph 11: Absent vaccination in the municipalities of the border May/21 [18].

According to the image above, 125 properties were regularized, leaving 15 establishments still without regularization, it is worth noting that these 14 properties are in the municipality of Corumbá, in places of difficult access, where not even with the support of a state plane was possible to carry out regularization, being necessary the support of a helicopter of the Military Police, however this aircraft is under maintenance, and as soon as possible will be used to assist the teams in order to zero the list of absentees, and 1 property is located in the municipality of Porto Murтинho, where vaccination began accompanied by

the inspectors of IAGRO, and could not finish yet due to a judicial issue. Forty-five infringement notices for non-vaccination against foot-and-mouth disease and 34 Infraction Notices were drawn up for lack of vaccine registration [18].

IV. CONCLUSION

Cattle ranching in the state of Mato Grosso do Sul directly and indirectly generates approximately 38,317,000 jobs and moves R\$ 24 billion annually, and this financial movement has increased by 18.2% per year, contributing to the state's GDP being R\$ 23.5 billion.

With the advance to a status of Free Of Aftosa without Vaccination, the health defense service of Mato Grosso do Sul is undergoing changes, where the withdrawal of vaccination should be replaced by actions that strengthen health surveillance, among them, the supervision of animal traffic, which reflects the need for an increase in the structure of animal traffic inspection, products and by-products, in meeting the new model of surveillance in properties, in the performance of fixed posts and steering barriers, strengthening in sanitary education with producers, with prioritization in risk areas with a surveillance system capable of detecting a outbreak of foot-and-mouth disease as soon as possible.

Among our challenges are the international lines with Paraguay and Bolivia, which together have more than 1,500 km of border, and pass through 12 municipalities, in addition to the Pantanal, where we have large properties with difficulties in accessing and managing herds, we also have a very large number of settlements and indigenous villages, which are places more susceptible to the illegal movement of animals and products, and greater direct contact between animals, and agglomeration of people and properties.

All this inspection process for the year 2022 IAGRO will be able to count on the support of 2 aircraft (an airplane and a helicopter), which will optimize the control actions, especially in properties difficult to access in the Pantanal and other regions of the state that are necessary, including the support of 22 state-of-the-art drones.

One of the most important means of transmission of diseases, is linked to the transit of animals, products and by-products, for this, IAGRO has intensified as shown in Figure 09, and it is intended to further intensify

inspections, with the aim of curbing the movement of animals, products and irregular by-products.

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