

Geodesign in Salvador Metropolitan Region: Regional Planning Based on Reproducible and Defensible Criteria

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Abstract. As a contribution to the meeting IGC – International Geodesign Collaboration, a group of 14 Brazilian universities developed a case study about Trees for Metropolitan Regions. One of them, and the last one developed, was about the Salvador Metropolitan Region. Being the last one, it was an opportunity to apply the observations collected during the previous experiments, in order to arrive to a framework based on reproducible and defensible criteria. The main improvements were new scripts to support decision making about the fulfillment of SDGs (Sustainable Development Goals) developed as WPS (Web Processing Service), and the composition of the groups (people from the area and not from the area). The results were analyzed according to the thematic, priority and locational assertiveness. From the collection of ideas, 67.9% were considered quite good and 23.2% were considered good. The indexes of the thematic and priority assertiveness were very high (96.4% and 89.2%), while the locational assertiveness was 73.2%. In face to these numbers, it was possible to affirm that the results were very good. It was an academic experiment, but the process of geodesign can be considered by the public administration in the regional plan that is under development.

Keywords: Participatory planning · Web Processing Services · GISColab

1 Introduction

Geodesign is a group of procedures to allow spatial planning, from the scales of landscape to local and territorial planning, considering the sense of participation, based on co-creation. It can be considered the application of contemporary values in planning, as it proposes to work with different actions, to structure different steps as a support to opinion and decision making. Moreover, it applies new digital technologies, mainly the web-based on, to give access to data, to allow the consumption of information and the creation of ideas to the area [1–6].

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To have the opportunity to discuss the possibilities of the Geodesign application, a collaboration group was created, the IGC – International Geodesign Collaboration. This group is getting together annually to test and discuss frameworks, procedures to reach the defined objectives, to exchange experiences about local specificities and knowledge. There are proposals about how to achieve the SDG – Sustainable Development Goals in planning, how to face the schedules of time to correspond to global agreements (UN Agenda 2030, Paris Agreement 2050). There is also the discussion about assessments to be considered to bring innovation to new projects and policies in planning.

As part of the annual meeting of the IGC 2021, a group of 14 universities in Brazil got together to develop 13 case studies, about some of the metropolitan regions in the country. To be able to compare results with the IGC participants, all the groups had to think about scenarios for 2021, 2030 and 2050; and to divide the designs in non-adopter, late-adopter or early-adopter behavior. These conditions were to make participants understand the results of working in a traditional way (non-adopter) and to measure the results of including innovations (from late-adopter to early-adopter values). There was a list of ideas, presented as assumptions, which could be used while proposing the ideas. And, finally, the results of the workshops had to be analyzed according to the fulfillment of the goals of the 2030 agenda [7].

Specifically for the Brazilian studies the groups had to follow the same basic framework, use the same collection of around 40 initial thematic maps, but they were free to add steps, to use additional methods or technologies, to compose the groups of participants according to their reality. The name of the Brazilian project was "Trees for metropolitan regions in Brazil", with the goal to test scalability and flexibility in the use of the Brazilian Geodesign platform.

We wanted to prove scalability because we were developing 13 case studies, but there are 74 metropolitan regions in Brazil, and the same process could also be applied in other scales and areas. We wanted to prove that we were using defensible and reproducible criteria, which are the base for comparisons. And we had as keyword the sense of adaptability, as we live in a continental country that requires flexibility to consider the many differences in geography, social vulnerabilities, economic resources, access to information, and the possibilities to be part of.

While presenting a common base, as also incentivizing local adaptations, we had the best from all groups. Because all of them followed a proposed structure, received the same support of the map collection and training to use GISColab (the Brazilian Geodesign Platform), but all of them added specific adaptations to the process [8]. The results from the 13 workshops were presented in the IGC 2021 [9].

The case study presented here was the last one developed. It was held on May 2021. The Brazilian workshops started in February and ended in May, all of them planned to be developed in 4-day meetings, synchronous or asynchronous, depending on the decision of the local coordinator. In the Salvador Metropolitan Region, the studies were developed in 4 days, with synchronous meetings to propose and explain the steps, followed by the additional possibility of completing the task in asynchronous participation. It was part of post-graduation course in the Geoscience Institute, Federal University of Minas Gerais, developed in 45 h, called "*Geodesign no planejamento territorial de regiões metropolitanas*" (Geodesign in territorial planning of metropolitan regions). In addition

to 20 h of the Geodesign workshop there were also lectures about the state of the art in landscape and regional planning, the role of Geodesign in contemporary planning, and to discuss the results from the workshop.

There was a group of students from Minas Gerais, UFMG, and a group of students and professionals from Bahia, from universities of the metropolitan region of Salvador, mainly the Federal University of Bahia (UFBA). The group started with 24 interested people, but ended with 13. This number is higher than the media of participants from other metropolitan regions (In Brazil, Belo Horizonte had 27, Recife had 5, the media was 11.6 and the mode was 12). From these 13, 8 were from Minas Gerais and 5 from Bahia. We believe that we had a smaller number from Bahia because they were volunteers, while from Minas Gerais they had to conclude the activities to receive the credits for the course. But the discussions and analysis were good enough to make us feel confident about the results.

As each group, from each metropolitan region had the possibility of adapting the workshop according to their expertise in knowledge and tools, as a result we had a mosaic of different possibilities about how to conduct a workshop. In Belo Horizonte they experimented the voting and agreements process in all the steps. In São Paulo they acted as projective professionals, designing the ideas. In Florianópolis they stated planning the ideas in tables and associating them with the systems and the SDGs, followed by the decision about the area, where to locate them. In Rio de Janeiro they used web-based technologies to create ideas in a VGI platform (Volunteered Geographic Information). In Fortaleza they divided the area in zones of landscape units and each participant was responsible for one of them. In Campinas they created groups of participants and tasks to be done according to the triad of sustainability: economy, social and environmental axis. In Belém they were very interested in maps and geoprocessing modeling. In Goiânia they took the opportunity to teach about the geography of the area. In Recife they tested the possibilities of developing asynchronous workshops. In Macapá they experimented geodesign developed by a group of technicians from public administration. In Palmas they were interested in understanding the area, as the metropolitan region is very new and it is not characterized as a metropolitan area. In Carbonífera metropolitan region they faced the difficulties in accepting innovations, as they are very traditional, and to discuss concepts and cultural references. Finally, in Salvador, as it was the last workshop, it was an opportunity to review the processes and to apply adjustments. The experiments were very interesting, because we prefer to analyze differences rather than similarities, because we learn with them.

1.1 The Case Study: Salvador Metropolitan Region

The RMS is composed of 13 municipalities where in 2021 almost 4 million inhabitants live in an area of 4,375 km^2, with 3,998,754 inhabitants resulting in a density of 900 inhabitants/km^2, and a GDP of 140,442 million [10]. The RMS was established by federal supplementary law number 14, of June 8, 1973. It currently comprises of the municipalities of Camaçari, Candeias, Dias D'Ávila, Itaparica, Lauro de Freitas, Madre de Deus, Mata de São João, Pojuca, Salvador, São Francisco do Conde, São Sebastião do Passé, Simões Filho and Vera Cruz. It is characterized by an extensive Atlantic coastline,

in an area with strong touristic potential, composed of islets and a large island, the Island of Itaparica, in addition to the Bay of Todos dos Santos (Fig. 1).

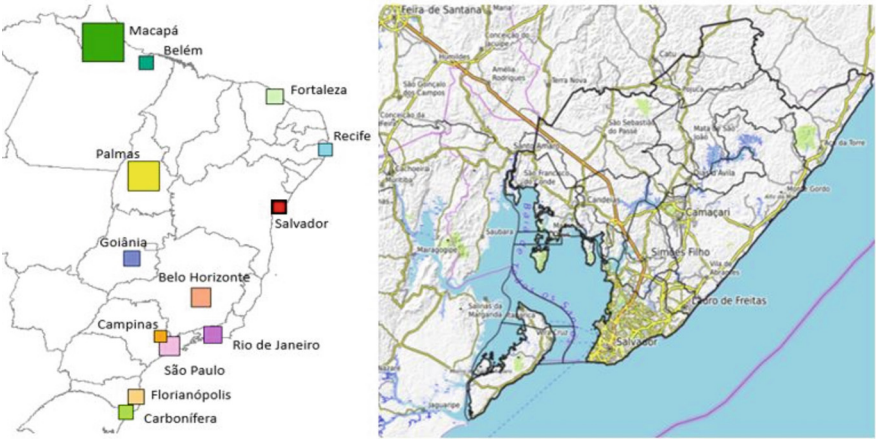


Fig. 1. Case study in Brazil and the Metropolitan Region of Salvador. Source: the authors.

It is important to emphasize that most of the municipalities that make up the RMS have the headquarters, districts and villages, in addition to rural areas. They are composed of industrial cities (Industrial Pole of Camaçari and Superintendence of Industrial and Commercial Development – SUDIC), cities developed due to oil extraction and refining activities, dormitory cities and touristic cities, for the most part. It comprises of areas of survival agriculture, extractives' activities and livestock and others not favorable to cultivation due to the regional climate (sudden variations in temperature, insolation, floods and heavy rains) and/or soil constitution.

Its main element of landscape is the tropical coastal strip, ranging from the dense urban occupation of the cities of Salvador and Lauro de Freitas to the borders destined for hotel hubs. The city of Salvador dates to 1549 and has always been an important commercial port. The capital is known for its Portuguese colonial architecture, Afro-Brazilian culture. The RMS is a composition of contrasts from very developed and qualified areas, together with areas of socially fragile occupations, where the population lives in slums and with poor sanitation conditions and services. The contrast is also observed in the economic conditions since the RMS is home to important industries at the Camaçari Petrochemical Complex and the Aratu Industrial Center. The economic base is petrochemical production, but due to its geographical position, the area has great potential for the development of alternative energy resources. The vegetation is characterized by the Atlantic Forest, but the areas delimited as conservation units are not significant, and are concentrated on the coast, in care of preservation of the shore. It is also necessary to better explore the great touristic potential for activities that are more committed to contemporary values of sustainability (Fig. 2).



Fig. 2. The complexity in landscape and land use. Source: Pinterest images.

The RMS has a large environmental heritage and tourist attraction - mineral water sources, coral reefs, beaches, dunes, remnants of Atlantic Forest, riparian forests, sandbanks and mangroves - and houses some conservation units: Environmental Protection Areas (APA) Joanes/Ipitanga, Rio Capivara, Lagoas de Guarajuba and Pinaúnas; Green Belt for the Protection of the Camaçari Petrochemical Complex; Abrantes Dunes Parks; Garcia D'Ávila; Restinga de Praia do Forte Municipal Natural Park and, still in the implementation phase, the Baiacu Ecological Park. The serious problems of soil contamination, water and air pollution, among others, that the region faces must be considered.

The region's development plan, which is still in process, will provide a Geographic Information System (http://www.emrms.ba.gov.br). In this plan, the PDUI – RMS (Integrated Urban Development Plan, Metropolitan Region of Salvador), the priority is the activities or services that one of the municipalities cannot perform alone or that impact its neighbors called Public Functions of Common Interest. The prioritized thematic areas are: Socioeconomic Development; Mobility; Planning, Land Use and Housing; and, Environment and Sanitation. During the construction of the institutional plan, the local government seeks to establish an urban sustainability agenda that encompasses the models of eco-energy rationality, metabolic balance, purity, citizenship, heritage, efficiency and equity [10].

The aforementioned plan aims to guide public proposals and actions in the RMS, especially in the area of urban mobility. It will cover the West Road System project, which includes the Salvador-Itaparica Island Bridge and actions of the Intermunicipal Urban Plan for the Island of Itaparica, the transversal corridors (Blue Line and Red Line), the Subway System and the Metro tram. The case study was an academic experiment to teach the geodesign method, and not a contribution to the institutional plan that is under development, as it. But the lessons learned can be a possibility for the future.

2 Methodology

The methodology had three levels of development: a) as a participant from the IGC meeting, it had to follow a framework proposed by them; b) as a participant from Brazilian case studies, it had to follow the framework that adapted the IGC proposal to local case studies; c) as a case study from the Salvador Metropolitan Region it had to consider the specifications of the experiment, mainly due to the participations of actors from different parts of Brazil (Minas Gerais and Bahia).

2.1 The IGC Proposal

The IGC 2021 meeting proposed a framework to be followed by all participants, while the workshops were expected to create scenarios or designs to 2021, 2030 and 2050, considering different behaviors by the actors of the society that were supposed to be "not-adopter" (traditional), "late-adopter" (initially traditional, but available to consider innovations) and "early-adopter" (available for innovations). The workshop had to consider 8 systems, and the coordinators could include 2 more. While thinking about ideas, it was important to considerer the Sustainable Development Goals. And, about the ideas of projects or policies, the organization provided a list of assumptions divided by the systems, which the participants could apply in their proposals [7].

2.2 The Brazilian Proposal

The group of 14 Brazilian universities developed 13 case studies about trees for metropolitan areas, with the goal to take part in the IGC meeting, but also to face challenges of planning in a continental country and to use some facilities developed here. The challenges are to work in areas with lack of data, lack of technological assessments, to include people that sometimes can have difficulties in using technologies, and so one. But the facilities were the use of a Brazilian Web-based Geodesign platform, called GISColab, and to have the support of the Geoprocessing Laboratory, from the Federal University of Minas Gerais.

Before the workshop itself, the mentioned Laboratory prepared all the data for all the case studies. It was a task that could be distributed or shared, but the researchers wanted to test the scalability of the process, arriving to a definition of a minimum collection of maps that could characterize the areas in the regional scale, and to measure the time required to prepare them [9]. Data from the SDIs (Spatial Data Infrastructure) were analyzed to select the best ones and the geoprocessing modelling was applied to arrive to thematic maps (i.g. Accessibility and Capillarity, Socioeconomic distribution of resources, Infrastructure, Land Use and Land Cover, Geomorphological conditions as Slope, Vegetation fragments and their metrics, and so one).

With the collection of 40 maps ready to be used, the files were uploaded in a Geographic Database in the web, they were prepared to be used as WMS or WFS (web map service or web feature service) in a Geoserver, metadata could be prepared, and finally were available to be used in a WebGis, where the "core" of Geodesign happens. The system is based on the OGC – Open Geospatial Consortium, which means it can dialogue with many other applications, as it uses common consensus standards. It was initially developed by GE21 Geotechnologies, and was optimized by scripts and programming to be used as "GISColab", the Geodesign platform [8].

The workshop starts, with all the maps organized in the WebGis as layers and distributed according to the main systems proposed by the IGC 2021 meeting. The framework proposed to the Brazilian group was planned to happen in 4 days. In the first day, the participants did the "Reading Enrichment" that is the analysis of maps collection and the register of pins called "Annotations". It is called reading enrichment because people learn about the area but also contribute with comments, alerts, additional information that are not in the presented data. These contributions are color-coded pins as annotations, colored according to the systems.

On days 2, 3 and 4 they construct scenarios, that are designs for the years and values proposed by the IGC 2021. They use the "Dialogues" resources in which they can draw points, lines or polygons with ideas of policies or projects. In these Dialogues they present the georeferenced idea, with its name and description. There is a step that all the participants read each idea to add comments, criticizing, suggesting changes or giving support with additional elements. And there is also the step of "Voting" in which the participants register if they like or dislike, approve or not the proposal (Fig. 3).

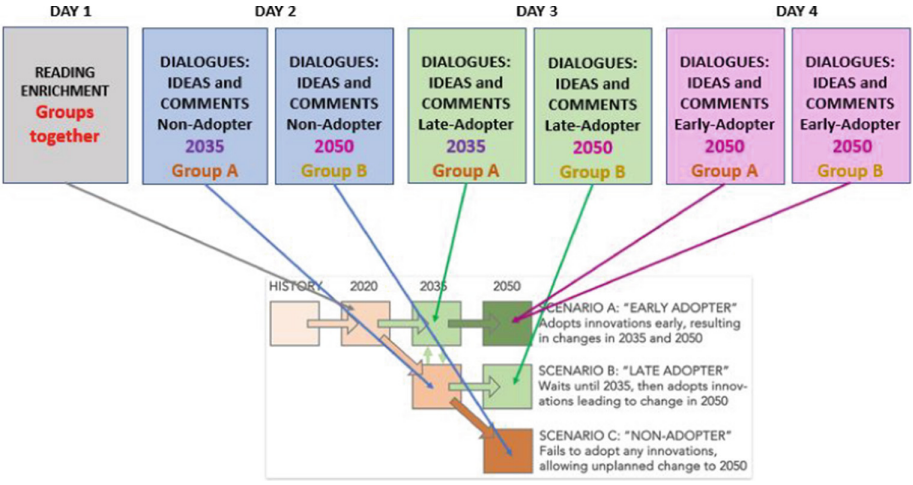


Fig. 3. Main steps proposed by the Brazilian framework. Source: the authors.

2.3 The Salvador Metropolitan Region Proposal

As the Salvador case study was the last one in the collection of 13 workshops, all the others had already been finished, we had some evaluation from participants and their coordinators, and decided to improve the framework.

The first improvement was in the use of the WPS resources (Web Processing Services) to produce dynamic information during the workshop, as support to opinion and decision making. It means that scripts were programmed to present the performances of the participants and their ideas, so that they could control whether they were achieving some workshop goals, whether they were considering the SDGs in the proposals, whether they were reaching the minimum increase of 30% in an area of qualified vegetation, and the calculation of possible carbon sequestration above and below ground resulted from the proposed ideas.

Another difference in the workshop, that happened due to the composition of the actors, the groups of participants, was to understand the role of people of the area and visitors of the area. A part of the actors were people that live in the Salvador Metropolitan Region and really knew about necessities, vulnerabilities and potentialities, from their daily life experience. But there was also a group that lives in Minas Gerais and knows

the area as visitors, as tourists, and don't know all the territory of region. In that sense, it was interesting to measure the possible contribution of the two groups of actors.

The proposed framework was based on 3 steps. It started with the Reading Enrichment in which people from Salvador were more active in inserting pins with additional information about the area, highlighting the main characteristics, but also data that were not in the systems. In that step, people not from Salvador used their time to analyze the map collection in details, to construct knowledge about the area. As a result, considering the sum of all the annotations, we arrived to a mosaic of interpretations about vulnerabilities and potentialities of the area.

In the second step the participants created ideas. We observed that people from Salvador were more interested in proposing projects and policies to attend to everyday needs, and in that sense one can say they were more traditional, comparable to non-adopter and late-adopter participants. On the other hand, people that are not from Salvador were less traditional, presenting an unthinkable innovation. As a result, we arrived to o mosaic of proposals that could fit both the needs and the possibilities of the area. After registering the idea, the opportunity to write comments on all of them was there, completing the Dialogs. Finally, in the voting process, that was step 3, the participants had already analyzed the proposed ideas, had already read the collection of comments about each of them, and were able to vote and to decide about "what", "where", "when" and "why". The final decision as the selection of ideas according to thematic, locational, and priorities assertiveness (Fig. 4).

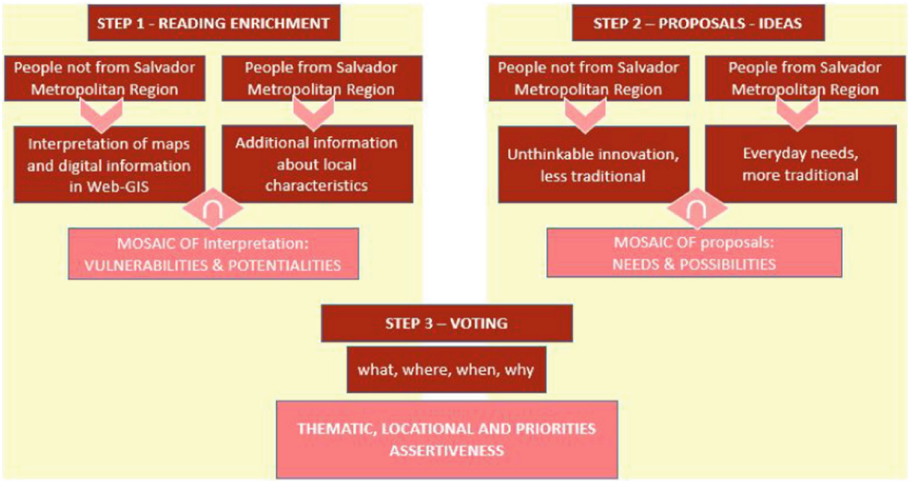


Fig. 4. Main steps proposed by the Salvador case study framework. Source: the authors.

3 The Development of the Case Study

A collection of 40 thematic maps was produced based on data present in platforms of spatial data infrastructure. From these maps it is possible to understand that urban land

use in the Metropolitan Region of Salvador is mainly concentrated in a conurbated area of Salvador, Lauro de Freitas e Simões Filho, along the bay, and there is an axis of growth along the coast, in the northeast direction. In the interior the reference is Camaçari, followed by Dias Dávila, Pojuca, São Sebastião do Passé e Candeias. But it is possible to summarize that the area is dominated by the concentration along the bay, by one attractor pole in the interior and there is a narrow axis growing along the coast. Map 8a presents the densified urban area, map 8b the distribution of income demonstrating the lack of distribution, map 8c presents the distribution of health services and it´s possible to understand they are concentrated in the capital. Map 8d presents the road network that, together with map 8e, which deals with accessibility and capillarity, proves the connection in the area of Salvador and Camaçari, the line along the coast, but also the empty space in the center part of the area. Map 8f presents the concentration of commerce and services, proving the spatial dependence to Salvador and Camaçari (Fig. 5).

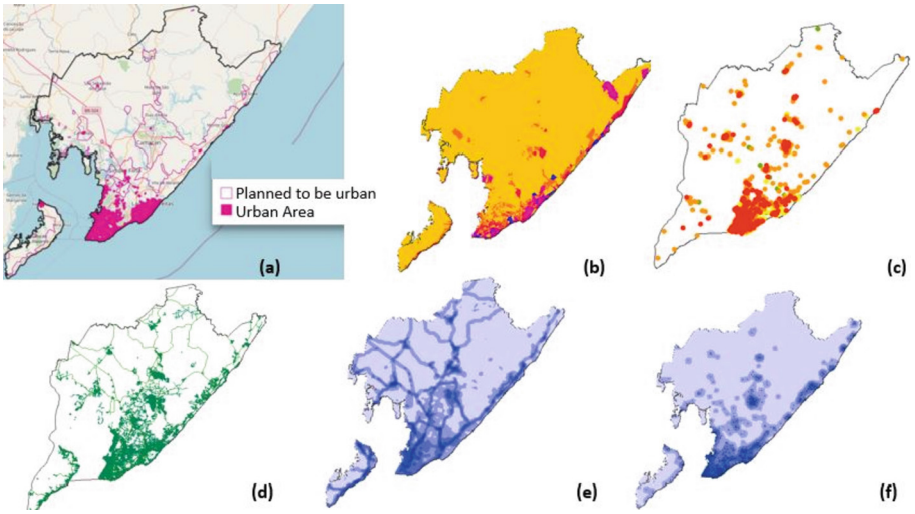


Fig. 5. Urban density (a), income (b), health services (c), road's network (d), accessibility and capillarity (e) and commerce and services (f). Source: the authors.

The physical conditions of landscape demonstrate that high temperatures are located in urban dense areas, which also have poor vegetation quality (Maps 06a and 06e). The area is characterized by a low slope with risks of floods, and urban land use are in areas of low altimetry, while the concentration of high altimetry is in the very north part, empty areas (Maps 6b and 6d). Analyzing the aspect, defined by the slope orientation, the flat areas that receive sun during all day are predominate (Map 6c). (Fig. 6).

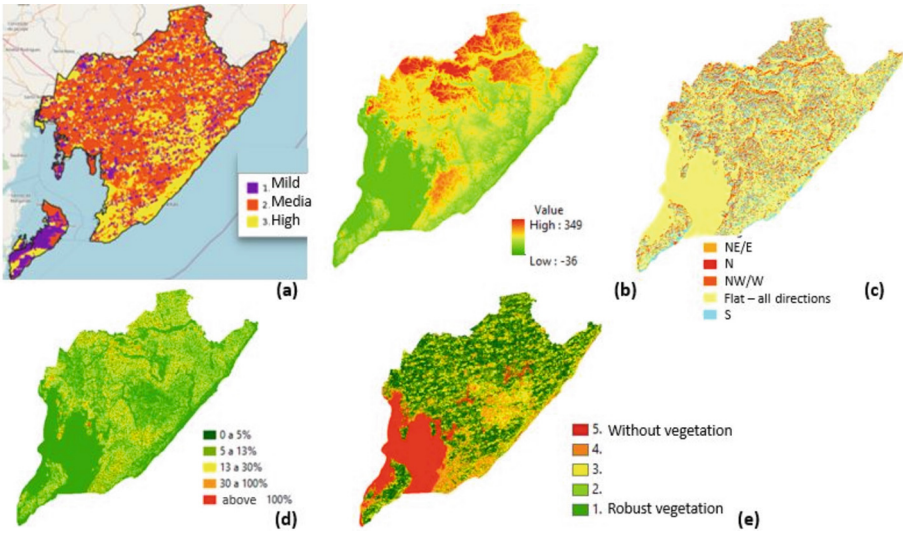


Fig. 6. Surface temperature (a), altimetry (b), aspect (c), slopes (d), NDVI – normalized difference vegetation index (e). Source: the authors.

The presence of forests with dense vegetation is not well distributed. The NDVI had demonstrated the presence of vegetation, but it is mainly composed by agriculture (Map 7a, Map 7b). The conservation units are more focused on sea areas, and are very poor in the continental area (Map 7b). There are plans to increase dense urban areas, where the

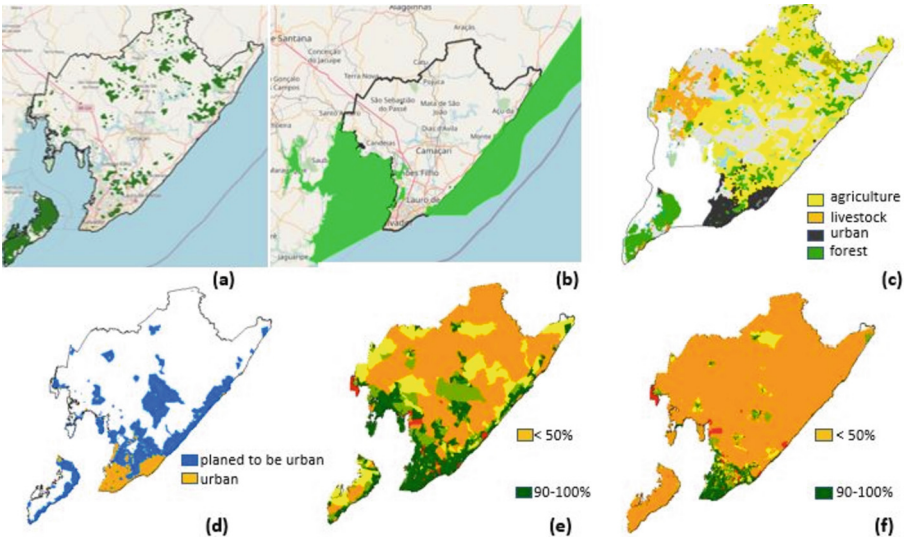


Fig. 7. Forests (a), conservation units (b), land use land cover (c), urban areas (d), water infrastructure (e), sewage infrastructure (f). Source: the authors.

water service is already available, but the sanitation condition is very fragile, with lack of services in already densely populated areas (Map 7d, Map 7e, Map 7f) (Fig. 7).

3.1 Reading Enrichment

The first step of the workshop itself was based on the reading enrichment, in which the participants were asked to read the collection of 40 maps to receive organized information about the area, but also to include new information that they had and was not presented in the maps. The participants inserted 52 pins with annotations, most of them as alerts about conflicts of land use.

There were 18 annotations about housing, with emphasis on registering lack of infrastructure, conflicts with environmental resources and alerts about incorrect land use. There were 17 annotations about green areas, all of them about conflicts of use and risks of losing the resources. There were 6 annotations about hydro, presenting alerts about risks of flood areas; 5 annotations about tourism, indicating existing conflicts with land use and lack of infrastructure to them; 4 annotations about institutional services, presenting new information and pointing out the absence of services; and 3 annotations about transport, indicating lack of services or even the inadequacy of the existing service (Fig. 8).

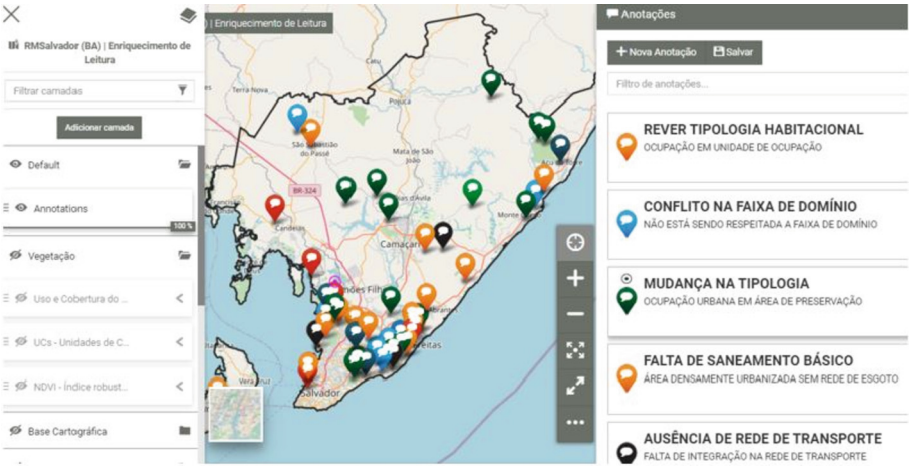


Fig. 8. Annotations in reading enrichment step. Color codes according to systems. (Color figure online) Source: the authors.

3.2 Dialogues – Proposition of Ideas

The participants were asked to construct proposals for the area for the scenarios of 2035 and 2050, considering non-adopter, late-adopter and early-adopter behavior. We understood that the scenario of 2021 was the reading enrichment, because in it they pointed out the main vulnerabilities and potentialities of the area. As the workshop was

developed in the GISColab platform [8], the construction of designs to each scenario is done in boxes of contexts, that open a digital working area with all the maps and all the tools (Fig. 9).

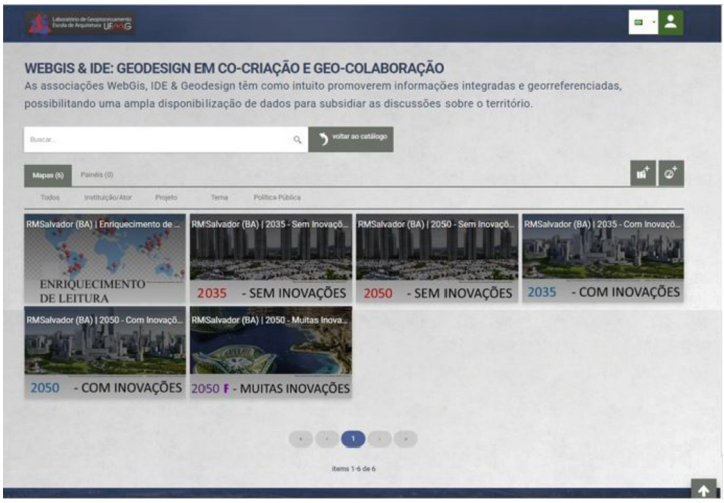


Fig. 9. The scenarios of the designs: 2035 non-adopter, 2050 non-adopter, 2035 late-adopter, 2050 late-adopter, 2050 – early-adopter. Source: the authors.

To each context, they were asked to design proposals of ideas. They could consult the list of assumptions provided by the IGC, in which there is a collection of ideas of innovations. They could use lines, points or polygons, but we asked them to use points when they were not secure about the drawing of an area but wanted to register an idea. In this sense, the idea could be developed by an expert based on the existing location, title and the description of it. It was important to use a colored spatial element, according to

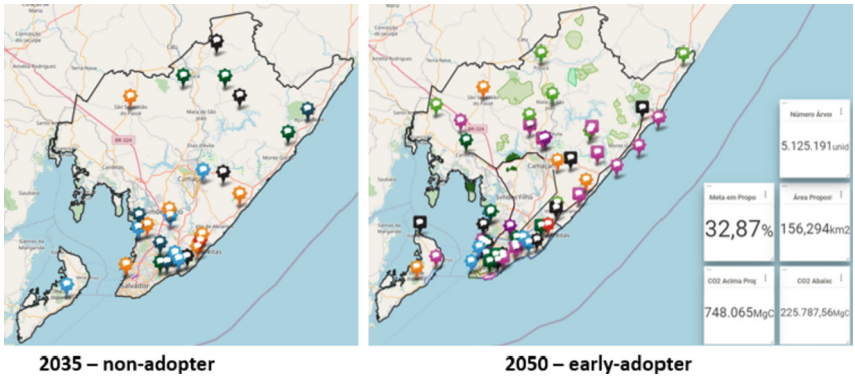


Fig. 10. Proposition of ideas to each scenario. Source: the authors.

the color code related to the systems, to add a title and a text with the description of the idea (Fig. 10).

3.3 Dialogues – Discussion of Ideas and Voting

After drawing the ideas, there was a step in which we asked the participants to read all the proposals constructed. They were asked to analyze the ideas, using the thematic maps as reference or their knowledge about the area to judge if they had locational and thematic assertiveness. They had to write opinions as texts of dialogues, criticizing, complementing the proposals, adding technical information as support to the discussions, and so on. After reading all the comments registered, it was time to vote (Fig. 11).

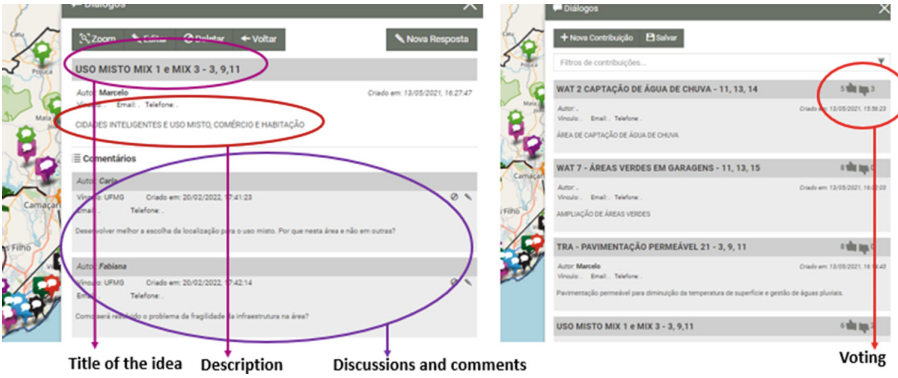


Fig. 11. Dialogues based on the title, the description, and the comments. Decision registered by voting. Source: the authors.

4 Results and Discussion

GISColab is based on OGC protocols and able to consume and provide data in the formats of the WMS (Web Map Service – uploading shapes and giving access to reading the maps), WFS (Web Feature Service – connecting directly to other web data platforms and allowing others to connect to it) or even the WPS (Web Processing Service that results in dynamic layers, processed according to the insertion of data).

WPS resources were very important to construct widgets as support to opinion and decision making. While participants were drawing the ideas, there were scripts to calculate indexes and to present them in graphics or boxes of numbers. We asked the participants, while acting as late-adopter and mainly as early-adopter, to consider the increasement of 30% in areas for carbon sequestration and credits. To check if this target was achieved, a script was constructed to calculate the areas of the drawn polygons, and according to the sum of areas to inform the percentage of increase, the number of trees that could be planted in the area, the quantity of carbon that could be sequestrated above ground and below ground. The results were presents in boxes as widgets (Fig. 12).

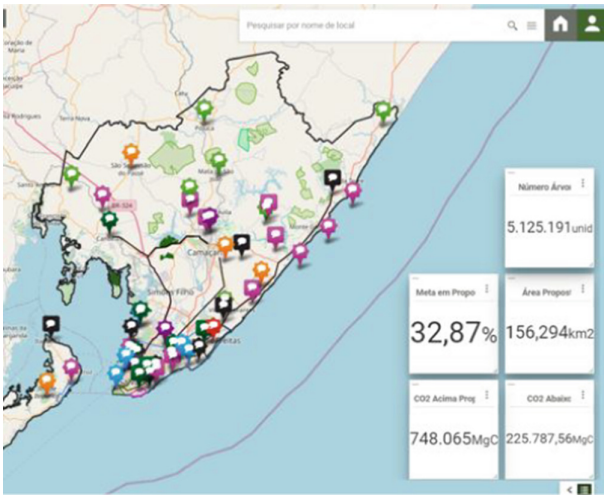


Fig. 12. Widgets based on the WPS to calculate the targets on CCO2. Source: the authors.

Also based on WPS, a script to count the number of times that an SDG was mentioned in the design was constructed. While proposing the ideas, the participant was asked to list which SDG it was contributing to, and a widget with a histogram presented the dynamic performance of the composed design (Fig. 13). Subsequently, for other case studies and workshops, the possibility to associate the negative impacts and the positive impacts to SDGs was also developed. In that case, two histograms.

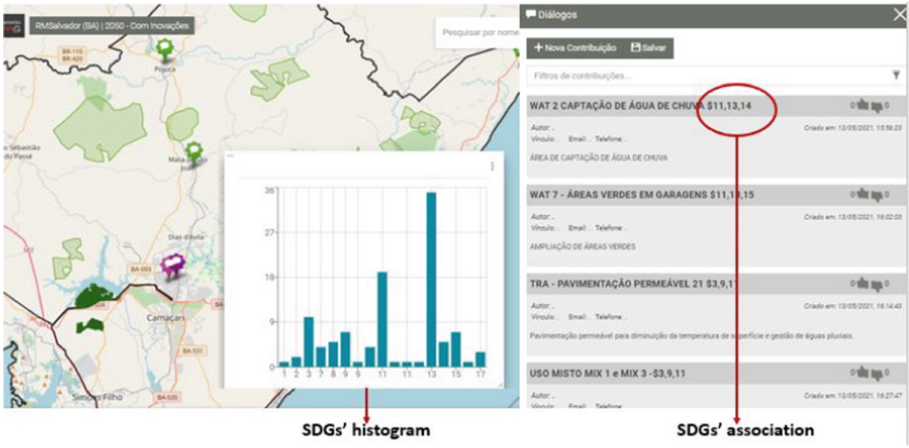


Fig. 13. Widgets based on the WPS to calculate the impacts to the SDGs. Source: the authors.

When analyzing the composition of the designs to each scenario and the participants' proposals according to non-adopter, late-adopter or early-adopter, it is very clear that they improved the design and learned with the experience. The last design was more complete,

well described and discussed. They achieved the goals regarding CCO2 and understood they could considerate some SDGs in their proposals, because the environmental goals were much more important for them rather than the other ones. This can be associated to the fact that most of the participants were not people of the area, and in that sense, it is easier to think or to associate the ideas to more generalist goals, which were: climate action, sustainable cities and communities, good health and well-being.

From the final design, an analysis was constructed by experts, composed by the organizers that know the area or constructed the maps. They classified each idea according to thematic, priority and locational assertiveness, related to "what", "why/how" and "where". A graphic was composed illustrating that most of the ideas were quite good (67.9%), because it had the three conditions of assertiveness; while 23.2% of them were good in two conditions but it failed in one condition (mainly in locational one); only 8.9% were considered not good because failed in two of the three conditions (mainly in locational and priority ones); and none of the ideas were considered totally not suitable (with three conditions with lack of assertiveness). The thematic assertiveness was the most important, present in 96.4% of the ideas, followed by priority assertiveness that was observed in 89.2% of the ideas, while locational assertiveness was the most problematic, that is present in 73.2% of the ideas (Fig. 14).

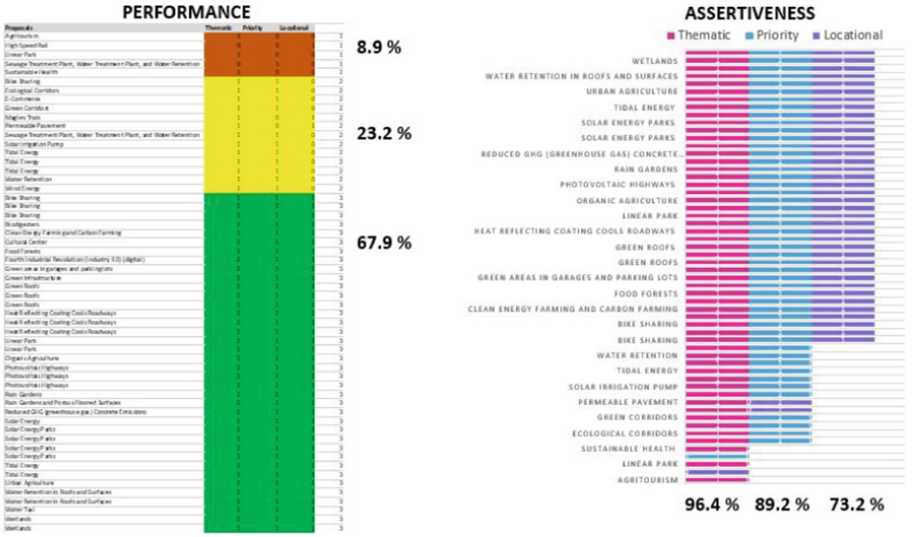


Fig. 14. Analysis of performance and assertiveness of the ideas proposed in the final design. Source: the authors.

5 Conclusions

All the indexes of performance and assertiveness were quite good, which means that the workshop arrived to a result with defensible criteria. It also means that processes have

reproductible criteria and can be applied to other case studies. The main challenge is the locational assertiveness, but in a future iteration the participants can change the position of some ideas and improve their proposals.

The PDUI (Integrated Urban Development Plan, Metropolitan Region of Salvador) that is under development by the local government, should provide common guidelines to metropolitan municipalities for integrated urban development in the areas of urban transport, housing, basic sanitation and territorial planning and management. In this sense, it´s interesting to observe that the guiding principles used in the project carried out in cooperation (Geodesign RMS) include these proposals. During the workshop the participants created ideas related to actions/activities in tune with the institutional agenda, although it was an academic experiment. But it's important to highlight that the appropriate suggestions presented in the Dialogues stage can be used by the PDUI-RMS team.

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