Wildlife corridors between the Brasília National Park and the Águas Emendadas Ecological Station

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Abstract

This study aimed to suggest wildlife corridor (WLC) between the Brasília National Park (PNB) and the Águas Emendadas Ecological Station (EEAE) in the Federal District, Brazil. The ArcMap 10.5 was used for data processing and map creation. Raster images of land use, land cover, and population density were obtained based on adaptations of vectorized files. These raster maps were reclassified as "cost" maps. Subsequently, the raster calculator function was used to obtain the map of total cost, which, together with the vectorized file of the PNB—using the cost distance and cost back link functions—resulted in two raster maps. Afterwards, these maps, together with the vectorized EEAE file, gave rise to the map containing the WLCs. Two WLCs were suggested, one "larger," with 34,905.44 ha, and the "smaller" one, with 15,487.78 ha. The smaller one consisted predominantly—91.26 %—of the classes of land use and occupation of grassland, forest, and savanna formations and permanent preservation areas (PPA), while the larger one consisted of 78.48 % of grassland, forest and savanna formations, PPA, and conservation units. The quality of the natural environment connecting the flora and fauna between the conservation units for the smaller WLC is therefore guaranteed by the greater representativeness of the vegetation domain of *Cerrado*, made up of the classes of use and occupation of grassland, forest and savanna formation, in the smaller WLC than in the larger WLC (2.3 times the size of the smaller WLC).

Keywords: Geographic Information System. Land use and occupation. Population density

Introduction

Conservation Units (CU) are territorial spaces created and protected by public authorities (at the federal, state, district, or municipal level) that assure the conservation and preservation of biodiversity and genetic resources of natural environments, in terms of water, soil, geology, geomorphology, speleology, archaeology, paleontology, and culture (BRASIL, 2000; ARAÚJO, BASTOS, 2019).

The Brasília National Park (PNB) is located in the northwest of the Federal District, occupying 7.31 % of its territory, with a predominant *Cerrado sensu stricto* vegetation domains, and containing the Bananal and Santa Maria/Torto creeks that flow into Lake Paranoá, which is part of the São Bartolomeu River Basin. The Águas Emendadas Ecological Station (EEAE) is a CU and has unique ecological characteristics, such as the spring found within the station that originates two streams that go in opposite directions, the "Brejinho" and "Vereda Grande," draining their waters into the Paraná river basin to the south and the Araguaia/Tocantins river basin to the north (BAGATINI, 2006).

Despite the ecosystemic importance of CUs, it is common for them to be isolated, which can compromise biodiversity conservation. Therefore, it is important to build "connective natural structures" (CESSA *et al.*, 2022), i.e., wildlife corridors (WLCs).

Establishing the locations for proposed WLC allocations is, above all, a multi-criteria problem, in which a set of factors and the weighted importance of each determine the areas suitable for installing these corridors. In general, the factors considered when integrating information to establish WLCs are land use and occupation—comprising the classes of agriculture, natural vegetation, permanent protection areas and

legal reserves, anthropized areas (urban and/or anthropized in some way, as well as road networks), bodies of water and soil slope (PIMENTEL, 2007; TAKAHASHI *et al*., 2021).

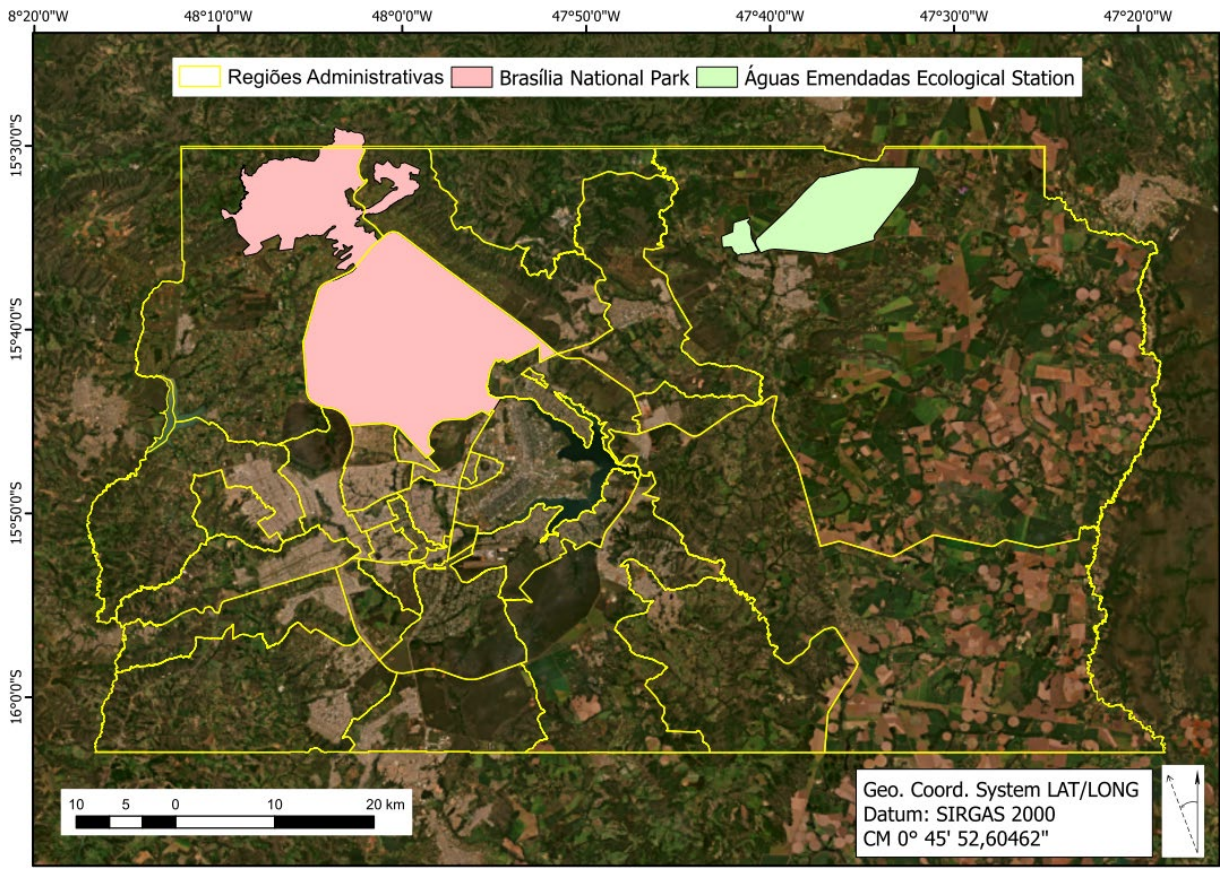
The final product of this multi-criteria analysis is a map of the spatial distribution of pixels with values of greater or lesser weight, depending on the weights assigned to the indicators, which can be used to evaluate cost scenarios via geoprocessing (ALEXANDER *et al*., 2016; DOS SANTOS *et al*., 2020). With this in mind, this study was carried out in the Federal District, Brazil, with the aim of proposing sites for the implementation of WLCs between the PNB and the EEAE.

Material and methods

This study suggested the allocation of WLCs in the Federal District, Brazil, in the physical space between the PNB and the EEAE, in the *Cerrado* biome (Figure 1). The spatial processing of the data and the creation of thematic maps were conducted using the ArcMap 10.5 geographic information system.

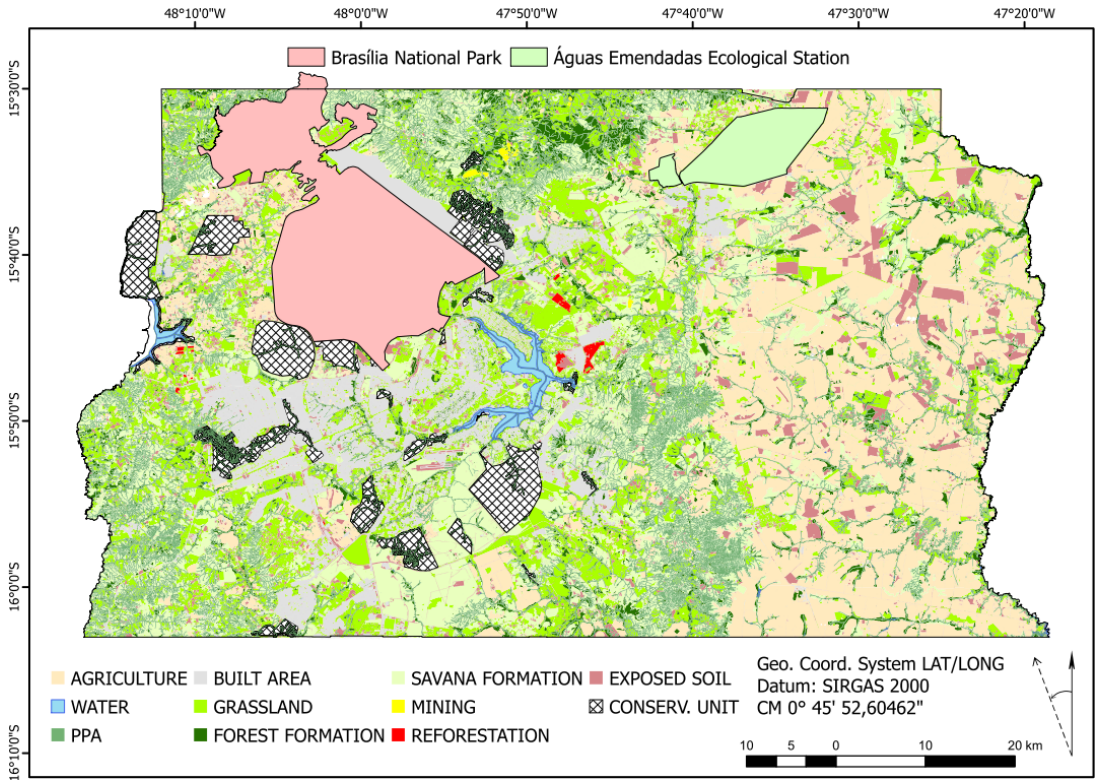
For the spatial allocation of WLCs, the methodology proposed by Louzada *et al.* (2010) was followed. First, raster images of land use and occupation and population density were obtained from adaptations of vectorized files of these same characteristics (Figures 2 and 3), which were provided by SEDUH (2023).

Figure 1. Location of the study area in the Federal District, Brazil.



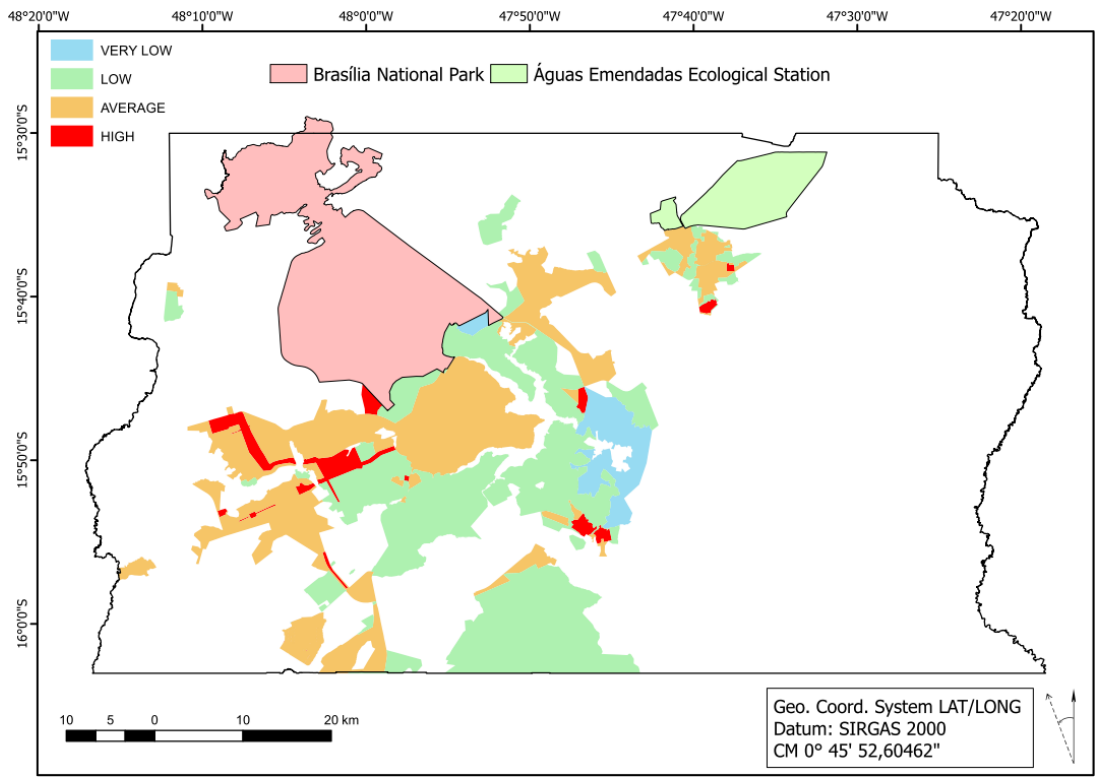
Source: prepared by the authors

Figure 2. Land use and occupation in the Federal District, Brazil.



Source: adapted from SEDUH (2023)

Figure 3. Population density in the Federal District, Brazil.



Source: adapted from Louzada *et al*. (2010)

The raster maps of land use, land cover, and population density were reclassified (reclassify algorithm function) according to Tables 1 and 2: "costs" were assigned to the classes, creating cost raster maps of these characteristics. A cost raster image (scale 1 to 100) represents some factor, or a combination of factors, that influence the establishment of a route in a given area.

After obtaining the cost maps of land use and occupation and population density, the total cost raster map was obtained using the raster calculator algorithmic function. Equation 1 was used for this purpose. The value (weight) of 0.50 described in Equation 1 was obtained following Saaty (1977), which deals with the decision of the problem at hierarchical levels. To this end, a pairwise comparison decision matrix was used, employing the Saaty fundamental scale, which linearly defines the hierarchy of importance between predefined factors (in this case, land use and occupation and demographic density). The values of the Saaty scale were established and applied to the cells of the Analytic Hierarchy Process (AHP) command in ArcMap 10.5, which allowed the data to be modeled considering various factors involved in diagnostic and decision-making processes (research, information gathering, verification of hypotheses, and possibilities), helping the objective integration of indicators (MORANDI *et al*., 2020; SAHOO *et al*., 2016; SCHWAIDA *et al.*, 2017).

Table 1. Classes and costs for land use and occupation in the Federal District, Brazil.

Land use and occupation	Cost
Agriculture	100
Water	1
Permanent Preservation Areas (PPA)	1
Built-up area	100
Grassland	1
Forest formation	1
Savanna formation	1
Mining	10
Reforestation	50
Exposed soil	80
Conservation unit	1

Source: adapted from SEDUH (2023)

Total cost = (land use and occupation raster image*0.50)+(population density raster image*0.50)

With the raster image of the total cost and the vectorized file of the PNB, using the algorithmic functions cost distance and cost back link, two more raster maps were obtained, which were used together with the vectorized file of the EEAE to create the map containing the WLCs using the cost path algorithmic function. The width established for each WLC was set at 10 % of its total length, in accordance with the National Environment Council (CONAMA), CONAMA Resolution no. 9 of October 24, 1996.

Figure 4 shows the flow used to process the data and images (maps).

Results and discussion

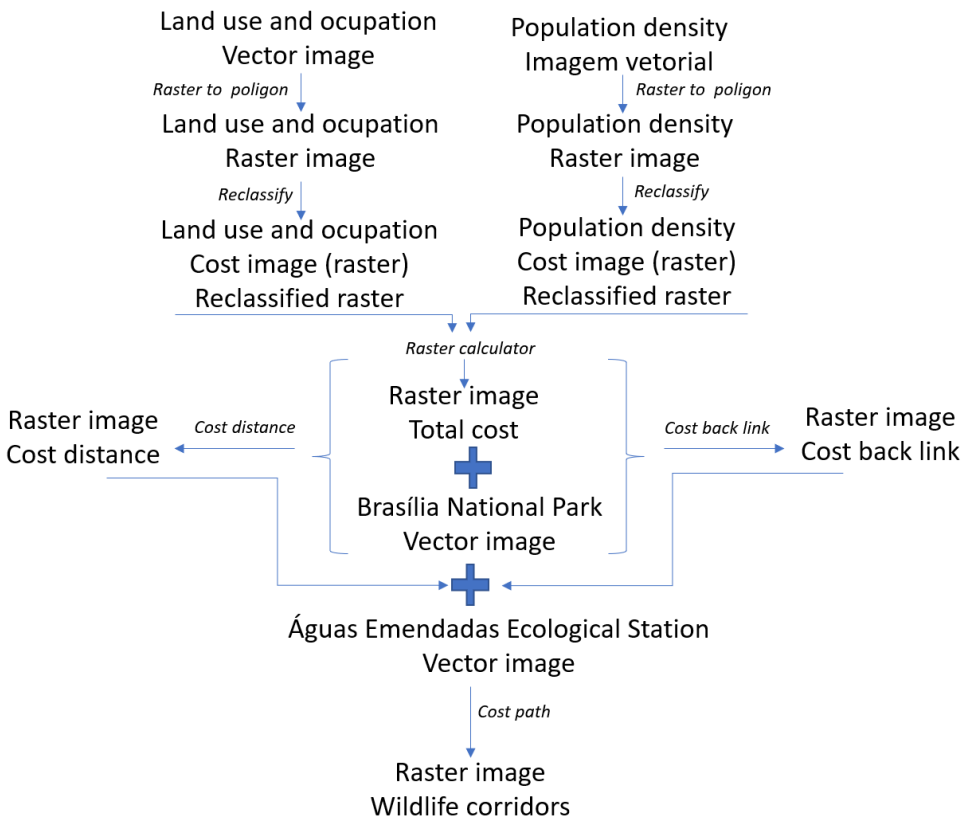
The first WLC between the PNB and the EEAE in the Federal District was 37 km long and covered an area of 15,488.51 ha, and the second one was 64.75 km long and covered an area of 34,905.44 ha (Figure 5). Their limits are established with a width buffer of 10 % of their length, in accordance with CONAMA Resolution no. 9 of October 24, 1996. Figure 6 shows the places of origin (starting from the PNB) and arrival (destination in the EEAE) of the smallest and largest WLCs.

Table 2. Classes and costs for demographic density in the Federal District, Brazil.

Population density	Cost
Very low	1
Low	1
Average	50
High	100

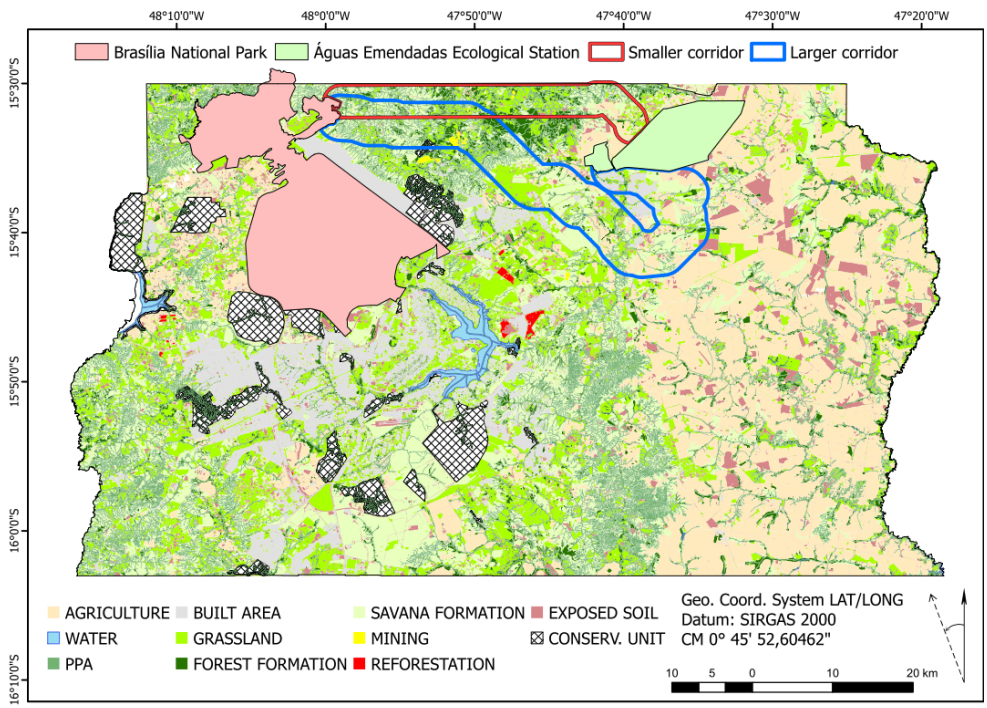
Source: adapted from SEDUH (2023)

Figure 4. Flow used to process data and images (maps).



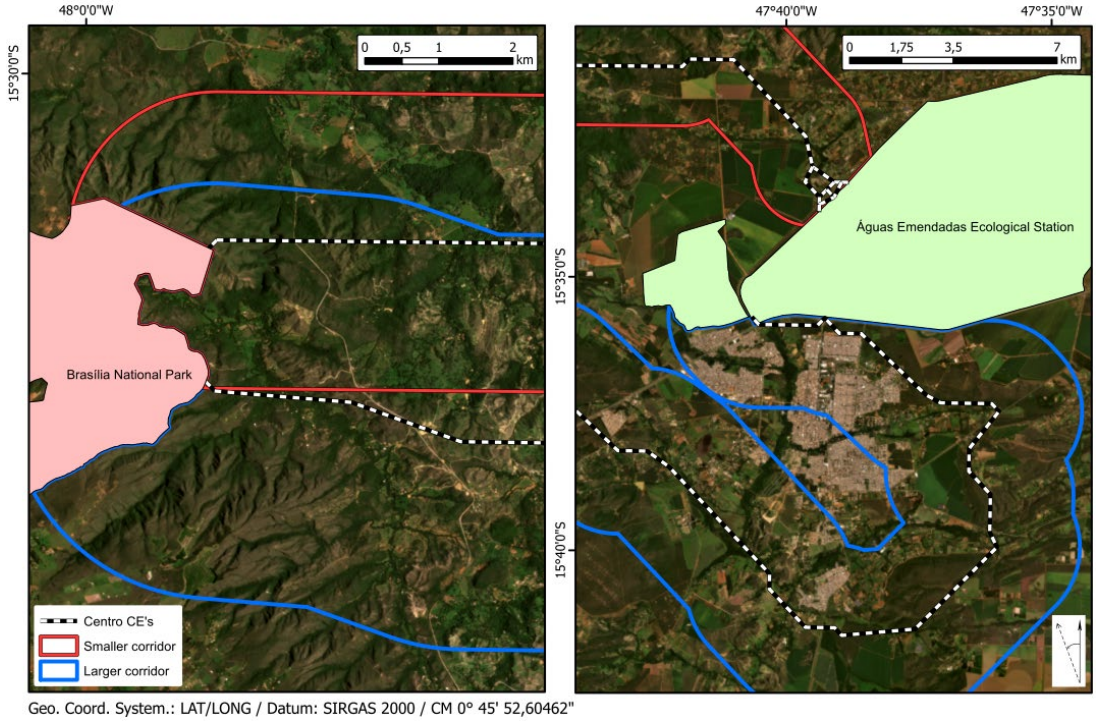
Source: prepared by the authors

Figure 5. Suggested wildlife corridors between the Brasilia National Park and the Águas Emendadas Ecological Station in the Federal District, Brazil.



Source: prepared by the authors

Figure 6. Places of origin (starting from the Brasília National Park) and arrival (destination in the Águas Emendadas Ecological Station) of the smaller and larger wildlife corridors. Federal District, Brazil.



Source: prepared by the authors

The area of the smaller WLC consisted in 91.26 % of the classes of land use and occupation of grassland, forest and savanna formations and permanent preservation areas (PPA), while the area of the larger WLC consisted in 78.48 % of grassland, forest and savanna formations, PPA and conservation units (Table 3). The smaller WLC had 5.91 % of its total area covered by the Agriculture and Built-up Area classes, while the larger WLC had 17.24 % of its total area covered by these classes.

This discussion highlights the importance of reflecting on the aspects that are to be prioritized

Table 3. Area (hectares) corresponding to each class of land use and occupation contained in the smaller and larger wildlife corridors.

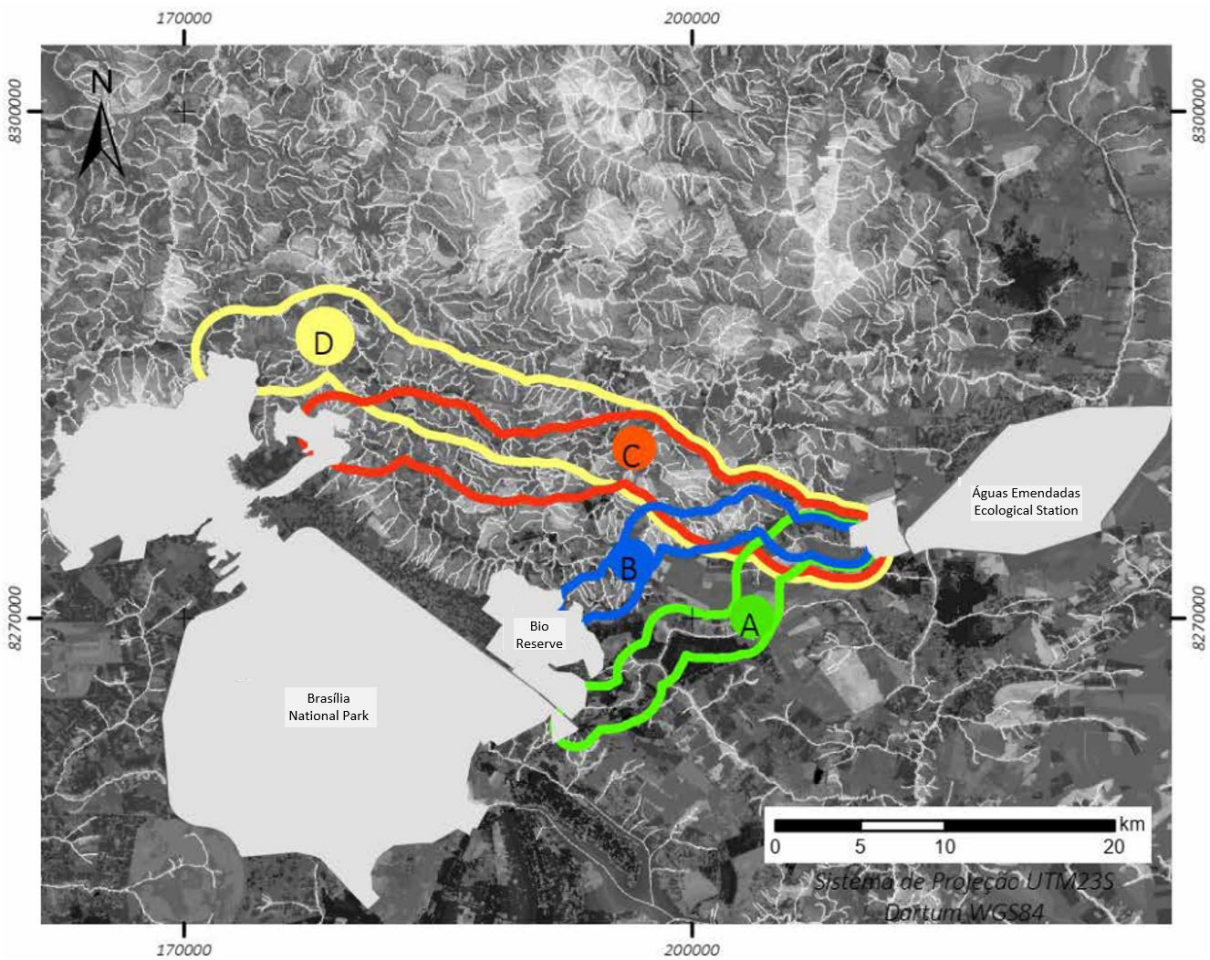
Land use and occupation	SMALLER WLC	LARGER WLC
Agriculture	842.77	4,195.156
Water	0.35	14.099
PPA	3,228.27	4,962.93
Built-up area	40.77	1,824.02
Grassland	3,777.55	7,480.26
Forest formation	2,943.52	4,004.942
Savanna formation	4,219.72	1,0852.86
Mining	38.02	172.95
Reforestation	1.50	4.89745
Exposed soil	399.06	1,301.16
Conservation unit	0.00	92.17

in the implementation of WLCs, especially their quality and not only their extension. The smaller WLC possibly provides better conditions for the natural environment, specifically the vegetation domain of the *Cerrado* biome distributed in the classes of grassland, forest and savanna formations, and the mere 40.77 ha of built-up area. Although 2.3 times larger, the larger WLC had lower proportions of these *Cerrado* plant domain, meaning that it would provide lower quality of the natural environment when connecting the flora and fauna between the points studied (PNB and EEAE).

Takahashi *et al*. (2021) studied the feasibility of wildlife corridors between the PNB and the EEAE. The most viable wildlife corridor proposed (Figure 7, wildlife corridor C) would start from the same location as the WLCs proposed here and would be more similar to the larger corridor. Furthermore, wildlife corridor C would intersect 70 % of its area with forest fragments of natural vegetation. It should be noted that corridor D in Figure 8 lies partly outside the boundaries of the Federal District and was therefore not used for comparison with our WLCs.

In the work by Andrade (2020), it can be seen that route 1, similar to corridor C in Figure 7, proposed by Takahashi *et al.* (2021), was one of the most suitable for the transition between fragments of natural vegetation proposed for the maned wolf (*Chrysocyon brachyurus Illiger*, 1815), but there are physical barriers constituted

Figure 7. Proposed wildlife corridors between the Brasilia National Park and the Águas Emendadas Ecological Station. Federal District, Brazil.



Source: Takahashi *et al*. (2021).

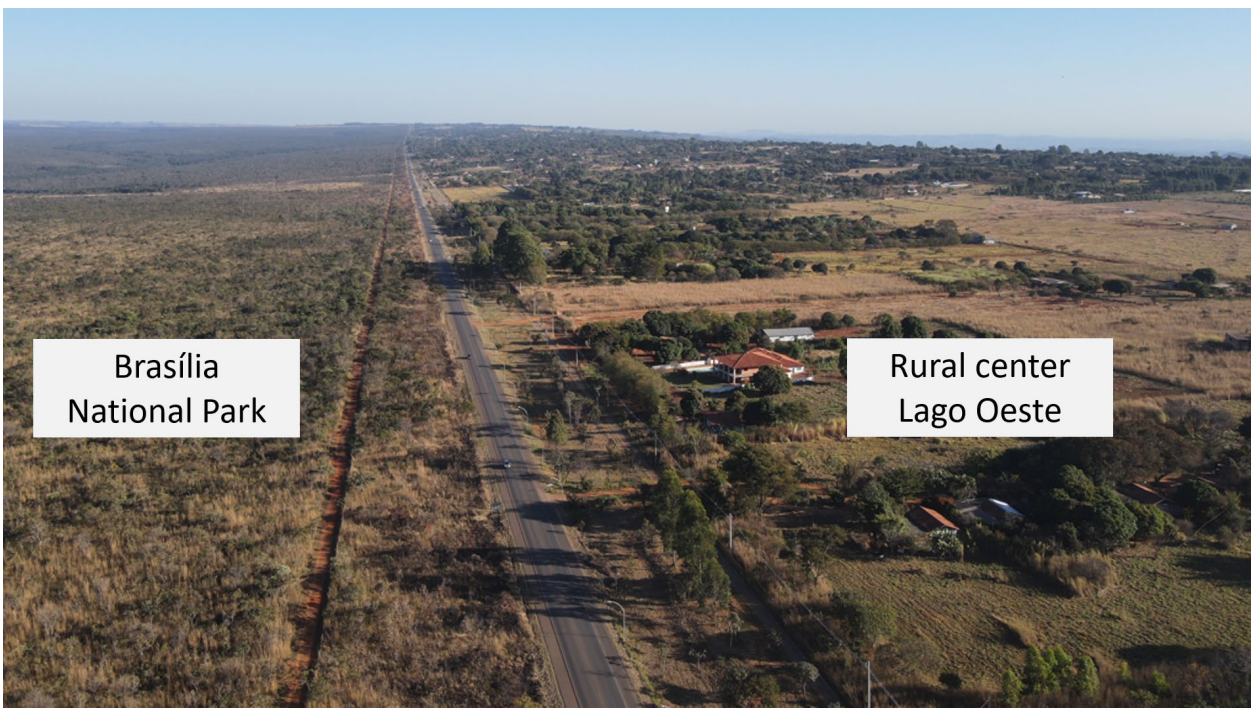
by urban areas and road networks (route 1), which are impeding and dangerous to maned wolves, considered worse than agricultural and reforestation activities.

Another observation is the current pattern of urban growth in the Federal District, which takes the form of sprawl (urban expansion away from the center, driving new residents into rural or environmentally protected areas), aggravating the fragmentation of the natural landscape and reducing its biodiversity (DUPRAS *et al.*, 2016; JACOB *et al*., 2021).

The sprawl that contributes to the fragmentation of the *Cerrado* landscape is partly due to informal land use and occupation, without legal approval, with a tendency towards a disorganized metropolitan population distributed in permanent, expanding and "shapeless" regional areas (SCHVARSBERG, 2019). There has been talk of the reproduced logic of subdivision, urbanistically simplified, closer to the notion of a "camp" than a city, expanding and segmenting the metropolitan fabric into peripheral and peri-urban zones.

In this contextual and simplified description of the sprawl occurring in the Federal District, the ability of certain urban sites, and/or those in the process of becoming so, to act as physical barriers to the passage of flora and fauna is not observed. Below the smaller and larger WLCs, at the points where they depart from the PNB (Figure 5), there is an inhabited area classified as a "built-up area" called Núcleo Rural Lago Oeste, which is considered an impediment by the cost path algorithm. Therefore, the starting point (origin) of the WLCs from the PNB towards the EEAE begins just above the aforementioned inhabited area. This also occurred in the study by Takahashi *et al.* (2021).

Figure 8. Núcleo Rural Lago Oeste, located below the starting points of the larger and smaller Ecological Corridors. Federal District, Brazil.



Source: prepared by the authors

Conclusions

Two WLCs were suggested between the PNB and the EEAE in the Federal District, Brazil, one smaller (37.00 km and 15,488.51 ha) and one larger (64.75 km and 34,905.44 ha).

The smaller WLC predominantly includes (91.26 %) the classes of land use and occupation of grassland, forest and savanna formations and PPA, while the larger WLC is made up of 78.48 % of grassland, forest and savanna formations, PPA and conservation units. The quality of the natural environment connecting flora and fauna between the points studied (PNB and EEAE) for the smaller WLC is therefore guaranteed by the greater representation of the *Cerrado* vegetation domain in this WLC than in the larger WLC.

References

ALEXANDER, J. L., OLIMB, S. K., BLY, K. L. S.; RESTANI, M. Use of least-cost path analysis to identify potential movement corridors of swift foxes in Montana. **Journal of Mammalogy**, v. 97, n. 3, pp. 891–898, 2016.

ANDRADE, B. R. **Conectando a Estação Ecológica de Águas Emendadas: proposta de corredores ecológicos para o lobo-guará (***Chrusocyon brachyurus***).** 2020. 112 p. Dissertação (Mestrado) Universidade de Brasília, Brasília.

ARAÚJO, T. M. S. DE.; BASTOS, F. DE. H. Corredores ecológicos e conservação da biodiversidade: aportes teóricos e conceituais. **Revista da Casa da Geografia de Sobral**, v. 21, n. 2, 716-729, 2019.

BAGATINI, T. **Evolução dos índices de atropelamento de vertebrados silvestres nas rodovias do entorno da Estação Ecológica Águas Emendadas, DF, Brasil, e eficácia de medidas mitigadoras.** 2006. 62 p. Dissertação (Mestrado) Universidade de Brasília, Brasília,

BRASIL. Decreto-lei 9.985, de 18 de julho de 2000. **Estabelece critérios e normas para a criação, implantação e gestão das unidades de conservação.** Diário Oficial da União, Brasília, DF, 19 jul. 2000.

CESSA, R. M. A.; LUSTOSA JUNIOR, I, M.; SILVA, F. G. R.; OLIVEIRA, C. M. M. De.; AMARAL, U. Do. Corredores etnoambientais em Terras Indígenas. **Cadernos de Geografia,** v. 1, n. 45, p. 69-80, 2022.

DUPRAS, J.; MARULL, J.; PARCERISAS, L.; COLL, F.; GONZALEZ, A.; GIRARD, M.; TELLO, E. The impacts of urban sprawl on ecological connectivity in the Montreal Metropolitan Region. **Environmental Science & Policy,** v. 58, n. 1, p. 61-73, 2016.

JACOB, P. P.; DRUMMOND, J. A.; BARRETO, C. G. A contribuição do espraiamento urbano de Brasília para a fragmentação da paisagem de Cerrado ao redor da cidade. **Revista Brasileira de Gestão Urbana**, v. 13, n. 1, p. 1-14, 2021.

LOUZADA, F. L. R. De O.; SANTOS, A. R.; SILVA, A. G. **Delimitação de corredores ecológicos no ArcGIS 9.3**. Alegre:CAUFES, 2010. 50p.

MORANDI, D. T.; FRANÇA, L. C. J.; MENEZES, E. S.; MACHADO, E. L. M.; SILVA, M. D.; MUCIDA, D. P. Delimitation of ecological corridors between conservation units in the Brazilian Cerrado using a GIS and AHP approach. **Ecological Indicators**, v. 115, n. 1, p. 1-10, 2020.

PIMENTEL, L. **A questão dos corredores ambientais no Distrito Federal: uma avaliação das propostas existentes**. 2007. 166 p. Dissertação (mestrado). Universidade de Brasília.

SAATY, T. L. A. A scaling method for priorities in hierarchical structures. **Journal Mathematical Psychology**, v. 15, n. 1, p. 234-281, 1977.

SAHOO. S.; DHAR, A.; KAR, A. Environmental vulnerability assessment using Grey Analytic Hierarchy Process based model. **Environmental Impact Assessment Review**, v. 56, n. 1, p. 145-154, 2016.

DOS SANTOS, A. R.; ARAÚJO, E. F.; BARROS, Q. S.; FERNANDES, M. M.; DE MOURA FERNANDES, M. R.; MOREIRA, T. R.; DE SOUZA, K. B.; DA SILVA, E. F.; SILVA, J. P. M.; SANTOS, J. S.; BILLO, D.; SILVA, R. F.; NASCIMENTO, G. S. P.; DA SILVA GANDINE, S. M.; PINHEIRO, A. A.; RIBEIRO, W. R.; GONÇALVES, M. S.; DA SILVA, S. F.; SENHORELO, A. P.; HEITOR, F. D.; BERUDE, L. C.; DE ALMEIDATELLES, L. A. Fuzzy concept applied in determining potential forest fragments for deployment of a network of ecological corridors in the Brazilian Atlantic Forest. **Ecological Indicators**, v. 115, n. 1, p. 106-423, 2020.

SCHWAIDA, S. F.; CICERELLI, R. E.; ALMEIDA, T.; ROIG, H. L. Desafios e estratégias na implementação de corredores ecológicos entre áreas protegidas no bioma Cerrado. **Revista Árvore**, v. 41, n. 6, p. 1-10, 2017.

SCHVARSBERG, B. Consistência do planejamento e da gestão urbana na área metropolitana de Brasília. **Revista Brasileira de Gestão Urbana**, v. 11, n. 1, p. 1-13, 2019.

SEDUH (Secretaria de Estado de Desenvolvimento Urbano e Habitação). GeoPortal-DF: **Infraestrutura de Dados Espaciais** - IDE/DF. Disponível em: https://www.geoportal.seduh.df.gov.br/geoportal/. Acesso 27 set. 2023.

TAKAHASHI, R. S.; CICERELLI, R. E.; ALMEIDA T.; SANO, E. E.; CONTRERAS, F.; RAMOS, A. P. M. Implementação de Corredores Ecológicos no Distrito Federal e Entorno Baseado em Critérios Ponderados. **Anuário do Instituto de Geociências**, v. 44, n. 1, p. 1-11, 2021.