Landscape Information Modelling to Improve Feedback in the Geodesign International Collaboration for Carbon Credit Enhancement in Metropolitan Regions – The Case Study of Fortaleza, Brazil

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Abstract. Better landscape designs demand better landscape analysis and vice versa. At regional scale, this feedback demands precision and integration among multiple scales. This work prospects the potential of information modelling to improve Geodesign in decision making and collaborative design through increasing feedback. As a participant of the International Geodesign Collaboration (IGC) workshop "Trees for Metropolitan Regions", this research has been developed for the Metropolitan Region of Fortaleza (MRF), the 6th largest in Brazil, located on the Northeast coast, and aimed at increasing green areas for Carbon Credit (CC) purposes. This methodological research achieved a script for subsequently information modelling application, which will improve precision in the achievement and evaluation of pre-established goals.

Six methodological steps accomplished a selection of data for latter parametric modelling: 1. Reading enrichment and definition of the planning concept; 2. Division of the metropolitan region into Landscape Units (LU); 3. Selection of squared cut out samples for each LU; 4. Proposition of innovative solutions; 5. Design for CC increment through conservation, expansion, and creation of green areas; 6. Evaluation of CC enhancement and feedback. For the fifth step, three future scenarios have been designed, in 2035 and 2050: the traditional, the late adopter and the early adopter. Replicating designed green areas from samples to their respective LU resulted in a total CC increase of 33.19% for the traditional scenario, 44.29% for the late adopter and 87.71% for the early adopter, all for 2050, which goal has been established by the IGC at 30%. Information modelling, using the identified parameters in this work, may review, accelerate and improve these results. This improvement will be enhanced when precision of sample recognition is increased to define smaller cut out squares. With opportunities of resources for data processing and design, information modelling allows the design of samples on microscale to feedback regional planning, which leads to adaptive goals and to

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develop a valuable tool for integration among multiple scales through Landscape Information Modeling (LIM).

Keyword: Geodesign · Metropolitan region · Landscape information modelling · Carbon credit · Fortaleza

1 Introduction

Evaluations and actions on landscape have seized the opportunity of the current transformative era of science, technology and innovation (STI) [1]. Landscape has been assessed through mathematical and computational models as much as any built infrastructure, which has provided a quantifiable and technological approach [2]. Available computer aid, especially regarding information modelling, which intertwines graphic and data [3], has provided an evolving prospect to be explored in landscape planning and design. Beyond representation, accuracy and quantification, technology has enabled better inclusion, participation and understanding from multiple stakeholders, especially from the community. Landscape professionals are not working alone. They are listening better from diversity and justice.

Geodesign [4] is an ongoing method that benefits from digital technology to encourage inclusion and participation in landscape practices. As an interdisciplinary planning method that uses systems thinking, geospatial technologies, and community participation to address environmental, social, and governance issues throughout the planning process [5], Geodesign is the methodological approach that supports this research in the application of information modelling to landscape planning. Using the Metropolitan Region of Fortaleza (MRF) as a case study, which represents the complex social and environmental dynamics of a growing touristic coastal area in Brazil's Northeast, this work prospects the steps for the application of information modelling to enhance feedback between landscape analysis (input) and design (output). The theoretical and practical basis for this research evolved from a worldwide network workshop entitled "Trees for Metropolitan Regions", supported by International Geodesign Collaboration (IGC).

1.1 Geodesign for a Global Green Design

Geodesign is a co-creation method of analysis (Geo) and project (Design) through a series of landscape transformation studies. It offers multiple scenarios for collaborative negotiation and definition of the best predictable alternatives for what it defines as an early adaptive design, with preparedness for the urgent challenges of mankind, especially in the context of the urban environment, such as development, maintenance, and protection [6]. The purpose of this methodology is to support cooperation in the construction of ideas, seeking specific goals, and taking into account the diversity of views and values from different stakeholders.

The particular workshop promoted by IGC and presented in this paper targets a design on a global scale for 2050. It aims to identify suitable areas to plant one trillion trees within metropolitan regions worldwide and raise Carbon Credit (CC) by up to 30% through

increasing green areas within the participant regions. For the case study of the MRF, the 6th largest in Brazil, the Geodesign Framework proposed by Steinitz [4] has been applied from the technical perspective of graduate and postgraduate students, professionals and researchers of Architecture and Urbanism and Environmental Engineering. A free digital platform for collaborative landscape analysis and proposal, developed in Brazil, the GisColab [7], was applied to accomplish the GeoDesign methodology. Considering the pandemic context of isolation, the platform supported very properly the discussions around the structuring and experimentation of an investigation process for improving studies in Geodesign, especially addressing the identified conflict of precision among multiple scales.

As a record of a methodological experimentation, the steps and procedures performed at this empirical work intend to subside the subsequent application of information modeling in planning (macro scale) and design (microscale), suitable for conservation, expansion and creation of green areas, with CC purposes at regional level. Based on theoretical approaches which support the greening of human settlements (Green Infrastructure and Nature Based Solutions), this research addresses parameters of urban sustainability that will be translated into design through application of information modeling to the landscape (Landscape Information Modelling - LIM).

1.2 Urbanization for Preservation: Green Infrastructure and Nature Based Solutions for a Sustainable Sprawl

Ecosystem services encompass a wide range of abiotic, biotic and cultural (ABC) functions and provide direct, economically and technically measurable benefits to man, classified as provision, control or culture [8]. At this work, CC is the ecosystem service addressed at metropolitan and global scale.

From ecosystem services, novel approaches have emerged to deal with numerous environmental, economic and social challenges, especially in large, growing cities. This paper focuses on green infrastructure (GI) and nature-based solutions (NBS) as premises to procedures for LIM exploration and respectively as the physical support and the techniques to enhance ecosystem services. For GI, this support consists of an interconnected green network which offers immediate and long-term solutions [9–12]. In the urban landscape, this network is a system of hubs (urban forests and parks), linear structures (such as street trees or water bodies) and stepping stone corridors (private gardens, green roofs) [12].

Inherently merged to GI, NBS are living solutions inspired by nature, that use nature and/or are supported by nature and perform a valid alternative for infrastructure development in new urbanization and infrastructure update in cities that are considering ways to rethink their time horizon and costs in maintaining them [13].

Currently, with most people in the world living in cities, the urban population is expected to continue growing [14] and, due to climate change, it is also predicted an increase in flood risk, heat stress, water shortage and air pollution [15]. Alves et al. [16] state that these environmental issues aggravate social and economic challenges and emphasize likely worst scenarios for large cities in developing countries, such as the case study of Fortaleza and its Metropolitan Region. Even with different severity, enhancement of livability, sustainability and resilience in cities is a global task, although

addressed in local (neighborhood, regional, national) scale [10]. Facing these multiple threats, GI and NBS are novel approaches that can reduce vulnerability and increase resilience and environmental justice [17] as their practices promote an urban sprawl that encompasses multi-functional green. Urbanization, therefore, when based upon these more sustainable approaches, is no longer an adversary of conservation, but an ally that suits population growth and urban sprawl with preservation, expansion and creation of green areas and their potential ecosystem services.

This urbanization model demands accuracy to negotiate the (social and environmental) callings and the priorities of each place with specific goals of planning and design, such as raising CC through the increase of green, as addressed in this work. This negotiation is exactly what Geodesign promotes in a participative and collaborative fashion. In Geodesign, precision is achieved not only through accurate data, but also through better feedback between inputs (Geo) and outputs (Design). In the case study of the MRF, LIM is a promising method to improve this feedback.

1.3 Landscape Information Modelling (LIM) and Geodesign: Shared Benefits for the Global Metropolitan Green Through Parametric Modelling

According to Eastman, et al. [3], information modelling brings the asset of a single data source that comprises two main components: (i) a graphic reproduction of the geometry (model), from which we can extract the 2D technical drawings; (ii) an integrated database that stores all information, properties, relationships, and presentations.

Information modelling also incorporates dynamic processes to design and enables visualization of several different possibilities before assembling the optimal result. This dynamic emerges from parametric modeling based on the principle that each model is built with entities, whose attributes may be fixed or variable. Fixed attributes are controlled and correspond to form, materials, performance and costs [3]. Variable attributes or parameters are the rules that define the geometric behavior (lines, surfaces, volumes, and their associations) and non-geometric behavior (materials, quantitative, performance, etc.) of the fixed ones, allowing objects to be automatically adjusted according to controlling and context changing.

Towards a LIM perspective and strategy, considering the changing essence of landscape, parametric modelling is a promising tool not only to incorporate dynamism to the processes of landscape planning and design but to achieve dynamic models where interactions among landscape, society and environment may be more accurately represented by functions and algorithms. Since it shares the benefits of integration, participation and dynamics with Geodesign, parametric modelling becomes the category of LIM addressed in this research for precision in the definition of the most suitable areas for green enhancement within the MRF.

2 Methodology

General guidelines from IGC for this workshop followed the methodology from Steinitz [4], which is based on three fundamental steps called “iterations”. The first “iteration” justifies the choice of the study area and “why” it is relevant: a complete study is made

through models that describe the area and support the construction of proposals for alternative futures. The second "iteration" consists of a methodological review to identify possible adjustments. The third and last "iteration" aims to answer "what, where, and when".

For this research, the first "iteration" corresponded to the "Geodesign Workshop" held in March 2021, promoted by the Geoprocessing Lab of the School of Architecture of the Federal University of Minas Gerais (UFMG) in partnership with the School of Architecture and Urbanism of the Federal University of Ceará (UFC). For the second "iteration" two arrangements have been made: (i) the size of the study area (total area of approximately 7,434.91 million square kilometers and 4,137,561 inhabitants) brought to a division of the MRF into Landscape Units (LU) following the geosystems methodology that outline these units based on social and environmental homogeneity. [18]; (ii) the complexity of data - reinforced by diversity of them among the LU, and the constraint in the number of participants in the local workshop due to quarantine and pandemic aggravation in Brazil - pointed out that the steps for the application of Geodesign could benefit from information modelling to enhance precision of results. The third step consisted of the choice of smaller samples within each LU, in which the landscape design propositions were made for the early adapter future of the LU, in 2035 and 2050 at a more approximate scale (Fig. 1).

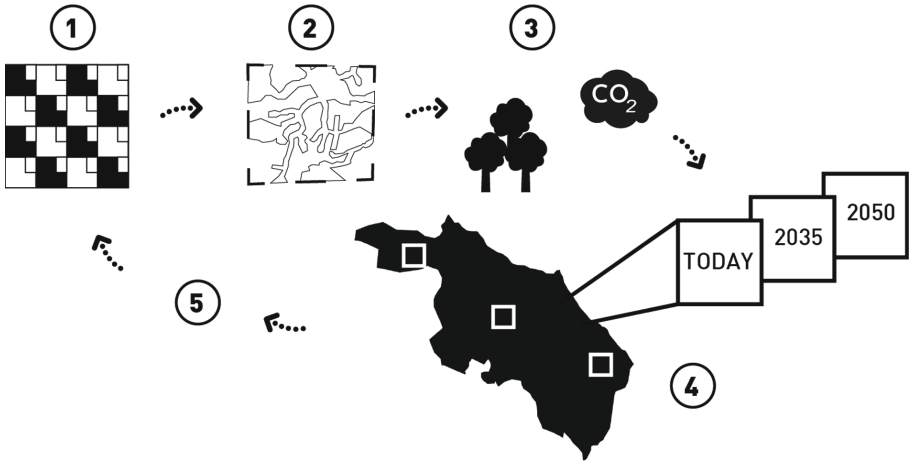

Fig. 1. Methodological diagram for LIM application to improve Geodesign feedback. 1 - Preliminary parameter for inputs. Layers used in spacial diagnosis; 2 - Proposed green areas; 3 - Giscolab platform algorithm; 4 - Percentage of carbon credit in different time scenarios; 5 - Future improvements in machine learning.

The MRF is characterized as a polarized metropolitan agglomeration, significative in the context of economic globalization. The contrast regarding development among Fortaleza and other cities of the MRF confirms the strong hierarchy present in the territory based on a center-periphery model. This condition is reinforced by the concentration of public investments in the capital. In the social sphere, the centralized model reveals

itself not only as a producer of inequalities, but based on unequal relations: the exacerbated dimensions of the City of Fortaleza is product of a system that engenders the irreversible impoverishment of the population through mechanisms of dispossession. The current structure is strategic for a development based on the exportation of the territory resources, which creates a system of transference of surplus value from labor exploitation. Production, orchestrated in this way, is not aimed at local development or specialized in the needs of the region's inhabitants, but in exogenous demands [19].

Based on the approach that the current trend of urban sprawl and growth within the MRF is unsustainable and thus unsuitable to green enhancement, regional planning for the MRF examined the territory possibilities for a multi polarized economic and spatial configuration, and made it feasible with the least possible environmental impact (Fig. 2). Then a macro-scale approach was devised to address relevant issues at the micro-scale. According to Novotny; Ahern; Brown [20], this method supports understanding the formation processes and future results, making it possible to deal with information beyond human intentionality - the proposals were made according to local specificities. The following 6 steps attended the Geodesign and IGC guidelines and also incorporated adjustments from "iterations" to improve integration among multiple scales and to subsidize LIM application for precision enhancement in results.

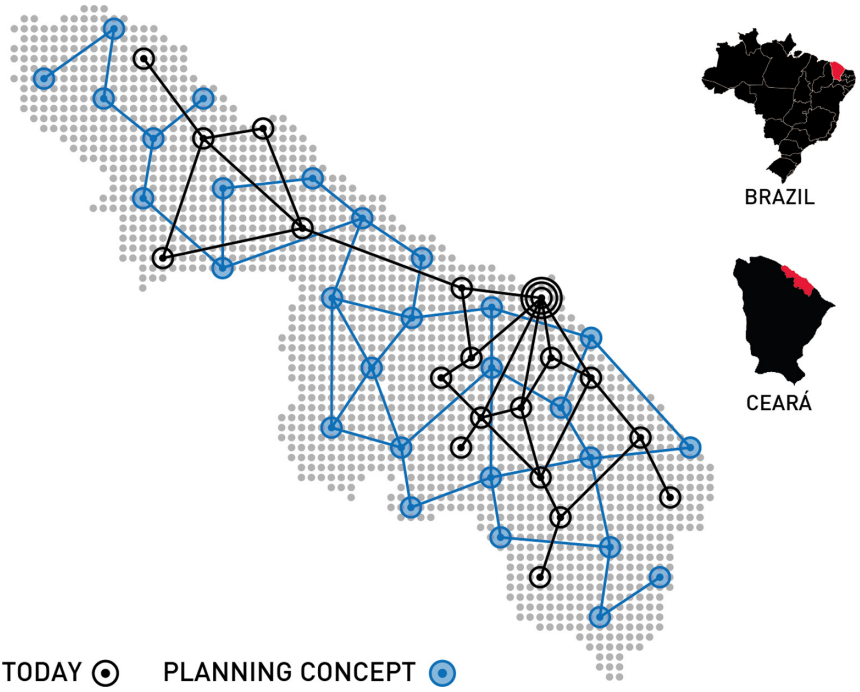

Fig. 2. Today's centralized metropolitan region and proposed planning concept

2.1 Reading Enrichment and Definition of the Planning Concept

This first step supports shared and participative comprehension of the case study region, and it consists of inserting pinned thematic annotations on a cartographic base of the MRF within the Giscolab platform. In order to elaborate these observations, the available 40 maps in the platform, organized in 10 categories (1. Vegetation/Green; 2. Agriculture; 3. Hydrography/Blue; 4. Housing; 5. Transport/Grey; 6. Institutions; 7. Industry and Commerce; 8. Energy; 9. Tourism and Recreation; 10. Carbon Credit) have been analyzed, individually and collectively. In the later, superpositions of maps granted better characterization of the area. Complementary information was also collected about the municipalities to understand their historical-economic-territorial formation and their main attributes and potentials.

2.2 Division of the Metropolitan Region into Landscape Units (LU)

The second stage was a methodological adjustment in an attempt to achieve Geodesign results within the programmed workshop period of April, 2021, Considering the extension of the case study, the complexity of data, the constraint in the number of workshop participants due to pandemic aggravation, and the lack of familiarity with other municipalities rather than Fortaleza, the region was divided into sub-areas. This resulted in the delimitation of 4 Landscape Units (LUs): 1. Coast; 2. Ridges; 3. Caatinga (Brazilian savannah); and 4. Productive macro region (Fig. 3).

This approach provides comprehension of the landscape as a mosaic of interacting systems. It also makes it possible to arrive at a more detailed analysis of the internal peculiarities of each LU, pointing out homogeneous and heterogeneous characteristics in each of them. This classification dialogues with the concept of geosystems [21].

The demarcation of the 4 LUs was based on the aerial images of the MRF available at Giscolab. These images were overlaid by layers of geographic and spatial data in order to cluster similarities and homogeneous biogeophysical aspects, as defined by MONTEZUMA et al. [22] and in accordance with Landscape Ecology principles:

> "(...) set of elements from the biogeophysical support, which includes, in the first level of analysis: topographic features; hydrology; coverage and land uses, identifiable through the interpretation of satellite images, photos of overflights, and field surveys" [22]

The boundaries of the LUs were not restricted to the administrative limits of the municipalities within the MRF as an attempt to recognize the existing dynamics in the territories that behave beyond political demarcation. It also considered the elements of the urban structure, observed through the layers of data available on the Giscolab platform, such as the urban-rural relationship, population density data, land use, concentration of urban services, and branching of the road network. The 4 LUs are described below:

a) *Coast*:
It displays two contrasting sectors, which appear to be temporal mirrors from one another. The Eastern territory is a large urban area which is widely occupied and

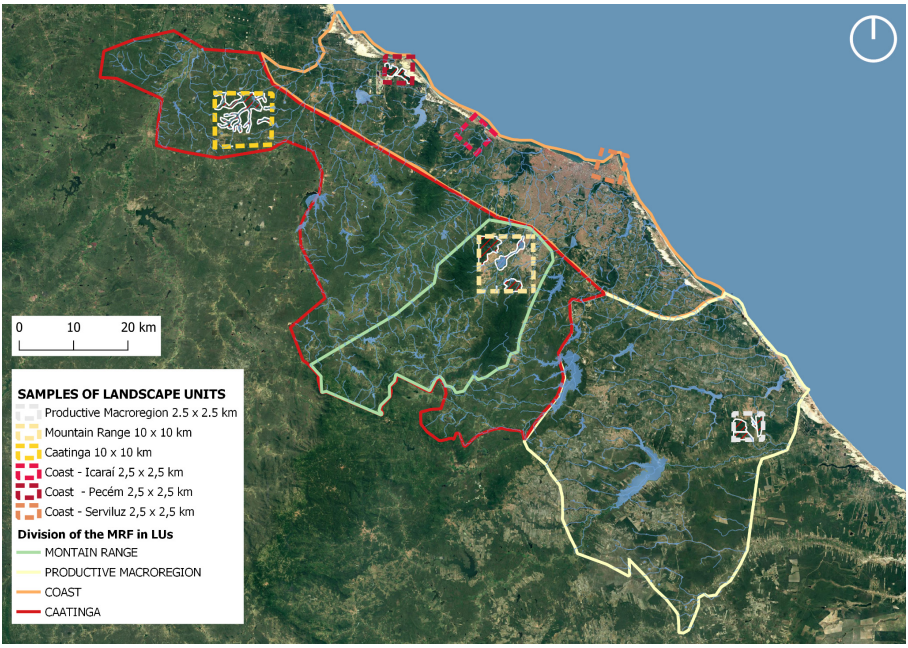

Fig. 3. Division of the Metropolitan Region of Fortaleza into Landscape Units

urbanized and concentrates most of the urban services and the higher population density (although it lacks qualified green open spaces and presents low environmental conditions). The Western portion presents a lower density and follows traditional planning, remaining a current vector of attraction for occupation.

b) *Ridges (mountain range)*
This LU has been delimited mainly based on its distinguishing topographic features. Much of this territory has steep slopes and masses of preserved vegetation. It is a region with high water provision relevance. Within them are located the springs of important water axes that flow towards the ocean and Fortaleza. Along them, landscape and territory adjusted themselves into river floodplains. There is a trend of the rapid advance of urban expansion onto this unit, with a mainly residential characteristic, expressed by many new ground divisions and real estate development.

c) *Caatinga (Brazilian savannah)*
This unit was defined by the area of occurrence of the biome of the same name in the territory, which is very well-preserved Brazilian savannah and surrounds the Ridges, expanding to the west of this LU. To the North, it plays an important role as a transition zone between the forested vegetation of the Ridges and the denser urban occupation of Fortaleza. To the West and South, this unit is still very little urbanized and is used mainly as an area for agricultural production, being shredded into large properties used for this purpose. The LU covers parts of 13 of the municipalities studied.

d) *Productive Macro Region*
This area presents municipalities with similar characteristics related to agricultural and cattle production. Despite presenting large green patches of unoccupied soil, these are of low-quality vegetation, typical of degraded soil.

2.3 Selection of Samples for Each Landscape Unit

The methodological adjustment that divided the studied metropolitan region into LUs resulted in areas with yet large extensions to be analysed and designed during the workshop period. An additional arrangement was then made and the LUs were distributed among the workshop participants who assessed their potentials and conflicts in order to select cut out samples able to adequately represent scenarios of the region at the micro-scale. It was also a strategy to identify new places for decentralization, using existing urbanization processes as an opportunity for planning a sustainable growth of medium cities. This approach allowed a detailed reading of the current situation so that proposals and means of implementation could be developed for what was identified as the most critical situation at the site. Thus, the samples were proposed starting with 5 × 5 km area units, with multiples of this value being used when this size was insufficient to be representative.

2.4 Proposition of Innovative Solutions

The division into LUs served to identify the great heterogeneity of the MRF. Such recognition led to the selection of different proposals for each LU in the fourth stage to achieve the final objective: sustainable development. The proposals were chosen from the catalog of ideas provided by Geodesign so that they would be consistent with the local characteristics. From there, the fourth step was the graphic definition of the maps, through the creation of polygons and points, where the innovative proposals would be implemented. These proposals were organized around future scenarios for the years 2035 and 2050, using innovative urban design and planning solutions as support to achieve the desired carbon credit goals in each scenario. This design was later used to verify the influence of the innovative area on carbon credit generation in the fifth and last stage.

2.5 Design for Expansion of CC Through Conservation, Expansion, and Creation of Green Areas

The definition of a clear and specific objective made each LU to be worked according to its specificity for the same purpose, being able to promote the flexibility of the types of proposed interventions, selecting them according to their particularities (Fig. 4).

2.6 Evaluation of Carbon Credit Enhancement for Design Feedback

Giscolab provided an algorithmic script for latter parametric modelling that expressed for the participants the quantitative significance of the carbon's credit area proposed on the territory. It was possible to visualize its size in Km^2, participation in the MRF's

Synthesis of steps 2.3 , 2.4 , 2.5				
	Coast sample	Ridge sample	Caatinga sample	Productive macro region sample
2.3 Selection of samples	Due to the strong spatial contrasts 3 samples were selected for the complete depiction of the area . The Eastern sample is widely occupied and urbanized and concentrates most of the urban services and the higher population density. The Western sample has a lower density and follows traditional planning, remaining a current vector of attraction for occupation. With the exception of these two extremes, the area is mostly recognized as a touristic region because of its beaches, it was where the third sample was chosen.	The sample connects to the MRF through its water and road axes, both very capillarized. Presence of rocky formations and abundant water resources, besides being an indigenous reserve area. The growth of the urban agglomeration results in conflicts among the urban expansion area, the conservation units, and existing preservation areas.	Large area of expressive vegetation (Caatinga) with high metrics for CC and patches of agricultural land in contrast with consolidated and expansion area.	The predominant activity of land use in the LU is rural, with a large presence of agriculture and livestock. A large presence of farms in the area of agriculture and also expressive vegetation divided into two biomes: caatinga and coastal vegetation.
2.4 Proposition of innovative solutions	For 2035 and 2050, gradually create a more efficient flow structure, improving the connection with Fortaleza through a coastal corridor of railway lines and shared transportation. For new occupations and urban renewal, the adoption of self-sustainable compact neighborhoods was indicated. Linear parks and green corridors, permeable sidewalk materials, and green roofs on buildings were also proposed.	For 2035, the proposals aim to make the new urban occupations compatible, combining green areas with educational uses, ecotourism, water BMP, and restoration of riverside ecosystems. It is also proposed the exploitation of cultural traditions as economic possibilities and the creation of mixed neighborhoods, supported by more efficient public transportation and rooftop solar energy production. By 2050, it is proposed to intensify these strategies, adding more technological innovations.	For 2035 have a resilient and repair character for vegetation, the use of shared bicycles, the smart city consolidated, use of sunlight for irrigation and the presence of renewable energy. For 2050 the intensification of the proposals of 2050, solar roads, sharing taken to the local economy and sustainable neighborhoods.	It is expected that a low-density occupation pattern will continue, inserted in agricultural lands in a dispersed way, with sustainable productive sites. The denser urban core will expand along the existing roads and highways, and around the consolidated urban core to the north. As an alternative to extensive farming strategies such as food forests, carbon farmings, rewilding, and adoption of agrotourism are proposed as another income possibility for sustainable farms.
2.5 Design CC	In the consolidated area it is proposed to gradually substitute the gray infrastructure with an integrated system of green infrastructure, which would increase the urban vegetation cover along the roads, and connect parks and wetlands. In the developing area it is proposed the conservation of these connections in their natural state, besides the preservation of parks constituted by dune areas; the proposal of occupation in the territory through compact neighborhoods. In the more touristic area, it is proposed the expansion of its tourist vocation through ecotourism poles, based on the strategy of conservation of the existing green areas.	In traditional planning, this sample would suffer reduction and loss of quality of its green areas to give way to the expansion of urban patches, which would advance over forest masses and water resources. Managing conflicts through innovative proposals for 2035, it is possible to conserve and qualify the existing vegetation, adapting the urban expansion to a design that allows the maintenance of ecological services (protection and recovery of APPs, APA, and indigenous reserve). Strategies such as compact neighborhoods, permeabilization of urban soil, adoption of renewable energy, and shared transportation can enable balanced urban expansion. For 2050, new green areas are created in continuity with the 2035 proposals, improving the shape and core area of LUs.	For the traditional scenario it was proposed the consolidation of the area of urban expansion and the increase of the road network and the conservation of the vegetation close to water resources. In the 2035 scenario, in addition to the conservation of the vegetation stretches of the previous proposal, would be added links between the stretches forming a unit. In the final proposal for 2050, the quality of the CC would be taken into account with the reduction of the existing borders in the previous proposal.	It has been proposed solutions that integrate low-density urban life and expansion with agriculture and the rural identity of the place, such as food forests, agrotourism, carbon farming, and rewilding. Due to the nature of the proposals, green areas are dispersed throughout the territory, within productive lands, and promote a gradual recovery of areas that today are degraded by extensive farming. Thus, the sample would combine conservation, expansion, and creation of green areas overtime in the territory.

Fig. 4. Synthesis of steps 2.3, 2.4, 2.5.

goal, tree units and quantity of CO_2 below and above the ground. During the execution, the visualization of these numbers served as a guide for the intervention in such a way that was pursued that these areas overcome quantitatively the proportional goal for the MRF, even if it was roughly. Throughout the development of the traditional, 2035 and 2050 scenarios, it was possible to establish gradual vegetation masses, defining foremost interventions for 2035 and which ones could be added for the 2050 goal achievement.

After designing samples, the indexes informed by the platform were used to calculate the metrics impact in proportion to each landscape unit. We organized the data found into a table, through which the corresponding area in each LU was found. Hereupon, for the verification of the accomplishment of the goals from the algorithm, bigger polygons were drawn in the Giscolab platform with the corresponding area calculated on the table.

3 Results

3.1 Percentage of Carbon Credit Enhancement for the Traditional and Early Adapter Scenarios for 2035 and 2050

The traditional scenario kept the current logic of urban expansion consuming green areas - the proposal was just to maintain the existing vegetation. The results showed that the coast has the worst performance, reaching only about 1/3 of the proportional goal of the productive macroregion. On the productive macroregion and ridges LUs, the results are consequences of the low population density and urban expansion. Although similars, the indexes for coast and caatinga LUs are based on different reasons: while the coast reflects the real state exploitation; the caatinga is a consequence of the urban expansion and local type of vegetation.

In 2035, the inicial innovative proposals were adopted. The proportional goal of coast, caatinga and ridges LUs increased until similar levels of the productive macroregion - coast presented the greatest advance, almost triplicating its indexes. Observing the indexes of the productive macroregion it is seen that there was no significant advance - the goal adopted for the proposals there was to increase the quality of the existing vegetation.

Consolidation and expansion of the strategies adopted in 2035 were the approach for 2050 scenario. Advance appears in all the indexes of all the LUs: with exception of the caatinga sample, LUs almost doubled indexes.In coast LU, which comprehends the capital, the existence of areas already dense and consolidated motivated the adoption of radical strategies to recover nature, aligned with the general goal of MRF's decentralization. Analysing the caatinga and productive Macro region LUs, it is verified that even areas with good performance can be improved. The case of caatinga LU shows the difficulty faced by some biomes in reaching the established indexes (Fig. 5).

3.2 Design Parameters for Enhancement of Green Areas Thorough Conservation, Expansion or Creation

The following images represent schematic scenarios that synthesize the proposals prepared for the samples of each LU, illustrating temporally the implementation of carbon credit patches (Fig. 6).

		Coast	Hills	Caatinga	Productive Macro region
LU area (km²)		892,59	952,37	2.210,67	1.793,26
Sample area (km²)		75	100	100	25
Traditional	Proportional goal (%/Km²)	0,003	0,007	0,004	0,01
	Project CO2 captured ABOVE ground (MgC/Km²)	152	406,6	263,72	585,92
	Project CO2 captured BELOW ground (MgC/Km²)	80,27	214,72	139,27	309,42
	Project tree numbers (units/Km²)	10.158	27.174	17.625	39.158
2035	Proportional goal (%/Km²)	0,009	0,009	0,005	0,01
	Project CO2 captured ABOVE ground (MgC/Km²)	802,78	513,17	306,601	605,56
	Project CO2 captured BELOW ground (MgC/Km²)	423,94	271	161,91	319,79
	Project tree numbers (units/Km²)	34.925	34.296	20.491	40.471
2050	Proportional goal (%/Km²)	0,024	0,01	0,01	0,022
	Project CO2 captured ABOVE ground (MgC/Km²)	1.437,83	578,02	597,31	1.350,05
	Project CO2 captured BELOW ground (MgC/Km²)	759,31	305,25	315,43	712,95
	Project tree numbers (units/Km²)	96.094	38.630	39.919	90.227

Fig. 5. Calculation summary table

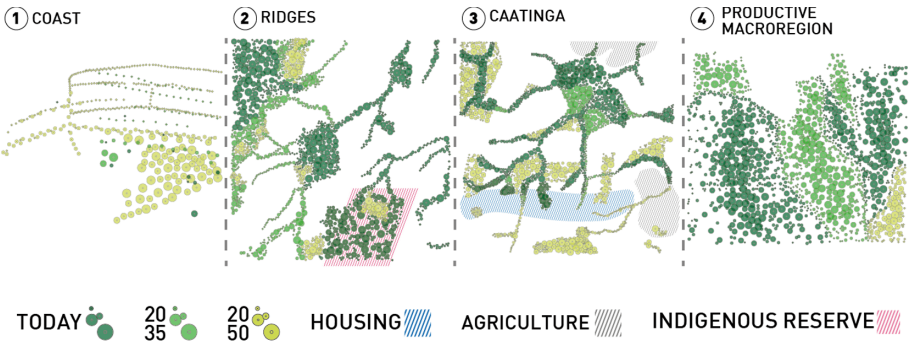

Fig. 6. Synthesis of the propositions in CC for the designed samples

3.3 Parameters for Latter Landscape Information Modelling Application

Steps for the Geodesign application resulted in the clustering of common parameters among all samples. These parameters were essential subsidies to design the green areas to be preserved, expanded or created. The analyzed mosaic of maps (Fig. 7) then consists of the script with a list of characteristics for subsequent application of an algorithm that is able to recognize data patterns for the most suitable places to green in a metropolitan region.

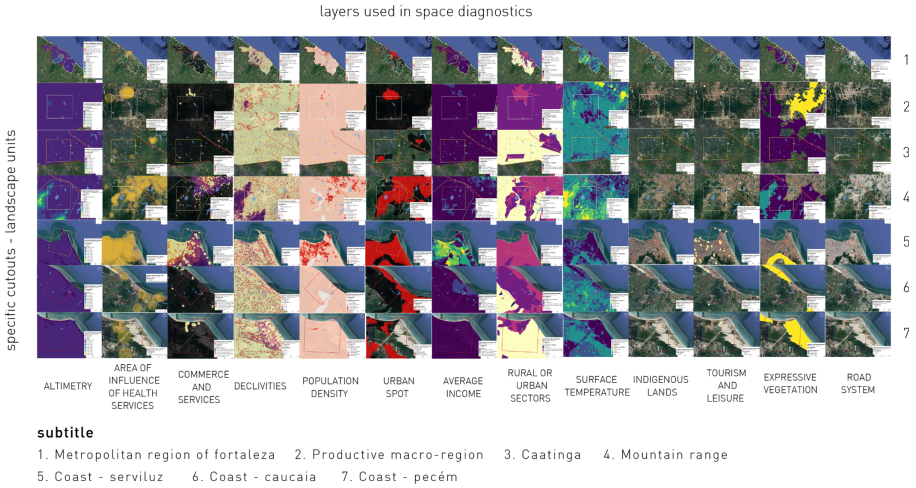

Fig. 7. Parameters for green and CC enhancement

4 Conclusions

Planning the intervention on the samples targeting the increase in 30% CC for the case study area, the MRF, represented an exercise of imagining the instant feedback from the cut out scale designs to macro effects, set off by the replication of micro strategies. Through the algorithm available by Giscolab, which helped the feedback, it was realized how the projection of the effect on interventions at design level on the regional goal achievement can be didactical for planners: observe, during the polygons tracing, the quantity and impact of the proposals makes the interscalar comprehension much more tangible.

Studying the microscale in the MRF territory reveals the perpetuation of environmental conflicts - although with much less intensity- similar to the ones already seen in Fortaleza. It has been observed the occupational pattern repeating the advance over fragile areas and the adoption of outdated strategies for the management of water and land resources. The development of new neighbourhoods shows the continuance of the functional similarity instead of multifunctional approach: the urban expansion is mostly for habitational purposes. How can the cities become less dependent on the capital if they keep adding so little diversity?

The habitational insecurity related to environmental degradation is connected with the tactics adopted by new urbanizations - if they will consider the ecosystem functions provided by nature; if they will find the specific strategy for each territory to guarantee the natural infrastructure maintenance. Planning of the CC areas on the microscale, we can see that they are not sustainable if they can't relate to local characteristics. Clearly, delimitating forests for preservation will not be sufficient as a way of resistance to the conflicts generated by the urban expansion. Which institutional, economic and social functions can add to each spatial sample, subsidizing the continuity of the green area? For this reason, the scale integration was very useful to allow the comprehension that the

conservation, ampliation and creation of areas for CC can't be dissociated from other aspects of urban planning. In reality, they will be enabled or prevented by them.

This exercise of feedback between scales shows the contribution of local interventions on regional and global goals, allowing for more precise planning through incorporating the existing differences and making more manageable the difficulties in the comprehension of great territorial dynamics. The Giscolab algorithm facilitated the continuous feedback process, necessary for the selection of suitable proposals for the established goal. As a recommendation for future studies, we saw the necessity for more precision in the algorithm development so it can incorporate a greater amount of local specificities. We emphasize the possibility of using parametric modelling as a way of toll improvement, thus enhancing the feedback between Geo and Design.

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