Geodesign in Regional Green Infrastructure Planning

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Abstract. The patterns of consumption of natural resources and land follow the development process and mark the shapes of occupation of the territories. This process has led not only to the exhaustion of the resilience of the ecosystems but also has demanded assertive interventions in urban land management able to prevent environmental impacts and guarantee essential ecosystem services for human activities. This paper, with the aid of producing data on the support ecological processes and landscape metrics for the study area, presents some solutions anchored in the geodesign methodology for action in the Federal District of Brasília, Brazil. Aiming to improve the assertiveness in facing the depletion of environmental services in urban areas, we present the work carried out on a WebMap/WebGIS platform where strategies were proposed for four subsystems: leisure and culture, provision, green and blue infrastructure to address pressures exerted on the Cerrado ecosystem and to promote urban resilience.

Keywords: Green infrastructure · Geodesign · Landscape planning · Participatory planning

1 Introduction

The consumption patterns of natural resources and land, accompany the development process and mark the occupation forms of the territories. The contemporary framework is understood as the continuation or evolution of practices before humanity's awareness of the finitude of natural resources. This has led to the exhaustion of the self-regeneration capacity of the ecosystems. The most visible expression of this process on human survival itself can be seen in the form of various impacts such as floods, landslides, droughts, food shortages, and diseases [1–4].

This context has demanded research for the structuring of territorial planning and project actions that can simultaneously prevent environmental impacts, resulting from

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territorial occupations and guarantee the provision of essential ecosystem services for human activities and the maintenance of the ecosystems [5, 9–11].

The present work is based on the research developed by the Urban Environmental Management Group of the PPGFAU/ UnB and supported by the UFMG Geoprocessing (GEOPROEA). This articulates their knowledge to develop solutions anchored by design tools to act assertively in the territory in the face of the problems of depletion of environmental services in urban areas.

The conceptual support is anchored in landscape ecology, green infrastructure, remote sensing, and geodesign, leading to the identification of ecological support processes and the construction of landscape metrics, which could support territorial design proposals to protect or promote ecosystem services and resilience.

This approach was only possible by adopting the methodology of geodesign, which can be summarized as a process that allows the co-creation of alternative futures to an area with different interests, creating a compromise through negotiation facilitated by visualization of geographic information [6]. Essentially, it is about planning and designing (future) from a geographical approach (past and present). It also strongly requires the perspective of different social actors through a dynamic construction conducted by a mediator [7, 8]. According to Steinitz [7] this process demands a methodological framework that consists of 3 iterations and 6 models, defined as the representation model, process model, evaluation model, change model, impact model, and decision model. The 3 iterations are to answer the goal "why" we are studying the area, "how" can we develop the case study, and "what, where and when" can we propose projects and policies (Fig. 1).

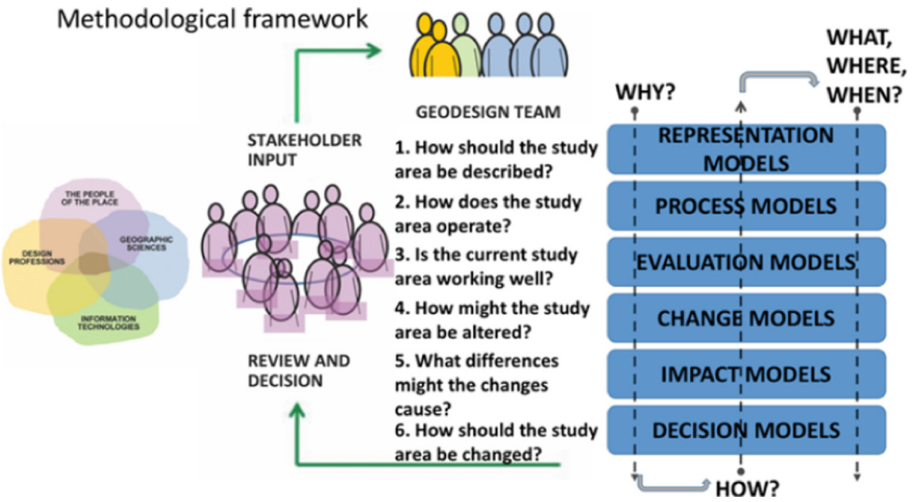


Fig. 1. The methodological framework. Source: Adapted from Steinitz, C. (2012). A framework for Geodesign: changing geography by design. Redlands, ESRI Press.

In turn, the designing process using geodesign allows for more assertive interventions in green infrastructure, at the territorial scale, focusing on both maintenance and promotion of ecosystem services.

Thus, green infrastructure as an intervention approach in the landscape can be seen not only for the conservation and for restoration of biophysical systems, but also as an agent of landscape transformation. This approach creates a system different from the previous one, more resilient, especially when ecological, economic, and social benefits become insufficient for human well-being. In this way, the greatest possible gradient of ecosystem services can be structured, whether it already exists or is under planning [17].

The research was carried out in the Federal District (DF), a federative unit of Brazil, which houses its capital, Brasília, in the Center-West region of the country [18], which, with just over 50 years of occupation, presents serious ecological risks arising from urban and agricultural uses. Among these risks, the suppression of the native Cerrado vegetation (a kind of savannah) and the loss of ability to recharge aquifers may be mentioned, causing a situation of water stress [13].

The result of the studies of the DF territory reached different conclusions regarding the performance of the vegetation. Among these conclusions are those concerning the ecological processes of support on the regional scale using the multispectral index CO_2flux. *This is* linked to the carbon flux to identify the photosynthetic efficiency of the vegetation and the Topographic Wetness Index [14, 15] that were added to the bases of the Economic Ecological Zoning of the DF (ZEE-DF). These parameters could compose a framework that allows the decision-making on the strategies of adaptability and transformability of the urban landscape of the DF.

However, the search for solutions in networked green infrastructure along the territorial mosaic is not a simple task.

It involves the crossing of various information in multiscalar, multifunctional, and synergistic dimensions.

To reach this goal, the research Urban Environmental Management Group from PPG-FAU/UnB, opted for a geodesign approach, aiming at a first spatialization of the various solutions to be considered in the planning and design. This approach depended on the involvement of environment design professionals of geographic sciences, of information technologies, and of local people, who together could propose solutions more aligned with Landscape Ecology [7, 8, 16].

To achieve this objective, the resources of geodesign were used to study complex aspects related to the architecture of the landscape through the organization of a Workshop, called Regional Green Infrastructure for the Federal District (IVR-DF).

This Workshop was carried out with the support of the Brazilian geodesign platform Giscolab, together with researchers and technicians from the Federal District Government concerned with the topic.

This experience will be reported here to demonstrate that when a consistent database is associated with adequate project tools, that is, solutions are supported by the intelligent use of technologies. This way it is possible to quickly advance in the understanding and modeling of the environment. Understanding the past and the present may be achieved, making it possible to reinterpret the landscape, in different perspectives of development consolidated in a co-design process [7, 12] built with assertive actions in the territory intending to increase resilience.

2 Methodology

One of the main reasons for choosing the Giscolab platform to support the geodesign workshop for IVR-DF was the possibility of this tool going beyond a territorial visualization platform.

Giscolab is based on a Spatial Data Infrastructure (SDI), whose ease of information circulation allows the manipulation of data and interpretation of information before planning. This software enables in-depth diagnoses of the territory, employing overlapping and combination of a supplied map system (layers).

This approach is provided by grouping four structuring components:

(i) A geographic base composed of information produced and stored in vectorial formats, raster, or BDG format.
(ii) A Geoserver map server for converting this geographic information into web services (Web Image Services-WMS; Web Feature Service-WFS or Web Processing Service-WPS).
(iii) A metadata catalog for documentation and distribution of contextualized data, used by other Spatial Data Infrastructures (IDE), standardization of documentation, as well as the search and rescue of information.
(iv) A WebMap/WebGIS platform to support visualization, shared opinion and decision-making [7].

The first step in preparing the layer systems (Fig. 2) sought to aggregate a set of information that, together, could offer different perspectives on the design of a regional green infrastructure for the DF.

These layers should together support the interpretation of essential characteristics for the definition of the required programs and projects for the proposition of the IVR-DF. This could be made through the process of a cooperative dialogue between the participants of the workshop. The layer system could neither be so simple as to lack information to support decision making nor so complex as to contain unnecessary or repetitive information.

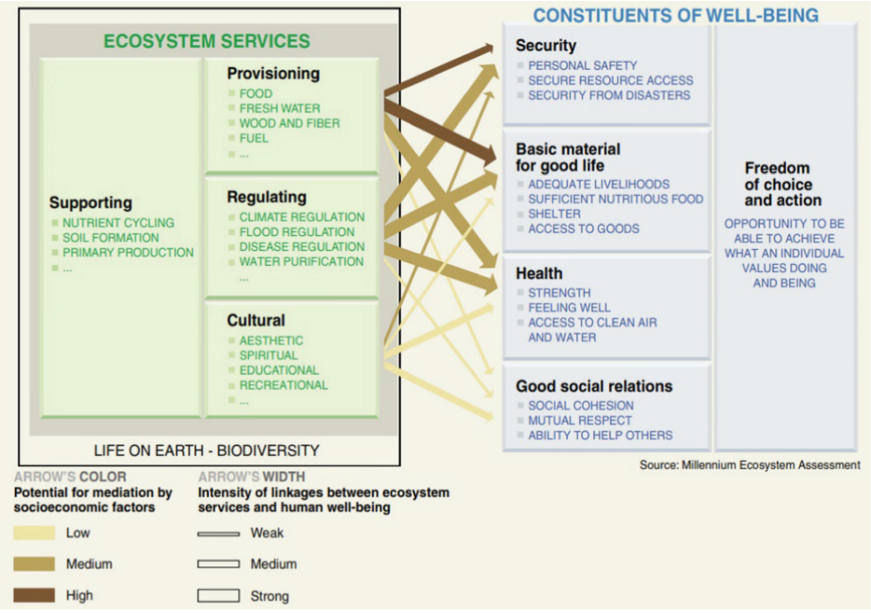


Fig. 2. Linkages between Ecosystem Services and Human Well-being. Source: Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-Being: Wetlands and Water Synthesis. World Resources Institute, Washington, DC.

The system was composed of 39 layers, grouped into 6 categories as follows:

(i) Landscape ecology: shape factor, core areas, connectivity, shape factor improvement potential, core area (hotspots) improvement potential, and connectivity improvement potential;
(ii) Supporting ecological processes (SPE): CO2 flux, Topographic Wetness Index (TWI), and Ecological Restoration Potential (ERP);

(iii) Landscape support: geomorphology, geomorphological compartments, geology, pedology, agricultural suitability, hydrography, hydrographic units, fractured hydrogeology, aquifers flow in the DF, lakes and ponds, risk of loss of aquifer recharge, hypsometry;
(iv) Landscape cover: number of trees, carbon in tree biomass (above and below ground), land use and soil cover, daytime surface temperatures, nighttime surface temperatures, heat islands, highways, implanted blocks;
(v) Territorial: Ecological-Economic Zoning (ZEE-DF), Zoning of the Federal District Territorial Planning Master Plan (PDOT-DF), Integral Protection Conservation Units, Sustainable Use Conservation Units, Water Sources Protection Areas (APM), Permanent Protection Areas (APP), Legal Reserves;
(vi) Socioeconomic: Social Vulnerability Index, Housing Deficit and Purchasing Power.

Among the main models elaborated above, we can highlight those produced for the workshop, which supports the provision of ecosystem services. These models are related to the support of the ecosystem services project, essential for planning the green infrastructure supporting ecological processes and landscape ecology.

The layers of the system address: (i) carbon sequestration in vegetation, through the spectral index CO2flux; (ii) the presence of soil moisture, expressed by the spectral index TWI and the (iii) ERP, resulting from the crossing of the CO2flux with the areas with the highest topographical humidity in the TWI, as shown in Fig. 3. The three layers, when associated with the others in the system, can indicate both the strategic areas for conservation, expansion, or creation of vegetated areas.

In turn, the Landscape Ecology system presents landscape metrics (connectivity, core area, and form factor) applied in two perspectives: (i) one referring to the contemporary structure of vegetation distribution along the Federal District and (ii) a potential one, referring to a scenario of conservation and expansion of patches and ecological corridors in the areas indicated by the layer. This layer system is essential for understanding the presence and flow of biodiversity in the cerrado, in proposing a regional green infrastructure network. Figure 4, as an example, presents the connectivity layer and the potential connectivity layer.

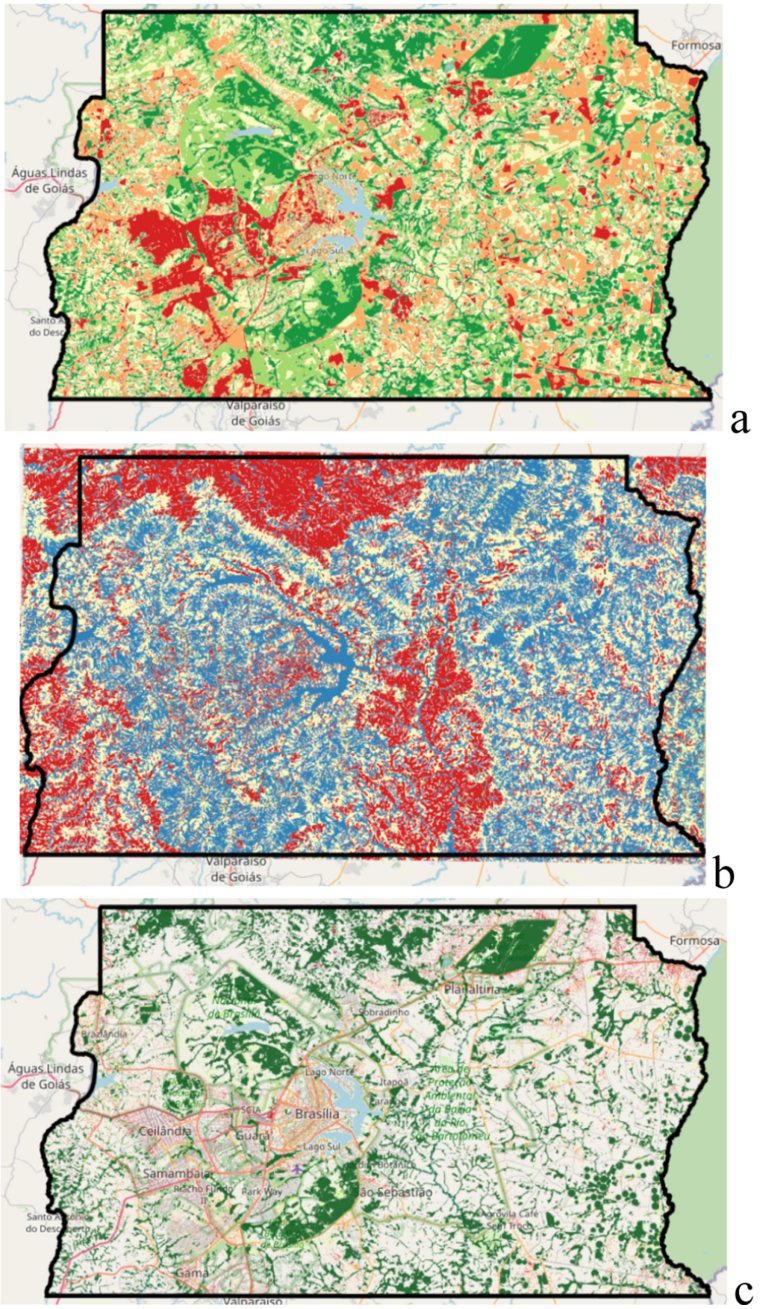


Fig. 3. Layers of the ecological support processes system: (a) CO_2 flux, (b) TWI e (c) Ecological Restoration Potential. Source: Giscolab Screenshot, adapted by the authors.

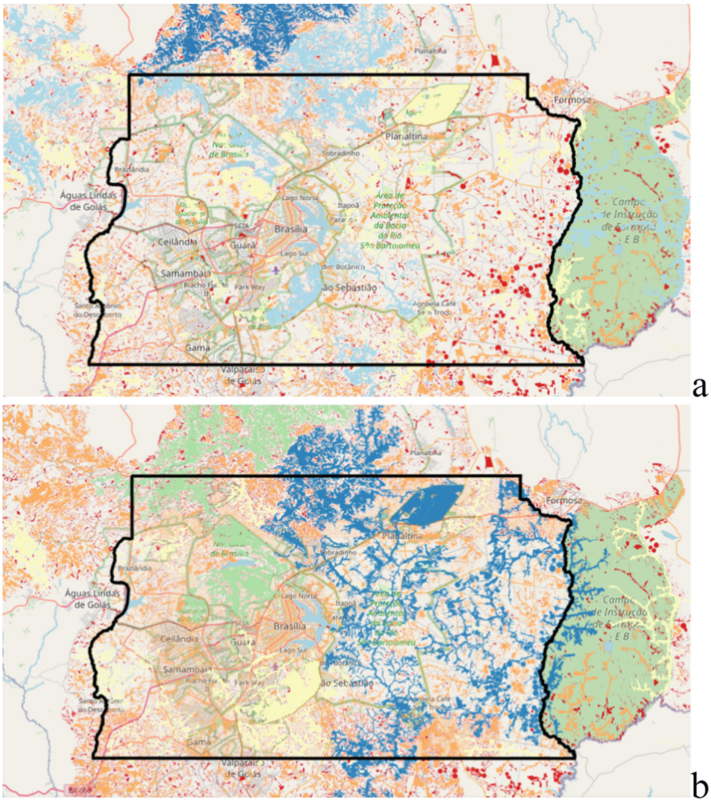


Fig. 4. Example of the landscape ecology system layers: (a) connectivity, (b) connectivity potential. Source: Giscolab Screenshot, adapted by the authors.

Aiming a conceptual alignment among the participants, a metadata spreadsheet (Fig. 5) was also provided with the description of the organizing concept of each layer and the respective source, grouped by category.

MAIN SYSTEM			
System	**Data name in GeoGiscolab**	**Description of the layer organizer concept**	**Data Sources: Bibliography and or database**
Socioeconomic	Social Vulnerability Index	The Social Vulnerability Index (SVI) is an indicator that allows for a breakdown of the living conditions of all socioeconomic strata of the country, identifying those who are in vulnerability and social risk. It is calculated from 3 dimensions of indicators: Urban Infrastructure; Human Capital; and Income and Work.	Codeplan and the Federal District Urban Development Department
	Housing Deficit	The Housing Deficit indicates the deficiency in housing in each region. It is usually a numerical indicator, which represents the number of deficient housing units. For its calculation, families living in conditions of cohabitation, excessive density, housing precariousness and/or excessive rent burden are considered.	https://www.geoportal.seduh.df.gov.br/geoportal/
	Purchasing power	Average monthly income per capita	Poder Aquisitivo (sipdia.df.gov.br)

Fig. 5. Example of a part of metadata presentation. Source: The authors.

3 IVR-DF Workshop Development

The development of the workshop took place online (Fig. 6), with only one recommendation for the distant groups concerning the number of members per working group. For a dynamic where it will be possible to comply with the principles of geodesign, the number of participants per group should vary between six and eight members plus the moderator who will be in charge of the operation of the geodesign platform.

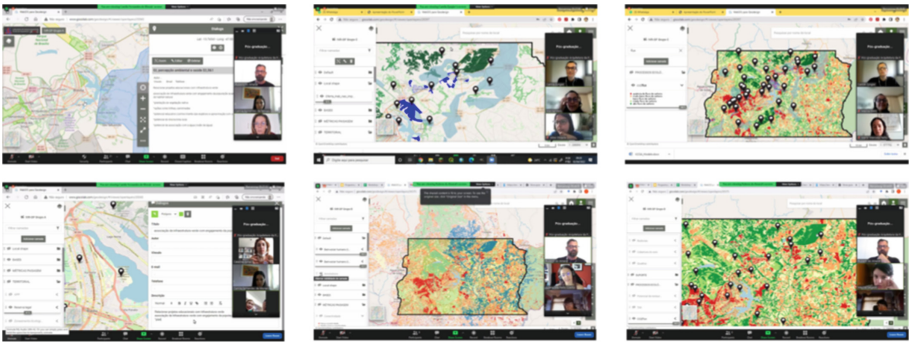


Fig. 6. Screenshots of the online participation dynamic held in March and April 2022. Source: The authors. (Color figure online)

After the database organization phase (information layers system) and the definition of the modus operandi, the next step refers to the profile and composition of the working groups to propose solutions for the regional green infrastructure.

In the case of the IVR-DF, eight participants were selected, covering three categories of participants, aiming at different perspectives on the landscape of the DF:

(i) A group of specialists in landscape architecture from outside the DF;
(ii) A group of researchers from the research project that generated the data on ecological processes (Urban Environmental Management Group from PPGFAU/UnB);
(iii) A group of technicians from the Federal District Government is already acquainted with land management planning in the environmental and urban areas.

The three sections of the Workshop were developed over 3 weeks, interspersed with days that were dedicated to individual work based on geodesign.

The works included predefined tasks of comments and complementation of ideas launched in the joint sections.

It is important to highlight that the first section was about leveling the bases of methodological information as well for the members to get to know each other. Subsequently, the participants were divided evenly into three groups (A, B, and C) (Fig. 7) that worked in two sections to develop design proposals for the DF on a regional scale.

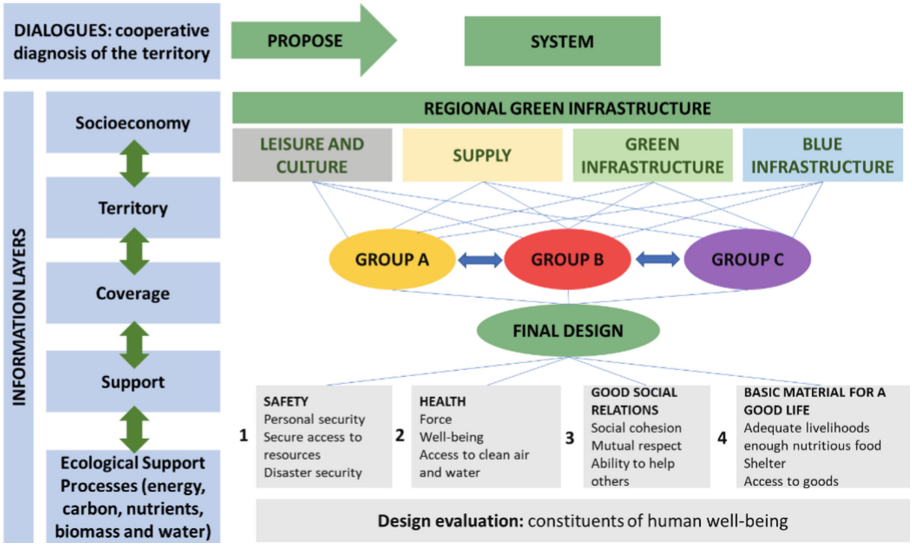


Fig. 7. Workshop framework. Source: The authors. (Color figure online)

From a methodological point of view, the geodesign proposals follow four main axes:

(i) Leisure and culture;
(ii) Provision;
(iii) Green infrastructure;
(iv) Blue infrastructure (Fig. 7).

Such axes aim to organize the discussion and not necessarily define the scope of the proposals that must adhere to the reality of each territory studied. They are axes of action in landscape architecture that helps to detect the needs of public policies for the study area, to protect, adapt and transform the landscape, aiming for its resilience.

Thus, the proposals could be composed either of programs or projects. Proposals should be divided into four subsystems: leisure and culture (gray), provision (yellow), green infrastructure (green) and blue infrastructure (blue) (Fig. 7). In addition, participants should confirm, through widgets, whether the launched proposals would affect, positively or negatively, the following well-being constituents:

(i) Safety;
(ii) Health;
(iii) Good social relations;
(iv) The basic material for a good life, which, according to the Millennium Ecosystem Assessment, configure the necessary dimensions for human beings' freedom of choice and action [5].

Each group made its proposals based on the analysis of the 6 categories of information layers, always considering the expertise of the group members and their level of knowledge of the problems of the DF.

As a result, three general maps were obtained with the set of proposals mapped in the colors defined for each thematic axis associated with a descriptor of the geodesign Platform with the characteristics of each proposal. On these proposals, during the following week, all the groups had access to them to comment on and analyze them considering the last section of collective design.

3.1 Partial Results

The final section was initially dedicated to the analysis, by each group, of the set of proposals from the other groups, submitted to a voting process. These votes, when taken to the plenary meeting of the 3 groups, indicated as rejected all the proposals with a rejection index above 70% of unfavorable votes by all groups (Fig. 8). In the case of the IRV-DF, two proposals were discarded.

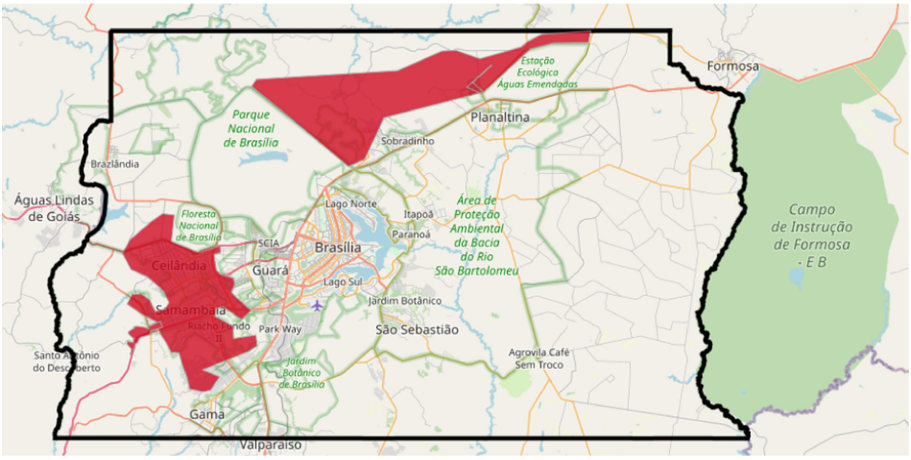


Fig. 8. Discarded proposals (red designs). Source: Giscolab Screenshot, adapted by the authors. (Color figure online)

However, when the votes reached a 60–40% or 50–50% ratio, the proposals were presented to the plenary, where a representative of each group defended their proposal, followed by the vote, which resulted in 4 approved proposals that followed the required subsystems. The following text analyzes each of these four proposals.

3.1.1 Green Infrastructure Subsystem: Approved Design

The green infrastructure subsystem denotes a common concern among most technicians and researchers. Such concern is indicated with the tracing of connections between the cores of the Cerrado Biosphere Reserve, which resulted in the design of biodiversity

corridors with potential for regional connectivity. These corridors are located between Águas Emendadas, the National Park and the Jardim Botânico region, and, in another quadrant of the DF, with the need to connect and protect the vegetated areas between the cities of Taguatinga (ARIE JK), Samambaia, Ceilândia and Recanto das Emas.

This implied the necessity of a connection between ARIE JK and Santo Antônio do Descoberto in the Southwest direction (Fig. 9).

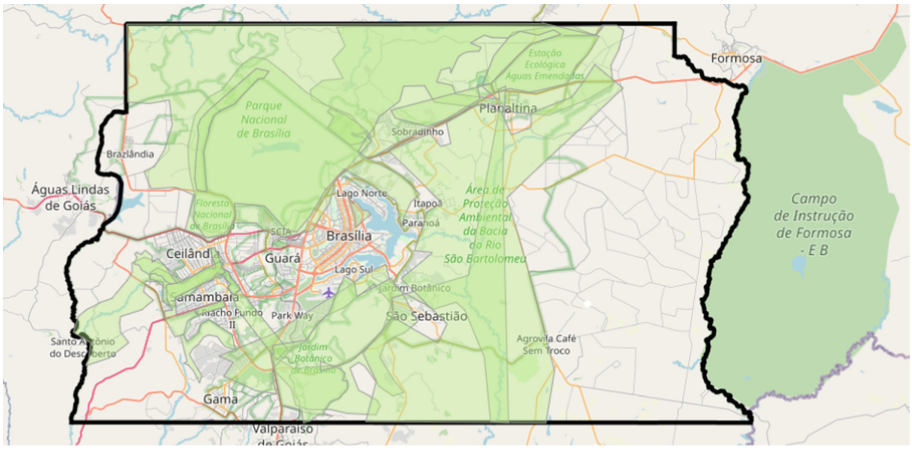


Fig. 9. Green Infrastructure Subsystem: design approved by the participants (light green designs). Source: Giscolab Screenshot, adapted by the authors. (Color figure online)

3.1.2 Provision Subsystem: Approved Design

In the provisioning subsystem, solutions were presented for the densification of the occupations along with the areas of influence of the Cerrado Biosphere Reserves through rural and/or urban occupations. These areas should be subject to Payments for Environmental Services with the promotion of agroforestry, permaculture and organic production, on the properties bordering these areas. For the essentially agricultural watershed of the basin of the Preto River in the DF, an incentive program was proposed to overcome the pattern of large monocultures based on pesticides and intensive use of water aiming carbon farming with water resilience, expanding the ecosystem functions of the region. The proposed program also aims to expand the ecological infrastructure beyond legal reserves and the introduction of other rural uses, not only monocultures but also productive farms for fruit and vegetables and rural tourism (Fig. 10).

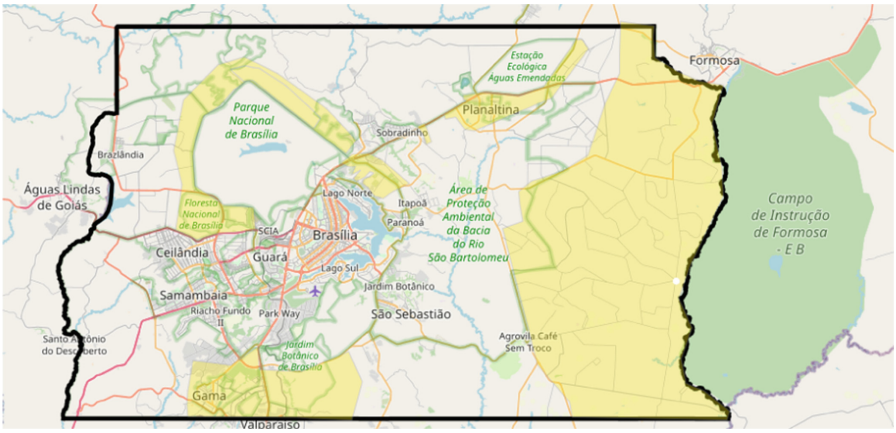


Fig. 10. Provision Subsystem: design approved by the participants (yellow designs). Source: Giscolab Screenshot, adapted by the authors. (Color figure online)

3.1.3 Blue Infrastructure Subsystem: Approved Design

Two areas form the scope of intervention to reinforce the blue infrastructure. The further west one refers to:

(i) The demand for requalification of the urban patterns of the cities located in priority aquifer recharge areas, to develop water resilience through the structuring of a system of urban green areas with the introduction of water into the landscape;
(ii) Review of permeability patterns of land and public spaces; (iii) incentives for public orchards and vegetable gardens and restoration of APP areas with native vegetation, all supported by environmental education actions (Fig. 11).

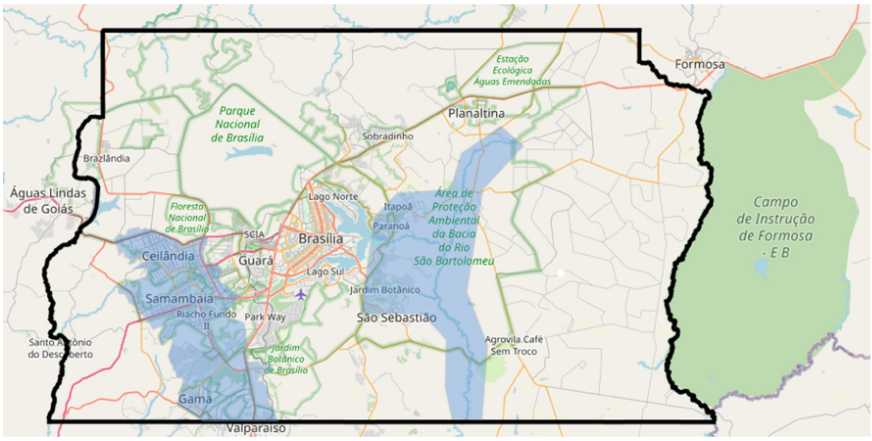


Fig. 11. Blue infrastructure subsystem: design approved by the participants (light blue designs). Source: Giscolab Screenshot, adapted by the authors. (Color figure online)

3.1.4 Leisure and Culture Subsystem: Approved Design

The final proposal was the result of a collective construction as there was only one design. The focus of this proposal was centered on rural and ecological tourism, where various potentials of the area were explored.

Among the verified potentials were the presence of waterfalls, eco-tourism, cultural tourism, sports and environmental education potentials, including the possibilities for recreation for the territory involving different income groups (Fig. 12).



Fig. 12. Leisure and culture subsystem: design approved by the participants (gray design) Source: Giscolab Screenshot, adapted by the authors. (Color figure online)

3.2 Overlapping of Approved Design Subsystems

A proposed summary for the general understanding of the designs of the 4 overlapping subsystems in the DF territory is presented below (Fig. 13). The overlapping shows that, in general, there was a need for connection between nuclei of the Cerrado reserve and concerns about blue infrastructure in areas at risk of aquifer loss.

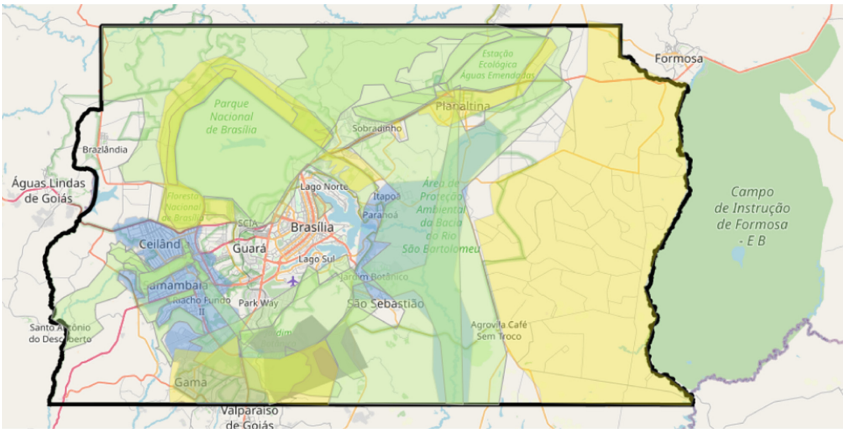


Fig. 13. Overlapping of the 4 systems approved by the participants. Source: Giscolab Screenshot, adapted by the authors. (Color figure online)

It should be noted that the systemic nature existing between the subsystems, which were separated only as a working methodology, is present when the set of proposals is brought together.

In this way, the necessary connectivity between the cores of the Biosphere Reserve that constitute the three hotspots of DF Biodiversity was mentioned by the three groups where the blue and green infrastructure proposals overlap to achieve the necessary connectivity.

Likewise, parts of the corridors formed between the three hotspots were highlighted as areas where ecotourism and leisure activities have the potential to occur, contributing to a green economy for the DF.

Another highlight regards a topic of extreme relevance to the DF, which is the water supply where the areas at risk of compromising the recharge of aquifers are occupied by settlements with high impermeability.

In this aspect, there are proposals in the southwest quadrant of the DF that outline strategies for retrofitting urban areas with the introduction of green infrastructure elements, providing soil permeability.

Also in this area, considering the existence of ARIE JK among the three largest cities in the DF, it was proposed to establish it as a biodiversity nucleus, functioning as a radiator of green wedges for the cities that surround it.

4 Results and Discussion

The use of the geodesign methodology in the planning and design process of a regional green infrastructure network, enabled through the synthesis of the adopted layers of information, the construction of a collective perception about the potential and territorial conflicts regarding its implementation. Geodesign also helped to bring out the relevance of layers related to supporting ecological processes and landscape ecology in design.

In this workshop it was possible to bring together in a co-design process, different perspectives of experts with different backgrounds, overcoming the false notion that the environment and urban development configure opposite fields.

The consensus worked out during the discussions throughout the workshop, made it possible to take a first step towards sketching, which would be a regional design for the territory studied. It also indicated the priorities for designing the project, both in terms of the project and in terms of processes and programs.

The results of the Workshop, although partial, point to some structuring bases of a more resilient occupation for the DF and can contribute to the revision of the PDOT-DF that is now under discussion. Among these, the need to create green area systems that advance from a traditional view of vegetation only for leisure and social interaction and progress towards the necessary function that a system of this nature has for the promotion of ecosystem services, has emerged as a great contribution.

A development already agreed upon between the Workshop members and the research groups involved from Universidade de Brasília (UnB), Pontificia Universidade Católica (PUC-MG) and Universidade Federal de Minas Gerais (UFMG) refers to the continuity of the geodesign process in a second iteration to consolidate the results achieved so far.

The use of geodesign tools, according to the case study presented here, provides a change in the planning and territorial design paradigm in which the design anticipates the proposition of plans, programs, and projects. This inversion indicates an important and much faster path than the "usual" for the planning, implementation and monitoring of policies without which a complex proposal such as the IVR-DF would not be able to be implemented at the time of the pressures and demands on the territorial occupation of the DF region.

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