

IMPACT OF FOREST COVER IN THE AIRPORTS ON THE WILDLIFE

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Abstract:

The occurrence of animal collisions has been present since the early days of aviation and causes billion-dollar losses to civil aviation annually. The current scenario of accidents requires investigation into the contribution of external factors to the airport environment for the presence of wildlife. In this context, the present study aimed to quantify the forest cover and urban infrastructure in the airport safety area (ASA) of civil airports, as well as the occurrence events of wildlife sightings, near-collisions, and collisions with aircraft. 134 airports were analyzed, and raster were generated with the classification of forest and urban areas for the ASA of each airport. Descriptive statistics of the data were performed, as well as an evaluation of whether forest cover and urban infrastructure around airports contribute to potentialize or reduce the number of wildlife collisions recorded in 2020. It was observed that the expansion of urban infrastructure in cities had a positive relationship with the increase in the number of occurrences of wildlife sightings, collisions, and near-collisions with aircraft at Brazilian airports for the analyzed period. The influence of forest cover in the ASA of airports did not return significant results, being a factor that requires further studies to verify its relationship with wildlife events.

Keywords: Wildlife hazard, wildlife collision, safety area, forest area, urban growth.

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INTRODUCTION

The occurrence of wildlife collisions has been present since the early days of aviation. Since then, this issue has claimed hundreds of lives and resulted in billion-dollar losses to civil aviation annually (Alencastro 2014). The current scenario of accidents requires investigation into the contribution of external factors to the airport environment for the presence of wildlife. Legislation imposes restrictions on the establishment of enterprises and activities in the vicinity of aerodromes. However, the disorderly expansion of urban areas, combined with the economic attraction potential of airports, subjects the surrounding areas to intense processes of landscape modification, directly affecting habitats and ecological balance. This alteration disrupts the living conditions and food availability for wildlife (Silva 2018).

According to Marateo et al. (2011), airports often represent attractive locations with resources available for some species of animals, especially birds adapted to open and rural areas. The buildings and trees around airports add feeding resources, nesting and resting sites for many species and at different heights (Sodhi 2002, Froneman 2000). Therefore, it is essential to evaluate land use and cover in the vicinity of aerodromes, as according to CENIPA, the greatest risk of bird strikes occurs during takeoff and climbing procedure, when the aircraft is close to the ground, with a full fuel load, a high angle of attack, low speed, little maneuvering margin, and close to performance limits (Brasil 2011).

A wildlife strike is defined as an event where at least one of the following occurs: crew perceives the collision; evidence or damage is identified on the aircraft by aerodrome or aircraft maintenance personnel; animal carcass is located within 60 meters of the runway or taxiway, as well as within 300 meters of the runway end; or wildlife inside or outside the airport has a significant effect on aircraft operations, such as aborted takeoff, runway excursion, go-around to avoid impact, etc. (Santos & Souza 2021).

The management of wildlife risk at aerodromes is based on information from reports of incidents involving wildlife, being one of the pillars for the development of strategies that guarantee airport operation safety. In this sense, the Avian Risk

Management System (SIGRA) is the national database maintained by CENIPA, consisting of an information source for the application of risk assessment criteria established by aviation authorities, as well as the authorization of the Wildlife Management Plan (Santos & Souza 2021).

The CENIPA provides a form for the reporting of events of interest involving wildlife, known as CENIPA Form 15, where aviation professionals involved in activities can report sightings, near-collisions, and bird strikes. This form is based on an electronic form available on the internet, through SIGRA, and the collected data serves for the elaboration of reports for the prevention of aeronautical accidents, as well as the mitigation of wildlife risk in Brazilian aviation. These reports are seen as proactive and predictive prevention within the flight safety context, as well as guides for making decisions in order to avoid future aeronautical accidents. An example of a report is the Wildlife Risk Yearbook, elaborated by CENIPA (Santos et al. 2017).

Controlling the attractiveness of an airport to birds and other wildlife is fundamental for good management. In fact, it is probably more critical than wildlife dispersal in terms of overall risk control. If an airport provides easily accessible resources for wildlife in terms of food, water, shelter, or breeding sites, they will continue to attempt to return despite any dispersal tactics used to discourage them.

According to Resolution No. 04, dated October 9, 1995, established by the National Council for the Environment (CONAMA), the Airport Safety Area (ASA) is defined as a circular area within one or more municipalities, determined from the geometric center of the largest runway of the aerodrome, with a radius of twenty kilometers. The use and occupation of this area are subject to special restrictions due to the attractive nature of fauna. This resolution was enacted in response to the increasing proliferation of degraded areas with inadequate basic sanitation near airports and their relation to the growing occurrence of bird strikes (Moraes 2016).

Data analysis of wildlife collisions, as well as observation and monitoring of wildlife activities, can reveal trends that will help airport authorities identify areas of concern that should be addressed through a well-managed wildlife control program.

The statistics of wildlife collisions can also be analyzed to determine the times of year or day when wildlife control is most needed (ICAO 2017). In this context, this study aimed to quantify the forest coverage and urban infrastructure in the Airport Safety Area (ASA) of civil aerodromes, as well as the occurrences of wildlife sightings, near misses, and collisions with aircraft that pose a risk to airport operation safety. Rasters were generated with the classification of forest and urban areas for the ASA of each aerodrome, and descriptive statistics were performed on the data. Furthermore, the study evaluated whether forest coverage and urban infrastructure in the vicinity of the aerodromes contribute to the potential increase or decrease in the number of recorded wildlife collisions in 2020.

MATERIAL AND METHODS

For this study, civil aviation aerodromes listed in the statistical summary of aerodromes published by CENIPA, which reported at least one wildlife sighting, collision, or near collision with aircraft in 2020 were selected. Thus, out of the 464 listed aerodromes, only 135 reported wildlife occurrences in that year. Additionally, the SBFN aerodrome was excluded from the study, due to the island of Fernando de Noronha not being included in the land use and land cover classification used in this work, resulting in a total of 134 aerodromes distributed throughout Brazil.

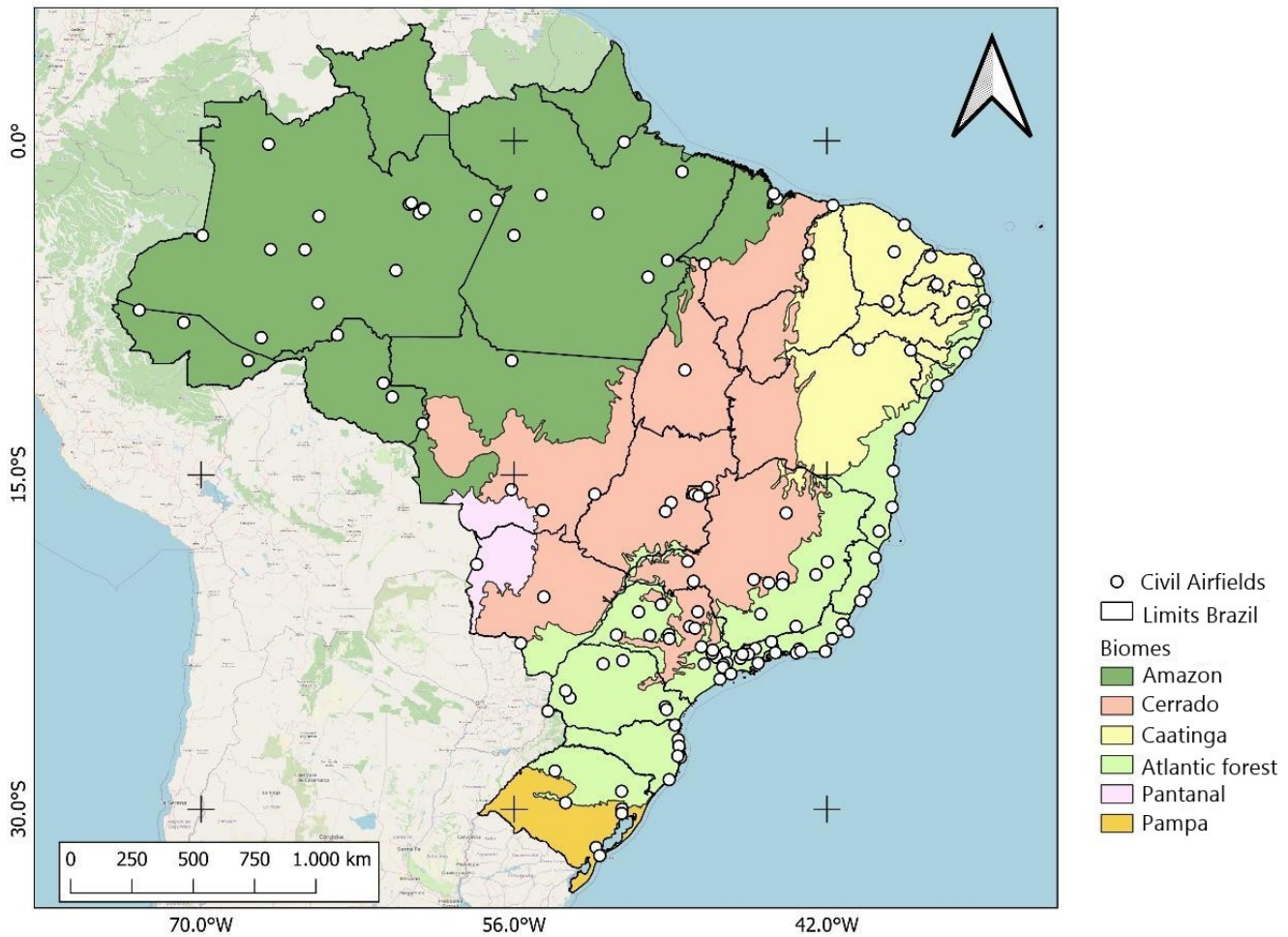


Fig. 1 Geographic distribution of Brazilian civilian airports covered by the study. Data source: Aisweb, IBGE, and Open Street Maps.

Since the data was not directly available in a structured format, a web scraping process was used to collect semi-structured data on April 10th, using the Python programming language and the Selenium library from three distinct websites. The codes used in each step are available on GitHub

(https://github.com/fabiomarciano7/web_scraping_aerodromos). The wildlife occurrence data used in this study were extracted from the Avian Risk Management System (SIGRA), which is the national database maintained by the Aeronautical Accidents Investigation and Prevention Center

(CENIPA) of the Brazilian Air Force since 2011. For each aerodrome, wildlife sighting, near-collision, and collision data with aircraft in 2020 were collected.

The coordinates of each aerodrome were extracted from the Aisweb website, managed by the Department of Airspace Control (DECEA), which is the official source of aeronautical information in Brazil. The collected coordinates were in degrees, minutes, and seconds format, which were converted to decimal degrees for ease of use in GIS environments. It was also necessary to collect information on the time zone in which the aerodromes were located, which was done using an online geographic data query tool provided by Montana State University. The data on wildlife events, coordinates, and time zone for each aerodrome were organized into a spreadsheet using Microsoft Excel, which was then imported into QGIS software as a shapefile with point geometry. In the GIS environment, the points of each aerodrome were separated into different shapefiles according to the time zone in which they were located (Figure 2A). A 20 km radius buffer was then created around each point (Figure 2B), resulting in a shapefile that corresponds to the Airport Safety Area (ASA) of each aerodrome.

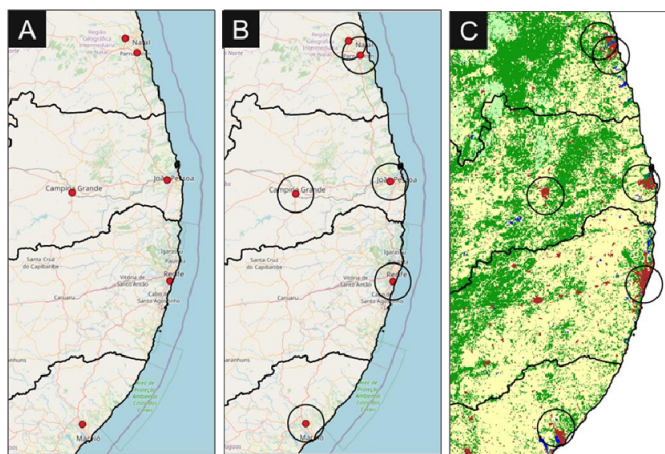


Fig. 2 (A) Detail in the Brazil zone 25, displaying the coordinates of the aerodromes (red dots) after importing into the QGIS software, and (b) Result of the buffer of the aerodromes' safety area. C. Land use and land cover classification from the MapBiomias plugin v1.4.

To classify land use and cover in the ASA of the aerodromes, data from the Annual Mapping of Land Use and Cover in Brazil (MapBiomias) project were used. MapBiomias is an open and collaborative monitoring initiative created in 2015 involving universities, NGOs, and technology

companies, which promotes the annual mapping of land use and cover in Brazil over the past three decades. The MapBiomias Collection v1.4 plugin was used, in which forest cover and urban infrastructure classes were selected for 2020 and exported as raster files for each time zone, using a UTM SIRGAS 2000 flat projection and a spatial resolution of 30 m, corresponding to the pixel size of Landsat images used by MapBiomias.

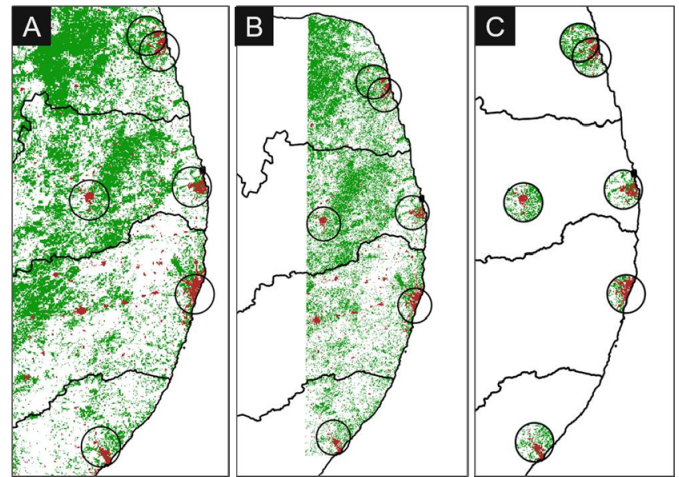


Fig. 3 A. Selection of forest and urban area classes. B. Clipping of forest and urban area classes for zone 25. C. Clipping of forest and urban area classes for the boundaries of the Airport Safeguarding Area (ASA) of each aerodrome in zone 25

The forest area was then cut to the extent of the ASA of all the studied aerodromes, and using the raster calculator (Figure 3C), the first spectral band of each raster was selected and extracted, indicating the pixel value for forest cover, which was 18 in the MapBiomias classification. The file generated by this process becomes binary, where pixels with a value of 1 represent the forest class and those with a value of 0 do not contain information, as shown in Figure 4A. The raster symbology was adjusted to "unique value palette" for visualization purposes, and the "transparency" tab was used to hide pixels with a value of 0, so they would not be included in the area calculation (Figure 4B). The same process was used for urban infrastructure, with the pixel value changed to 175 in the raster calculator.

In this way, the result of the number of pixels in the ASA obtained through the zonal statistics tool was multiplied by the area of 1 pixel and divided by 10,000 to obtain the forest area and urban area in the ASA in hectares.

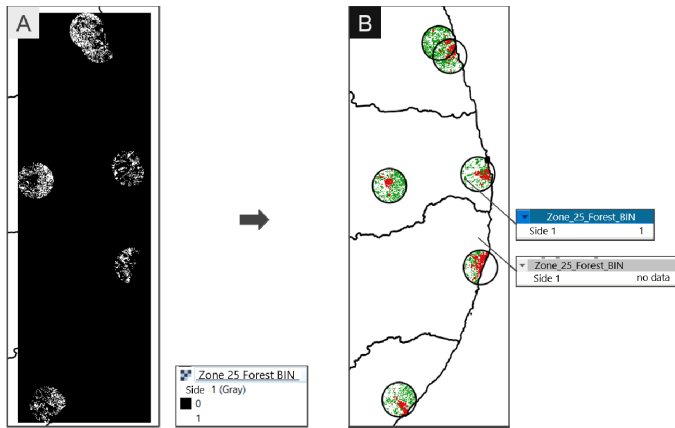


Fig. 4 A. Binary raster file, where pixels with a value of 1 represent the forest class and those with a value of 0 do not contain information. B. Symbolization adjustment and classification result after hiding pixels with a value of 0.

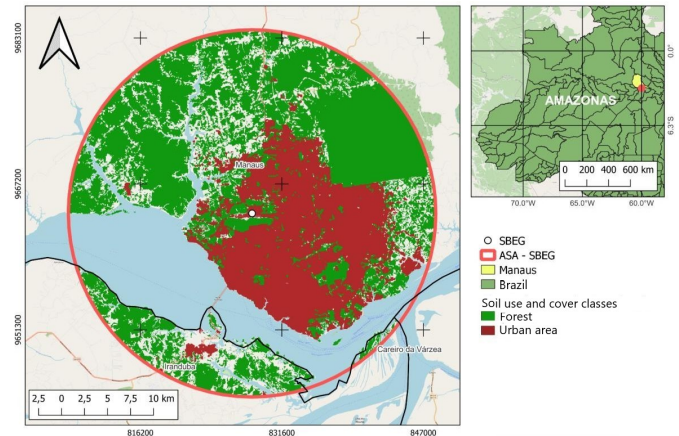


Fig. 5 Land use and land cover classification map within the Airport Safeguarding Area (ASA) of Manaus/Eduardo Gomes International Airport (SBEG). Data sources: MapBiomias, IBGE, and OpenStreetMaps.

The forest coverage and urban infrastructure area within the ASA of each aerodrome were added to the table containing the data of wildlife occurrences reports. Subsequently, descriptive statistics of the data were conducted using Microsoft Excel software, with results being separated by biome. Furthermore, the relationship between forest coverage, urban infrastructure area, and the number of wildlife occurrences recorded at the aerodromes in the year 2020 was examined. As the data represents a cross-sectional study, the Ordinary Least Squares (OLS) regression model was employed for analysis to determine if there is a positive or negative correlation between the forest and urban area within the aerodrome surface area and the number of occurrences recorded at each location. For this analysis, Gretl software was utilized, into which the collected data table was inputted, and the analysis was generated. The regression models were fitted with wildlife occurrences as the dependent variable.

RESULTS

The 134 analyzed civilian aerodromes reported a total of 7,815 wildlife-related occurrences in the year 2020, including 2,003 collisions, 559 near-collisions, and 5,253 sightings. Descriptive statistics by biome are presented in Table 1, with the Pantanal biome being excluded due to having only one aerodrome with occurrence records in the studied period.

The Atlantic Forest biome had the highest number of aerodromes reporting occurrences, along with the highest mean for wildlife sightings and the samples with the highest numbers of near-collisions and sightings. Additionally, it presented the highest mean of urban area and contained samples with the lowest forest coverage area and highest urban area recorded in the study.

The Cerrado biome recorded the highest mean of collisions, as well as the sample with the highest number of collisions during the period. The Pampa biome showed the highest mean of near-collisions during the same period. All biomes had aerodromes that did not report any wildlife-related events in the year 2020. Moreover, 52.9% of the aerodromes recorded less than 10 occurrences in the studied period.

The adjusted model to investigate the influence of urban area expansion on the number of wildlife occurrences is depicted in **Fig. 8**, where the urban infrastructure area within the ASA of the aerodromes returned a significant result at 1% confidence level in explaining the report of fauna occurrences in the year 2020, with a coefficient of determination of 0.36. Therefore, besides demonstrating a positive relationship, it indicates that a 1% increase in urban area within the ASA leads, on average, to a 0.92% increase in the occurrence of wildlife events. The model residuals displayed normal distribution at the 5% significance level (Figure 10), and the regression line adjustment can be observed in **Fig. 9**.

Table 1. Descriptive statistics of the collected data for the 134 Brazilian civilian aerodromes in the year 2020.

Biome	Analyzed data	Mean	Median	Standard Deviation	Min	Max
Amazon Forest n= 32	Forest Area (ha)	1.250,3	55.658,2	28.405,6	18.798,2	124.888,1
	Urban Area (ha)	5.935,6	2.228,0	8.922,6	0,0	32.055,2
	Collision	6,4	1,0	11,5	0,0	49,0
	Near-collision	5,2	0,5	15,4	0,0	68,0
	Sighting	16,7	2,0	37,7	0,0	181,0
Caatinga n= 9	Forest Area (ha)	1.896,6	48.822,4	32.299,5	19.135,4	97.103,3
	Urban Area (ha)	1.954,1	9.134,3	14.218,7	1.090,5	47.201,9
	Collision	9,0	7,0	11,8	0,0	37,0
	Near-collision	0,9	0,0	2,0	0,0	6,0
	Sighting	8,0	2,0	10,3	0,0	27,0
Cerrado n= 26	Forest Area (ha)	3.839,3	31.116,1	20.341,6	9.197,0	95.364,1
	Urban Area (ha)	4.725,1	9.361,0	13.500,9	1.282,5	55.412,3
	Collision	21,2	7,5	34,8	0,0	157,0
	Near-collision	2,4	0,0	6,0	0,0	26,0
	Sighting	31,3	4,5	83,8	0,0	415,0
Atlantic Forest n= 61	Forest Area (ha)	7.102,5	22.287,6	17.544,3	307,6	75.500,4
	Urban Area (ha)	0.373,8	13.563,1	22.190,7	1.651,9	101.886,5
	Collision	18,2	4,0	32,8	0,0	150,0
	Near-collision	4,8	1,0	19,0	0,0	145,0
	Sighting	60,5	6,0	181,2	0,0	1.270,0
Pampa n= 5	Forest Area (ha)	1.807,4	26.296,7	13.343,7	2.456,6	37.632,8
	Urban Area (ha)	6.920,5	6.909,3	17.288,3	5.536,9	45.700,4
	Collision	11,2	1,0	18,3	0,0	43,0
	Near-collision	6,0	0,0	12,9	0,0	29,0
	Sighting	17,4	1,0	30,6	0,0	71,0

In recent years, there has been an increase in occurrences involving wildlife hazards at airports. According to Alencastro (2014), the growth in reported collisions is partially explained by the significant increase in flight operations occurring each year. However, as stated by Blackwell et al.

(2009), another contributing factor to this increase is the expansion of urban areas into natural ecosystems, leading to wildlife pressures in areas suitable for their establishment or colonization of previously uninhabited areas. Changes in land use and land cover patterns have diverse effects on ecological balance and habitat conditions. As per Silva (2018), land cover transitions have the potential to attract wildlife, facilitating their interaction with anthropogenic environments and activities.

In the Amazon and Caatinga biomes, the highest means of forest coverage and the lowest means of urban area. These biomes also exhibited the lowest average numbers of collisions and sightings recorded. However, the result of the regression model adjusted for the forest coverage area within the ASA of the aerodromes was not significant in explaining the occurrences with fauna in the year 2020 (Figure 6). Furthermore, the model's residuals did not exhibit a normal distribution, compromising the accuracy of the OLS estimators. The regression line adjustment can be observed in Figure 7. Thus, despite the descriptive statistics indicating a possible relationship where larger forest areas within the ASA of aerodromes may lead to fewer fauna occurrences, the regression cannot confidently affirm such a relationship.

From the land use and land cover classification within the ASA of the aerodromes, it was possible to generate thematic maps, as exemplified in Figure 5, concerning the ASA of Manaus/Eduardo Gomes International Airport (SBEG). The map shows forest classes represented in green, and the urban area quantified in this study displayed in red. The airport where there is a greater concentration of forest in the surrounding area.

In the Figure 8 is possible to observed the descriptive statistics where the Atlantic Forest, Cerrado, and Pampa biomes showed the highest means of urban area within the ASA of the aerodromes and also the highest means of wildlife occurrences during the period. Urbans areas proximity to aerodromes increases the chance of the wildlife invading airports. Airports are often located on the outskirts of major cities, and these areas have experienced increased occupancy due to population growth and unregulated land use. It is common to find settlements with inadequate

sanitation near airports (do Nascimento et al., 2010). Consequently, as stated by Bastos (2000), in Brazil, the issue of bird collisions is mainly associated with urban areas where an increase in bird populations is observed due to urban growth in the periphery.

Model 2: MQO, using observations 1 – 134
 Dependent Variable: log_occurrences

	<i>Coefficient</i>	<i>Standard Error</i>	<i>ratio-t</i>	<i>p-value</i>	
const	5.22212	2.01632	2.590	0.0107	**
log_ForestArea	-0.274263	0.195460	-1.403	0.1629	
Dependent var. mean	2.402061		D.P. var. dependent	1.885700	
Residual sum of squares	465.9795		Regression E.P.	1.878869	
R-quadrat	0.014697		R-adjusted quatrate	0.007232	
F (1. 129)	1.968887		P-value(F)	0.162914	
Verissimilitude log	-273.6400		Akaike criterion	551.2800	
Schwarz criterion	557.0757		Hannan-Quinn criterion	553.6352	

Residual normality test -
 Null hypothesis: the error has a normal distribution
 Test statistic: Qui-quadrat (2) = 12.5282
 with p-value = 0.0019341

Fig. 6 Result of the Ordinary Least Squares (OLS) model for the logarithm of forest area within the Airport Safeguarding Area (ASA) of the aerodromes and the logarithm of the number of wildlife-related occurrences in the year 2020.

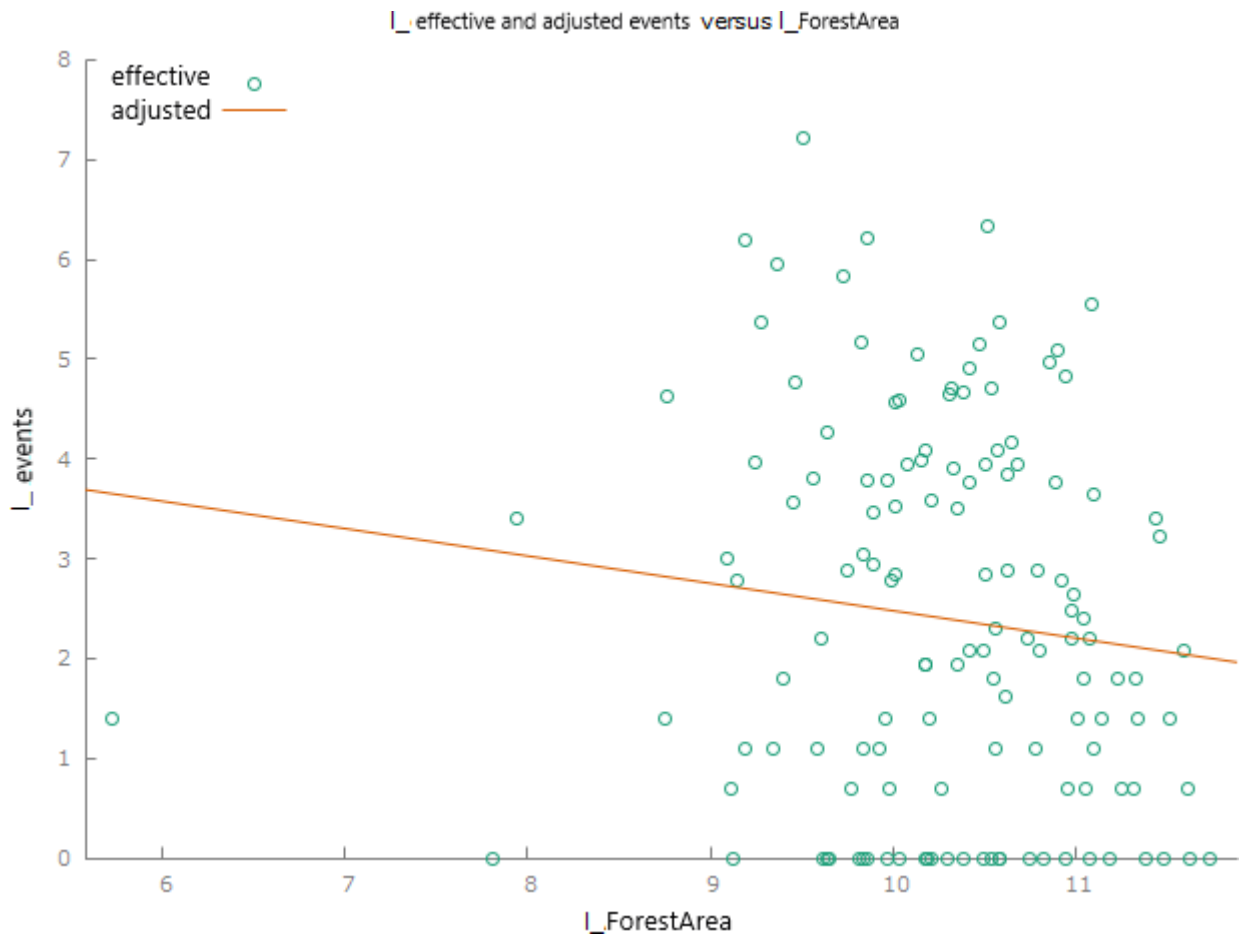


Fig. 7 Regression line fitting for the logarithm of forest area within the Airport Safeguarding Area (ASA) of the aerodromes and the logarithm of the number of wildlife-related occurrences in the year 2020.

Model 2: MQO, using observations 1 – 134 (n = 131)
 Missing or incomplete observations were ignored: 3
 Dependent Variable: log_occurrences

	<i>Coefficient</i>	<i>Standard Error</i>	<i>ratio-t</i>	<i>p-value</i>	
const	- 5.90984	0.983216	-6.011	<0.0001	***
log_UrbanArea	0.924467	0.108222	8.542	<0.0001	***
Dependent var. mean	2.414652		D.P. var. dependent	1.863448	
Residual sum of squares	288.3224		Regression E.P.	1.495011	
R-quadrat	0.361295		R-adjusted quadrate	0.356343	
F (1. 129)	72.97106		P-value(F)	03.18e-14	
Verissimilitude log	- 273.5527		Akaike criterion	479.1054	
Schwarz criterion	484.8558		Hannan-Quinn criterion	481.4421	

Residual normality test -
 Null hypothesis: the error has a normal distribution
 Test statistic: Qui-quadrat (2) = 0.314556
 with p-value = 0.854467

Fig. 8 Result of the Ordinary Least Squares (OLS) model for the logarithm of urban infrastructure area within the Airport Safeguarding Area (ASA) of the aerodromes and the logarithm of the number of wildlife-related occurrences in the year 2020.

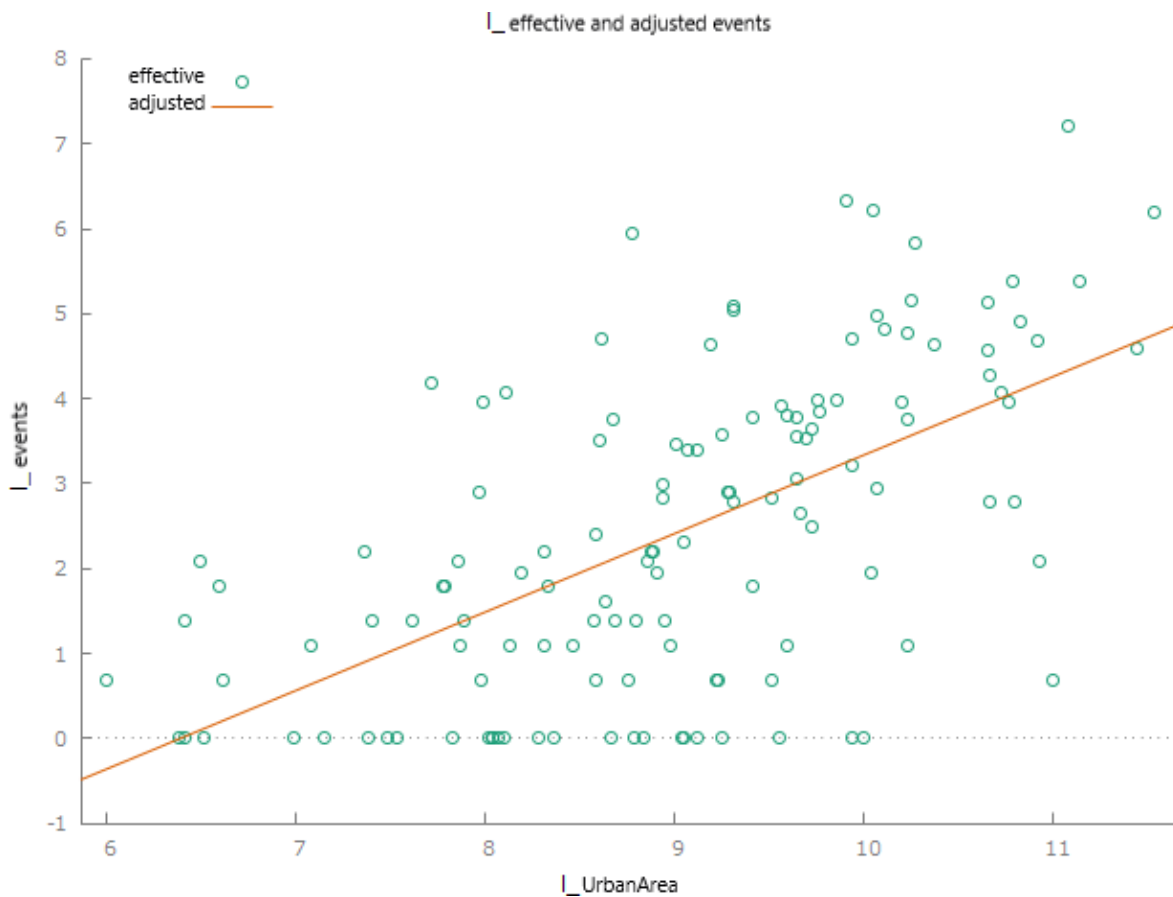


Fig. 9 Regression line fitting for the logarithm of urban infrastructure area within the Airport Safeguarding Area (ASA) of the aerodromes and the logarithm of the number of wildlife-related occurrences in the year 2020.

CONCLUSION

Based on the results obtained in this study, it is observed that the expansion of urban infrastructure

in cities showed a positive relationship with the increase in the number of wildlife sighting, collision, and near-collision occurrences with

aircraft at Brazilian aerodromes during the analyzed period. The influence of forest coverage area within the ASA of the aerodromes did not yield significant results, suggesting that this factor requires further investigation to ascertain its relationship with wildlife events. Additionally, raster data with the classification and quantification of forest coverage and urban infrastructure area within the ASA of the 134 aerodromes that reported wild life related events were generated, providing relevant information for future studies that require such data.

The results reinforce the importance of monitoring occurrences at aerodromes to feed the database, aiming to ensure the quality of available information and enabling more accurate and objective analyses. This supports the development of risk mitigation measures in wildlife risk management plans, ensuring the safety of Brazilian airport operations. It is suggested to evaluate factors related to urban expansion that may contribute to wildlife attraction, such as landfills and areas with sanitation issues near airports, to provide more clarity to the presented models.

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