

Environmental diagnostics in areas with high potential fragility in the Federal District, Brazil

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Received in: February 21, 2021 | Accepted in: September 29, 2021

Abstract

This study aimed to conduct environmental diagnostics of areas with high potential environmental fragility in the Federal District, Brazil. Reclassified thematic maps of soil slope and vulnerability to water erosion were combined to create the soil susceptibility map to water erosion, which, in turn, was combined with the thematic maps of soil use and rain erosivity. The result was then reclassified, giving rise to the potential environmental fragility map. In the places identified with high potential environmental fragility, information was collected by observing the aspects of the physical, biotic, and anthropogenic environmental components of the landscape. Areas with high potential environmental fragility in the Federal District were found. In those locations, the uses and occupations of the soil observed were intensive farming, small rural activities, managed intensive livestock and degraded intensive livestock. Land use and occupation in areas with high potential environmental fragility of the Federal District, with “degraded intensive livestock”, make such sites environmentally fragile since there is a scarcity of non-preserved natural areas and there is no soil conservation method. It was concluded that, for the use and occupation of the soil with high potential environmental fragility areas in the Federal District, which are taken by intensive farming, small rural activities, and managed intensive livestock, the conservation of the natural areas and the vegetative and mechanical soil conservation techniques must be implemented.

Keywords: Land use planning. Soil morphogenesis. Soil usage and coverage.

Introduction

Environmental fragility is defined as the natural vulnerability of the environment associated with the protection or not that different land uses are capable of promoting over a given area (SCHIAVO *et al.*, 2016). Its assessment methodology advocates land use planning and considers the environment as a dynamic product of the interaction between soil elements from the perspective of morphogenesis (slope, top shapes, drainage microchannels, among others), pedogenesis, for example, texture, depth, and thickness of horizons, permeability and complex of soil electric charges, and soil use and coverage (anthropogenic aspects), in addition to climatic aspects in compatibility with socioeconomic development (KAWAKUBO *et al.*, 2005; CALIJURI *et al.*, 2007).

The different types of soil specialized in a region determine the efficiency of its uses and occupations, as well as the intensity of environmental impacts (TRENTIN; ROBAINA, 2012). The slope, for example, is a factor of analysis in the study when observing the erosive processes of the soil, and that can be more intense according to the incline of the land.

Environmental fragility is based on the Ecodynamic Units predicted by Tricart (1977) within an ecological conception, in which the environment is analyzed on the Theory of Systems, which assumes that in nature, the exchange of energy and matter takes place through dynamic balance relations, that in turn is often altered by anthropogenic interventions of environmental components, generating moments in environments of temporary (unstable) or even permanent (stable) imbalances.

On the concepts of Tricart (previously mentioned), Ross (1990) inserted criteria to define the Stable and Unstable Ecodynamic Units (SEU and UEU, respectively), which will define potential environmental fragilities associated with the natural vulnerabilities of the environments, and emerging environmental fragilities, associated with the natural vulnerabilities of the environments and the protections corresponding to the types of land use and vegetation cover. The SEUs were spared from human action and are found, therefore, in their natural state, as a forest of natural vegetation. The UEUs that underwent anthropogenic interventions intensely modified natural environments through deforestation and practices of diverse economic activities.

The conceptual improvement of the definitions of Ecodynamic Units by Ross (1994) started to consider the potential of natural and anthropized environments as a defining factor of environmental fragility, no longer separating them into emerging and potential. It was considered that even an untouched environment is always being indirectly affected by anthropogenic action, either by air pollution or by groundwater, among others.

Today, the main tool for the analysis of environmental fragility is Geographic Information Systems (GIS), which can prepare the information collected and georeferenced, and synthesize it for the creation of final products, such as thematic maps (PADILHA, 2013), allowing the territorial planning of public policies in a relatively fast, dynamic-interactive, and low-cost way.

In this work, a map of potential environmental fragility was “built” by combining a soil susceptibility map - arisen from the combination of the slope with soil vulnerability to erosion - with the erosivity of rainfall and land use and occupation. Therefore, the intended environmental diagnosis will outline, through the visual description of

the landscape, the composition of the physical, biotic, and anthropogenic aspects in the areas with high potential fragility. Such areas possibly contemplate soils vulnerable to erosion by aspects of pedogenesis or morphogenesis and present in places with erosive rainfall in the condition of “unprotected” or anthropized use.

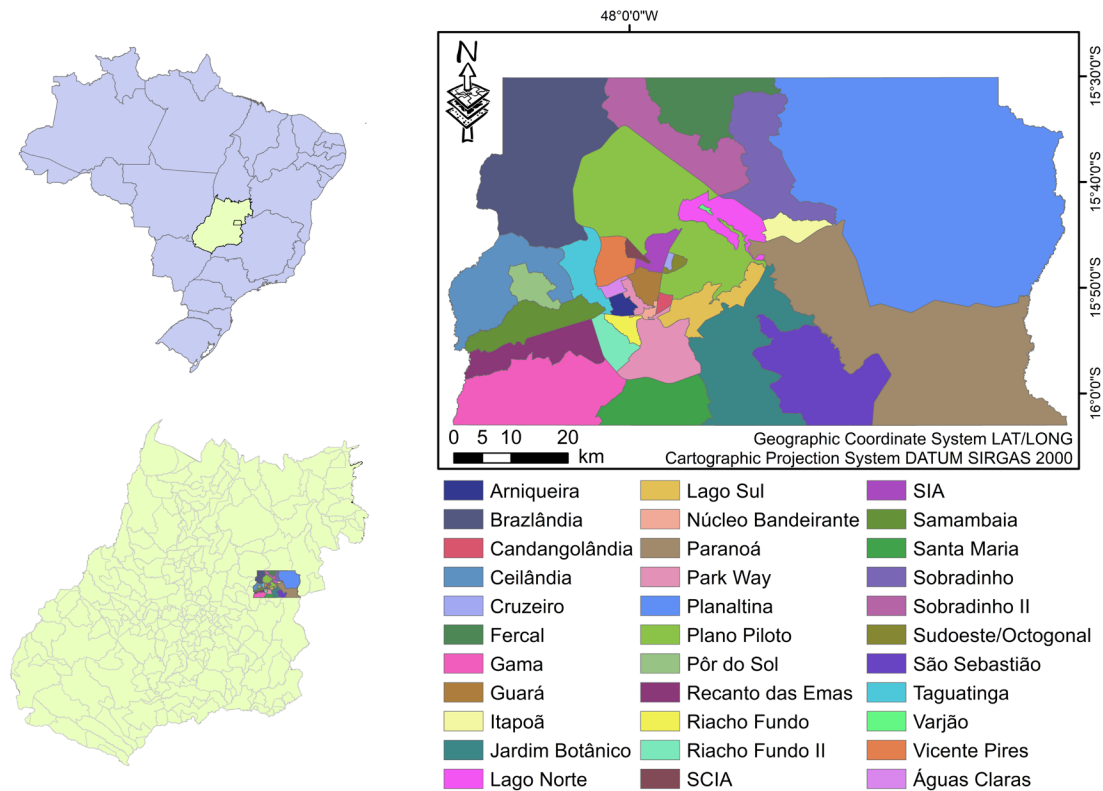
This study is aimed at carrying out environmental diagnostics by observing some aspects present in the physical, biotic, and anthropogenic environmental components of the landscape, of areas with high potential environmental fragility in the Federal District, Brazil.

Material and methods

The study was carried out in the Federal District (DF) area, located between the geographical coordinates 15°30' and 16°03' South latitude and between the meridians 47°25' and 48°12' West longitude, in the Brazilian Midwest region. According to CODEPLAN (2012), the DF occupies an area of 5,789.16 km², equivalent to 0.06% of the national territory. Its altitude varies from 850 m to 1,400 m in relation to sea level. Currently, it is divided into 31 administrative regions (FIGURE 1), with a total population of 2,570,160 inhabitants, according to the 2010 census carried out by the Brazilian Institute of Geography and Statistics (IBGE, 2021).

The methodological steps used to prepare the map of potential environmental fragility in the DF consisted of the delimitation of representative classes of soil slope and vulnerability to erosion, as well as their use and occupation and the erosivity of rainfall. For this, the vector data had to be converted into matrix format, which enabled the development of map algebra operations through the computational application ArcMAP 10.5.

Figure 1. Location of the Administrative Regions of the Federal District, Brazil.



Source: Prepared by the authors (2021).

Initially, the map was obtained in the DF slope raster format from the digital elevation model (vector format) available in GeoPortal (2019) of the Government of the Federal District. Subsequently, the rasterized slope map was reclassified (“reclassify” function) from the information in Table 1: (FIGURE 2).

Then, the map of soil vulnerability to water erosion was obtained, vectorized in the 1:250,000 scale, available in the State Geoinformation System (2018) of the State of Goiás, authored by the Company of Technical Assistance, Rural Extension and Agricultural Research, which was rasterized and reclassified (FIGURE 3) according to Table 2.

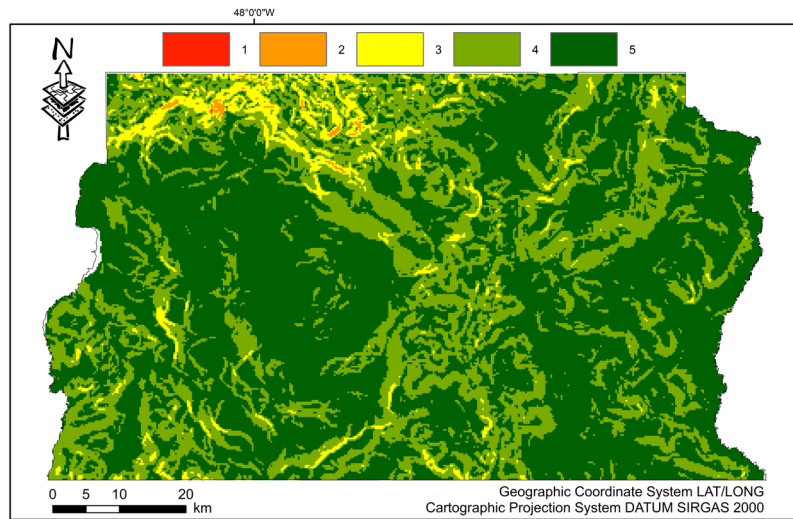
Table 1. Ground surface slope classes and coefficients used for slope map reclassification. Planaltina-DF, 2021.

Slope (%)	Favoring*	Coefficient
0.0 to 3.0	Very weak	5
3.0 to 8.0	Weak	4
8.0 to 20.0	Average	3
20.0 to 45.0	Strong	2
45.0 to 75.0	Very strong	1

*favoring soil water erosion by the formed relief

Source: Adapted from Mendonça, Lombardi Neto, and Viêgas (2006).

Figure 2. The slope map was reclassified from the coefficients. Brasília, Distrito Federal, Brasil



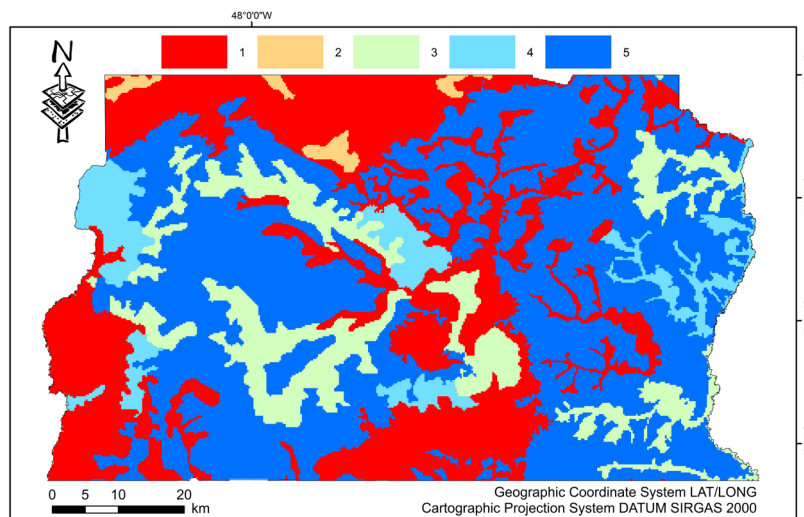
Source: Prepared by the authors (2021).

Table 2. Classes of soil vulnerability to erosion and coefficients used for slope map reclassification. Planaltina-DF, 2021.

Degree of vulnerability of the soil to water erosion*	Class of vulnerability	Coefficient
1 to 1.3	Very low	5
>1.3 to 1.7	Low	4
>1.7 to 2.2	Average	3
>2.2 to 2.6	High	2
>2.6 to 3.0	High	1

Source: Adapted from Crepani *et al.* (2001).

Figure 3. Map of soil vulnerability to erosion reclassified from the coefficients. Brasília, Distrito Federal, Brasil.



Source: Prepared by the authors (2021).

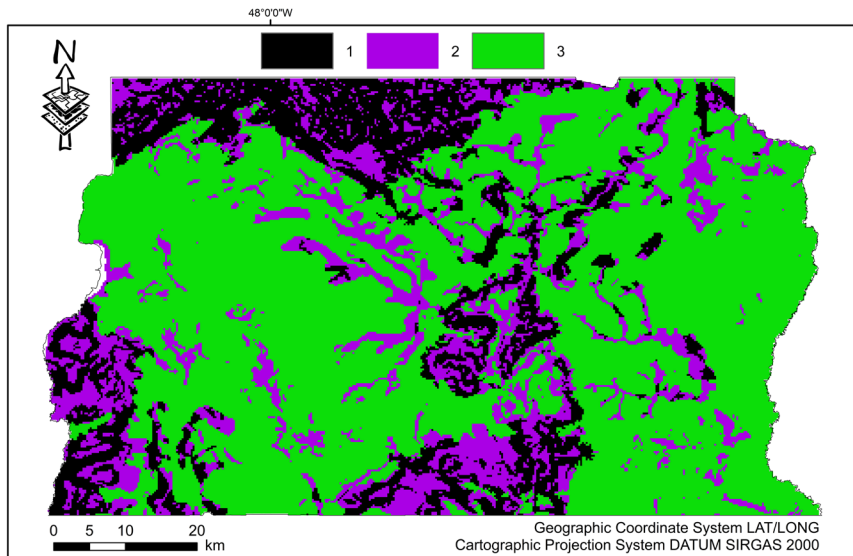
From the reclassified maps of soil slope and vulnerability to water erosion, through the “raster calculator” function of the computational application ArcMAP 10.5, a map according to the subjective equation $(\text{slope} \times 0.60) + (\text{vulnerability} \times 0.40)$ was obtained. This map was reclassified according to Table 3, resulting in a thematic map of the soil susceptibility to water erosion (FIGURE 4).

Table 3. Classes of soil susceptibility to erosion. Planaltina-DF, 2021.

Class	Coefficient
Low	3
Average	2
High	1

Source: Prepared by the authors (2021).

Figure 4. Map of soil susceptibility to water erosion reclassified from the coefficients. Brasília, Distrito Federal, Brasil.



Source: Prepared by the authors (2021).

Subsequently, the vector maps of land use on the 1:20,000 scale (GEOPORTAL, 2019) and the average annual rainfall (from 1997 to 2006) were obtained, made available by the Geological Service of Brazil – CPRM (2011) on the 1:5,000,000 scale, within the scope of the project *Atlas Pluviométrico do Brasil*.

The land use map was rasterized and reclassified (FIGURE 5) according to Table 4. The vector map of the “rains” had its values recalculated according to Galdino *et al.* (2015), for erosivity values of the rainy season (October, November, December, January, February and March). It was later rasterized and reclassified (FIGURE 6), according to Table 5.

Table 4. Classes of soil vulnerability to erosion and coefficients used for slope map reclassification. Planaltina-DF, 2021.

Land use	Protection condition *	Coefficient
Water	-	-
Built area	Very High	4
Road system	Very High	4
Cerrado Formation	High	3
Forest Formation	High	3
Field Formation	High	3
Agric. and/or Livestock.*	Average	2
Exposed soil	Very low	1

*ability to protect it from the erosivity of rainfall.

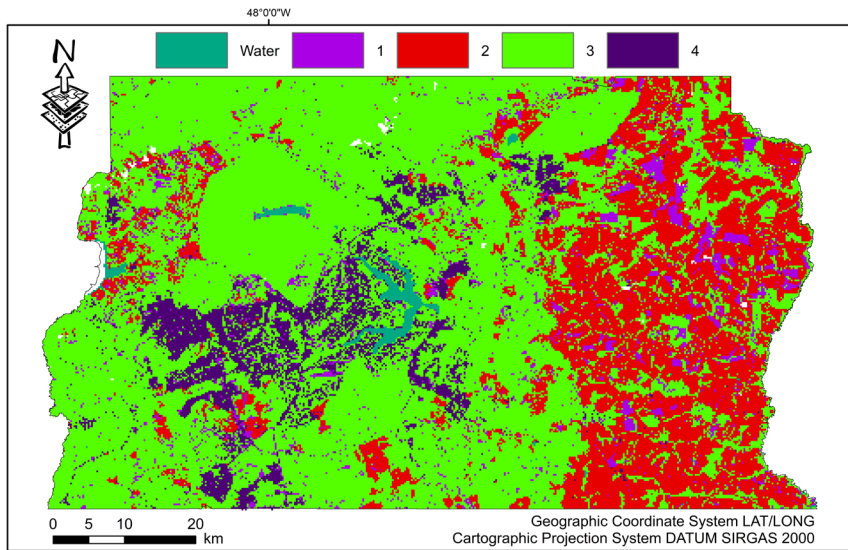
Source: Prepared by the authors (2021).

Table 5. Classes of erosivity of rainfall in the rainy season and coefficients used for slope map reclassification. Planaltina-DF, 2021.

MJ mm ha ⁻¹ h ⁻¹ year ⁻¹	Class erosivity	Coefficient
14,440 to 15,472	High	3
> 15,472 to 16,543	Very High	2
> 15,543 to 17,898	Extremely High	1

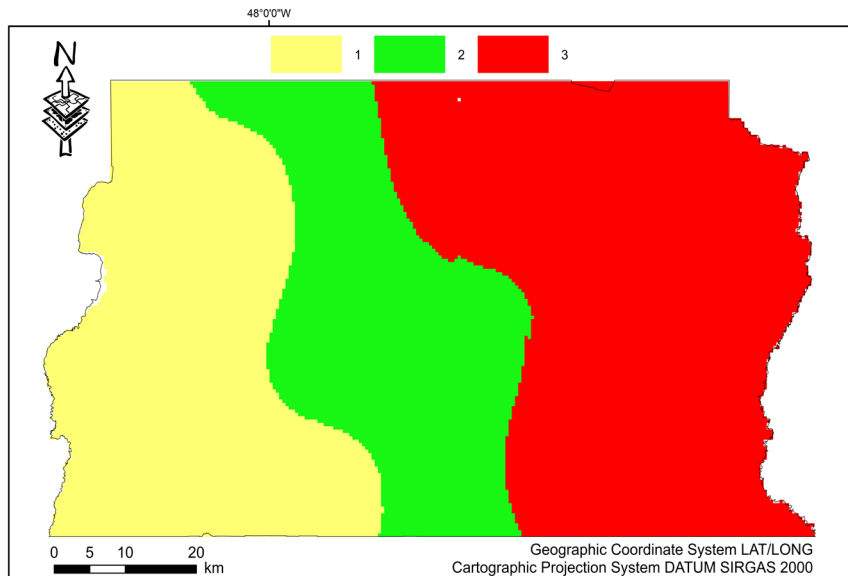
Source: Prepared by the authors (2021).

Figure 5. Map of land use reclassified from the coefficients. Brasília, Distrito Federal, Brasil.



Source: Prepared by the authors (2021).

Figure 6. Map of erosivity of rainfall in the rainy season (October, November, December, January, February and March) reclassified from the coefficients. Brasília, Distrito Federal, Brasil



Source: Prepared by the authors (2021).

Finally, through the “combine” function of the computational application ArcMAP 10.5, the soil susceptibility map to water erosion was interposed with the maps of soil use and annual average erosivity of rain, according to the criteria in Table 6. This procedure allowed the creation

of the thematic map (raster format) of potential environmental fragility of areas of the DF.

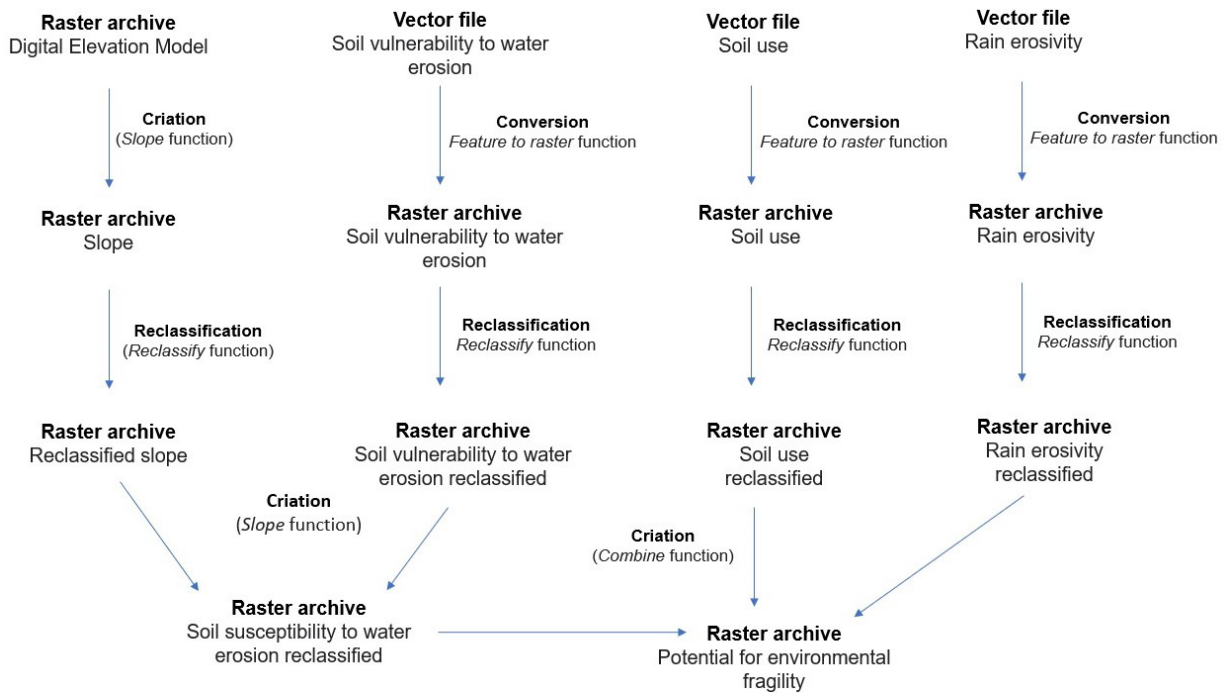
Figure 7 shows the workflow to obtain the map of potential environmental fragility of the Federal District.

Table 6. Coefficients used to reclassify and obtain the map of potential environmental fragility and its classes. Planaltina-DF, 2021.

Suscept. areas	Erosiv. rains	Use soil	Potential Class environmental fragility
2	1	1	high
1	3	2	high
2	3	2	high
2	3	1	high
2	1	2	high
1	1	1	high
1	2	2	high
2	2	2	high
1	2	1	high
1	3	1	high
2	2	1	high
1	1	2	high
1	1	3	average
1	2	3	average
1	3	3	average
3	3	1	average
3	2	1	average
3	1	1	average
3	2	2	average
3	1	2	average
2	1	3	low
2	2	3	low
2	3	3	low
3	3	2	low
3	3	3	low
1	2	4	low
2	1	4	low
1	3	4	low
3	3	4	low
3	2	3	low
1	1	4	low
3	1	3	low
2	3	4	low
3	1	4	low
3	2	4	low
2	2	4	low

Source: Prepared by the authors (2021).

Figure 7. Workflow to obtain the map of potential environmental fragility of the Federal District.



Source: Prepared by the authors (2021).

In the places identified with “high” potential environmental fragility of the Federal District, exploratory information was collected and systematized in a spreadsheet (TABLE 8) by observing the aspects of the landscape’s physical,

biotic, and anthropogenic environmental components (TABLE 7), considering a radius of 2,000 m. To this end, “on-site” visits to those places with high potential environmental fragility were carried out.

Table 7. Aspects of the physical, biotic, and anthropogenic environmental components considered in the environmental diagnostic assessment of areas with high potential environmental fragility of the Federal District.

Component of the medium	Analysis
Physical	Elements identified in the landscape: patterns of soil use and terrain favoring soil water erosion.
Biotic	State of conservation and extension of conservation areas.
Anthropic	Conservationist measures: terracing, conservationist cultivation or that allow the adequate protection of the soils and the quality of the rainwater drainage system.

Source: Adapted from Lima (2018).

Table 8. Information collection spreadsheet for environmental diagnosis of areas with high potential environmental fragility of the Federal District.

Environmental components																					
Physical				Biotic				Anthropic													
Land use	Terrain ¹			State conservation			Terraces	Some conservationist method	Conservationists measures												
	Very weak	Weak	Average Strong	Extension ²	Conservation ³				Nonexistent	Deficient	Adequate										
				Little	Representative	Preserved	Intermediate conservation	Degraded													
Intensive agriculture																					
Managed intensive livestock																					
Degraded intensive livestock																					
Extensive livestock																					
Degraded extensive livestock																					
Small-size rural activity ⁵																					
Preserved area. Occupied																					
Urban occupation																					
Rural occupation																					

¹degrees of favoring soil water erosion by the formed relief assessed based on the percentage slope of Table 1; ²visual and subjective assessment of natural areas. If nothing is indicated in this item, it is understood that such areas are absent; ³the quality of the conservation status of the natural areas was visually and subjectively assessed, if any; ⁴the rainwater drainage system will be visually and subjectively assessed; ⁵the development of family-sized agricultural or livestock activities.

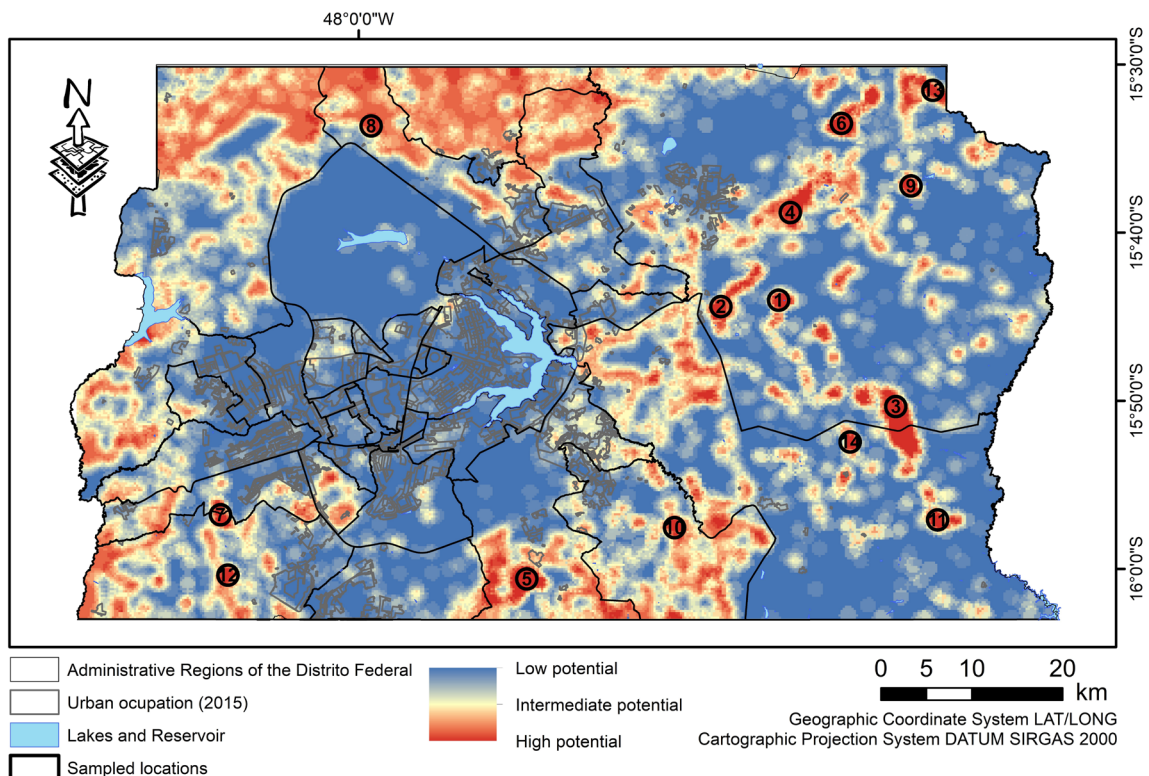
Results and discussion

Figure 8 shows the areas with high potential environmental fragility of the Federal District (DF) where the environmental diagnostics were carried out through physical, biological, and anthropogenic elements observed in the landscape and which are circled and listed.

With the analysis of the information collected in the places identified with high potential environmental fragility in the Federal District, it can be seen that:

- 28.57% have soil used for “intensive crops”, with a very weak to a weak degree of favoring soil water erosion due to the terrain. In those places, in general, there is a representative presence of natural areas with intermediate conservation, and some type of soil conservation method is still used. The rainwater drainage system is deficient;
- 57.14% have soil used for “small rural activities”, with a weak degree of favoring soil water erosion due to the terrain. The representativeness of natural areas and their conservation status is varied, and some type of soil conservation method is mostly used. The rainwater drainage system is deficient;
- 7.14% have soil used for “managed intensive livestock”, with a weak to medium degree of favoring soil water erosion by the terrain. In those places, there is a representative presence of natural conserved areas, and some type of soil conservation method is still used. The rainwater drainage system is deficient;
- 7.14% have soil used for “degraded intensive livestock”, with a low degree of favoring of soil water erosion by the terrain. In those places, there is little representative presence of natural areas that are not conserved, and no soil

Figure 8. Map of potential environmental fragility (Low, Medium or High) in the Federal District, Brazil containing the places where the information was obtained to create the environmental diagnosis.



Source: Prepared by the authors (2021).

conservation method is used. The rainwater drainage system is deficient;

Environmental fragility is caused by natural factors such as slope, soil types, and precipitation and, above all, by land use and vegetation cover (ALVES *et al.*, 2017; GUERRERO *et al.*, 2018). The distribution of degrees of environmental fragilities is associated with anthropization processes in natural areas, especially soil occupation practices that favor the suppression of areas of native vegetation (TREVISAN; MOSCHINI, 2016).

Given the above, it is noted that in the areas of high potential environmental fragility of the Federal District, in the areas occupied as “intensive crops”, it is necessary to prioritize actions that favor the improvement of practices that fall on the conservation of natural areas, such as reforestation and combating fires, as well as the diffusion of the importance of implementing vegetative and mechanical soil conservation techniques, such as a direct sowing system, sowing at the level and implantation of level terraces. Regarding areas with soil used for “small rural activities”, actions that favor the creation or maintenance of natural areas and that reaffirm the improvement or implementation of vegetative and mechanical soil conservation techniques are pertinent. In areas with “managed intensive livestock”, actions that improve or implement vegetative techniques of soil conservation mechanics must be strengthened. In areas with “degraded intensive livestock”, it is essential to implement natural areas, as well as the maintenance (conservation) of existing ones. The implementation of vegetative mechanical techniques for soil conservation is fundamental.

Considering the types of land use that were found in the environmental diagnostics of this study, it is noted that intensive livestock farming on degraded areas in places of high potential environmental fragility in the Federal District makes the condition of this type of location no more

potential, but above all, environmentally fragile. It is common the existence of pasture areas in places of environmental fragility, promoting little land cover and gullies (ALVES; SILVA; ALVAREZ, 2018). The ability of degraded pastures to transform areas with potential environmental fragility into environmentally fragile areas was also found in the work of Abraão and Bacani (2018), in which these authors observed strong environmental fragility in areas of a sub-basin occupied by degraded pasture, without observing conservationist practices and with advanced soil erosion processes. To mitigate the fragility of the areas, the authors suggested the use of techniques to obliterate erosive processes and the adoption of soil conservationist practices.

Degraded pasture areas are usually associated with degrading practices, such as the use of fire and intensive grazing, and the types of soil present and rugged topography. They also have reduced soil coverage and are highly susceptible to erosive processes, which explains the fragility of these areas (FERREIRA, 2016). Campos (2018) found areas with high environmental fragility being occupied and degraded, requiring adequate policy and technical interventions for the conservation of natural resources in the Caratinga River basin in the State of Minas Gerais.

The importance of policies in the Federal District to promote the implementation of management techniques for soil conservation in pasture areas, through access to technical assistance, environmental education programs, and appropriate credit lines is, therefore, inherent to the preservation of areas with high potential environmental fragility.

The non-conservation of pastures in the Federal District, especially those in areas with high environmental fragility, possibly occur for the same reasons found in the work of Freitas *et al.* (2016). Those authors found, in an investigative study in three agricultural

properties containing degraded pastures, that only one of the owners knew how to perform most of the practices necessary for the conservation of the pasture areas, while the others do not conserve or are not aware of almost any action to pasture conservation. Furthermore, the authors add that the degradation of pastures in the properties studied is not only due to the lack of information on management but, above all, to its absence.

Conclusions

Areas with high potential environmental fragility were found in the Federal District, and, in those locations, the uses and occupations of the soil observed were intensive farming, small rural activities, managed intensive livestock and degraded intensive livestock.

The use and occupation of land in areas with high potential environmental fragility of the Federal District, with “degraded intensive livestock” makes such areas environmentally fragile, since in these locations there is little representative presence of natural areas that are not conserved, and no soil conservation method is used.

Degraded intensive livestock areas in Brazil are frequent, possibly associated with cultural, economic, access to assistance, private or public, and incentive policies bringing the responsibility of agricultural production with the requirement of internal and external consumers concerned with sustainable production systems.

For the use and occupation of the soil of the Federal District in areas with high potential environmental fragility occupied with intensive farming, small rural activities, and managed intensive livestock, in general, the conservation of natural areas and the vegetative and mechanical soil conservation techniques must be improved.

Acknowledgments

The authors thank the Federal Institute of Education, Science and Technology of Brasília and the National Council for Scientific and Technological Development, public notice No. 06/2020 of the Institutional Program for Scientific Initiation Scholarships (Higher Education) 2020/2021, for their financial support.

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