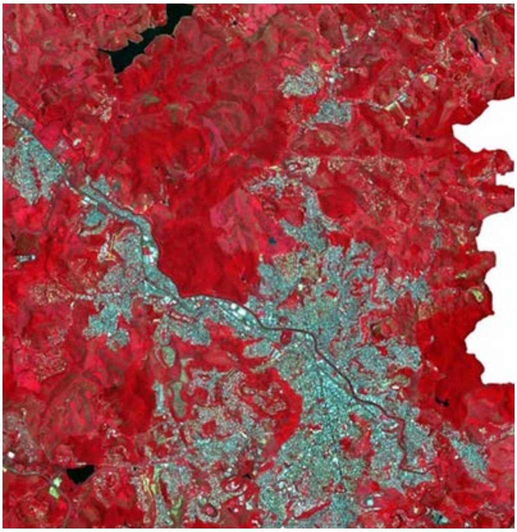

FROM THE LOGIC OF DESKTOP TO WEB SERVICES APPLICATIONS IN GIS

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ABSTRACT

Design planning in cities in collaborative approach requires holistic thinking about urban space. It is important to recognize specificities of the territory and to understand that cities are complex ecosystems. Cities can be represented by models that are portraits of reality, according to spatial, temporal, conceptual and methodological simplifications. Using models, it is possible to select main variables and parameters of the place, to identify relations among them, and compose structures that represent main characteristics, vulnerabilities, attractiveness, and essence of the place. Our goal of the research was to produce of a minimum collection of spatial data in urban areas, to be used as basis for master plans and site management. The study proposes the use of free access data, reached in data warehouses by scripts, based on web map services, and automatically construct evaluation maps to be used in geodesign studies. Using evaluation models, the participants design the future of the place. We constructed scripts to produce a group of first data and evaluation systems, about themes that are used in the majority of the case studies (green systems, transportation system, urban system and, agriculture system), so that any user can have access to dynamic data, produced by demand using the most recent information available in data warehouses. In this sense, users don't need to be GIS experts, but only GIS consumers, only freely accessible data will be used, and the municipalities will be able to have a minimum collection of dynamic evaluation models about their realities.

KEYWORDS

Geodesign; Urban Planning; Collection of Spatial Data; Web Maps and Web Services

1 INTRODUCTION

Design planning in cities in collaborative approach requires holistic thinking about urban space. It is important to recognize specificities of the territory and to understand that cities are complex ecosystems. Cities can be represented by models that are portraits of reality, according to spatial, temporal, conceptual and methodological simplifications. Models become even more important in the era of technologies of geoinformation. It is necessary to think of new proposes about land use and the necessities the people of the place – considering cultural values and genius loci – requiring the ability to project not only on local scale, but also considering the scale of the territory. Thus, to build effective interventions, is important to respect the specific features of the territory and to understand that cities are complex ecosystems comprised of abiotic and biotic elements. They are always interacting in time and space and are unique to the space.

In short terms, cities can be represented by models that are portraits of reality, according to spatial, temporal, conceptual and methodological simplifications. Using models, it's possible to select main variables and parameters of the place, to identify relations among them, and compose structures that represent main characteristics, vulnerabilities, attractiveness, and essence of the place

The conditions to explore technologies of geoinformation started with GIS - Geographic Information Systems in the 60's. In the begging, the goal was to combine geo-referenced layers, followed by the possibility of associating alphanumeric data resulted in proposing scripts and more complex combination of variables. Important changes came with the inclusion of geoprocessing tools in the software, to apply spatial models, based on map algebra, combining data about variables and reading their specific parameters. (Eastman et al., 2011; De Magalhães, 2013). The application of GIS associated satellite images data allowed the digital information processing, with high and medium spatial resolution (low cost and high frequency) products when compared from classical aerial photogrammetry (high cost and low frequency). It contributed to studies about land cover and vegetation cover. Nowadays it's possible to find free data services, contributing to the democratic accesses to the data (de Bessa, 2005). Although, even with all the facilities in the use GIS and to get free access to data, most of the municipalities are not able to produce their thematic maps. To use the tools and data about geographic information it is required specific knowledge about technical resources and methods to manipulate data and produce information. Our goal of the research was to produce of a minimum collection of spatial data in urban areas, to be used as basis for master plans and site management. The study proposes the use of free access data, reached in data warehouses by scripts, based on web map services, and automatically construct evaluation maps to be used in geodesign studies. Geodesign is a method to promote co-creation and co-planning of alternative futures to an area, that requires a minimum collection of information about the place, known as evaluation models, that tells if the area is working well. Using evaluation models, the participants design the future of the place. The idea is to avoid using desktop geoprocessing tools, in which data and software are stored in the personal computer of the users, but to provide a web service that gets the data from a database and applies a script that represents the algebra that produces the evaluation map. There are some advantages of it: data will be always the more updates one, users don't need to be GIS experts, only freely accessible data will be used, and the municipalities will be able to have a minimum collection of evaluation models about their realities. The idea of this study came in two previous opportunities: when Geoprocessing Laboratory contributed in a project from the Ministry of the Cities in 2016. After that experience the group of the geoprocessing laboratory realized that the same logic of solving the problem of providing evaluation analysis about the main themes on a case study could be quite useful to geodesign process. In the project with the Ministry of the cities, the goal was to give support to all the municipalities in

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Brazil to construct evaluations about feasible and not feasible places to construct housings to attend to the program "Minha Casa Minha Vida". It was important to create an easy way for them to construct their thematic evaluation maps, analyzing the possibilities of places to install the housing program, according to main variables (presence of services, infrastructure, avoiding clusters with other housing units, with accessibility to the urban area, and so one). As most of them were not GIS users, the project created scripts with the use of ETL tools (Extract Transform and Load) so that the thematic maps, classified according to the suitability to receive the houses. As a result, all the municipalities produced the same thematic maps, according to the same methodologies, and the federal government was able to compare results and analyze the information.
The second experience happened in several workshops conducted by Geoprocessing Laboratory using Steinitz's Geodesign framework and the web-platform GeodesigHub©. According to Steinitz (2012), geodesign is a method to project with and to the geography, which is based on 6 steps, composed by models: representation, process, evaluation, change, impact and decision. A group of defined actors (people of the place, administration, technicians, and representatives from different sectors of society) take part in a workshop to construct alternative futures to the place. As basis to the discussions, they receive evaluation maps, which are thematic maps according to main vulnerabilities and attractiveness of the place. In our workshops, as we are senior users of GIS, we didn't have difficulties in producing the representation, process and evaluation maps, but we realized that, if another group was conducting the experiment, that could be a trammel to be solved. And this is the reality of most of the municipalities in Brazil: lack of knowledge and resources to produce evaluation analysis and thematic maps. After these experiences, we decided to write the main steps to be followed by any researcher, through two methods: the traditional desktop using GIS and the webased using the digital platforms to create the evaluation maps. From those collections of steps, Ballal, the programmer of GeodesignHub, constructed web map services, which are scripts that get data of free access in warehouses and transform them according to map algebra, producing evaluation maps. Scripts like this will provide basic maps to any geodesign user, that will not be required to be GIS experts to propose and to organized workshops. A group of main thematic was structured, and in the future all main systems can have their initial maps easily done. The first systems produced were: green, urban, agriculture, and, transportation. In the future, the 10 basic themes to receive this kind of support must be: history/cultural, agriculture, blue infrastructure, green infrastructure, gray infrastructure, energy infrastructure, industry, housing, commerce and institutions.

2 METHODOLOGY

The methodology to produce the evaluation maps was developed from two main methods: the traditional method desktop using GIS and the using the digital platform cloud based webservices maps. The systems elaborated in this study were developed from the basic maps with open access data to give support to produce the systems the accessible way to city halls in support of its master plans. Thus, the methodology was divided in two steps: the traditional method using desktop and, the webservices to produce the evaluation maps.
The methodology used to produce the system were – Green system, Transportation system, Agriculture system and, Urban system. The Green system aims to identify the green areas existents and the protected areas. This system is important to manage the green areas existents and promote its protection and development. The transportation system aims to identify the main street access, highways and access to the city. This system is important to develop strategies for public and private transportation management. The agriculture system was developed to identify the potentialities of land, the water resources and, the best location to drain agricultural production, this system is important to develop strategies for agriculture, access, transportation and, trade in

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agricultural products. The urban system was developed to identify the different types of land use, green patches, water resources existent, and impervious and pervious areas in the city. This system is important to develop strategies for urban management, urban growth, and potential areas to industry, housing and others.

2.1 TRADITIONAL METHOD USING DESKTOP APPLICATIONS

First, it was necessary acquire the data to elaborate the basis maps (Fig. 1) using the cloud-based geoprocessing system. Very used web platforms to get georeferenced that are those from Nasa and USGS[1], Copernicus Project[2] and we can also mention Actinia[3]. After the data acquisition, the pre-processing step followed. The Sentinel image was used to produce the green maps through the NDVI index. The slope map was derived from the NASA SRTM elevation data. The data from "OpenStreetmap.org" was used to create the street network map, and the water data was obtained from the official government database. Then, the data processing step which included based on land use and land cover, slope, water resources and roads started in order to get the results. To illustrate this study, we will use, as a case study, Juiz de Fora, a medium-sized city of Minas Gerais, in Brazil (Fig. 2).

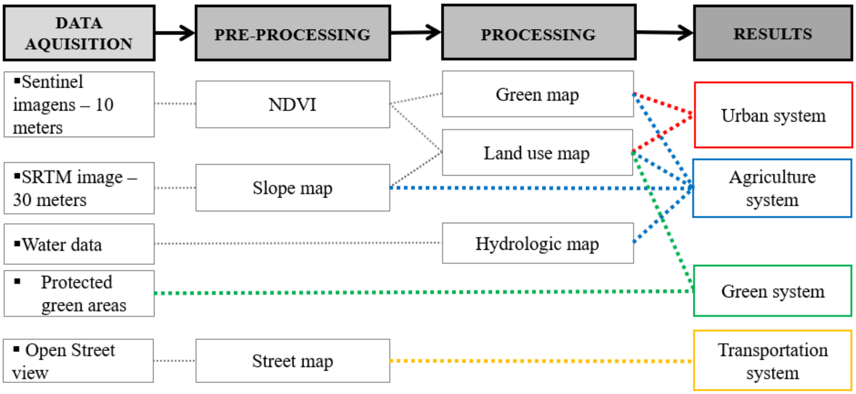

Fig. 1 Methodology framework. Source: Authors

<u>The use of satellite images – Copernicus sentinel – 2</u>

The satellites Sentinel-2 of the European Copernicus Mission collected the data to needed produce the NDVI map of the year 2017 (10 meter resolution). This satellite has the mission to monitor variability in land surface conditions, and its wide swath and high revisit time supporting and monitoring of changes to vegetation within the growing season[4]. The Sentinel-2 satellites were designed by a consortium of around 60 companies led by Airbus Defense, in the Copernicus Mission by the European Community. This satellite had as its mission, monitoring variability in land surface conditions, and its wide swath and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days

[1] https://earthexplorer.usgs.gov/
[2] https://scihub.copernicus.eu/dhus/#/home
[3] https://www.mundialis.de/en/actinia-geoprocessing-cloud/
[4] Corpenicus Mission, 2015.

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at mid-latitudes) support monitoring of changes to vegetation during the growing season. The coverage limits are from 56 ° south and 84 ° north (Corpenicus Mission). The Multispectral Instrument (MSI) on-board SENTINEL-2 undertakes systematic acquisition in a single observation mode, operating in 13 spectral bands, four of which are in the electromagnetic spectrum known as ”visible”, the other bands covering near and shortwave infrared at different spatial resolutions ranging from 10 to 60 m. These following bands are relevant for vegetation monitoring: Red (band 04) and near infrared (band 08), which can identify changes in chlorophyll levels and plant cell structure. Due to these characteristics, Sentinel-2 satellite images are suitable for separating vegetation from other land uses, as well as to classify different phenological conditions of vegetation cover in those bands the spatial resolution is 10 meters.

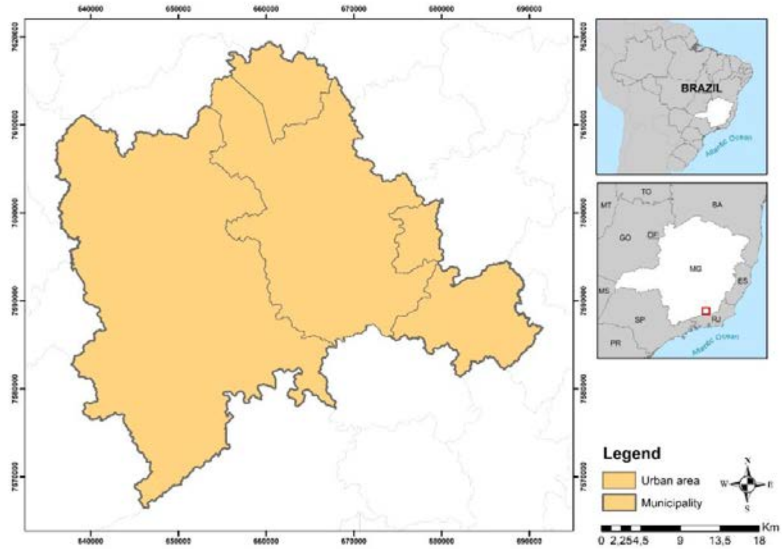

Fig. 2 Case study – Juiz de Fora Municipality, Brazil. Source: Authors

<u>NDVI (Normalized Difference Vegetation INDEX)</u>

From the selected Sentinel-2 image scene (June 2017), we used the band 4 corresponding to the red band and band 8 corresponding the infrared band commonly used to calculate the NDVI index via band algebra, according to the following formula (1):

$$NDVI = (\rho ivp - \rho v) / (\rho ivp + \rho v) \qquad (1)$$

Where: ρivp is the reflectance in the near infrared; ρv is the reflectance in the red.

The NDVI is based on the spectral signature of the target’s behavior. Vegetation presents specific responses related to photosynthesis the process of absorbing solar radiation in the red range of the spectrum. The plant cells reflect more strongly in the near infrared range. Variations in plant condition are identifiable due to the portions absorbed in the red and reflected in the infrared. We can associate them with other normalized indexes to make correlations and verify the studied place’s ambiance as well as improving its management (Freire & Pacheco, 2005; Myneni et al., 1995; Rocha et al., 2016; Rouse et. al., 1973).

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The NDVI result it is a normalized index, the resulting image distributed between -1 and +1 values. When the result is closer to -1, it has a weaker spectral response in infrared bands, and we can conclude this is water, exposed soil, shadow and impermeable areas soil, all of which have a high coefficient of runoff. When the result is closer to 1 the stronger spectral response identifies the type of vegetation (Fig. 3).

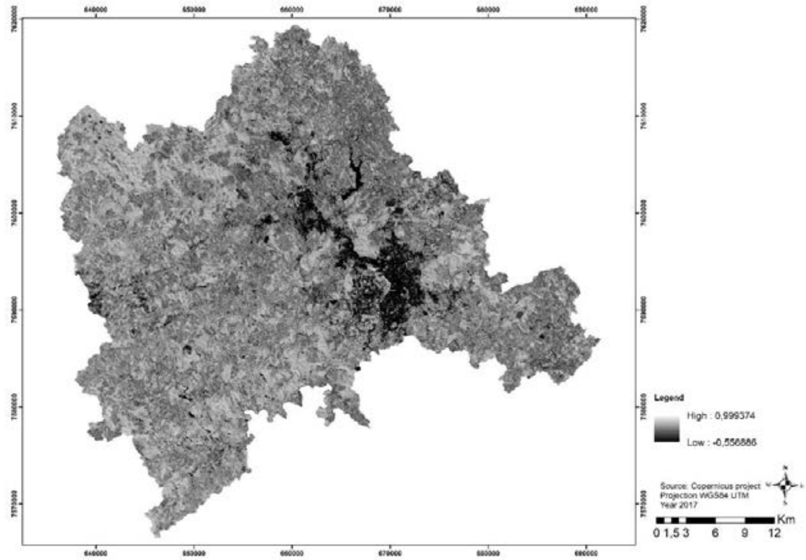

Fig. 3 NDVI map, Juiz de Fora municipality, Brazil. Source: Authors

From NDVI classification index, we could classify in ranges of land use and vegetation existent, that is, in yellow is the land use without vegetation, exposed soil, building, shadow or water; the grassy land cover is in orange; the shrubbery vegetation is in pink, and in purple is the dense vegetation (Fig. 4). The classification can be based on supervised methods, using samples, by Natural Breaks separating tendencies or by Maximum Likelihood. We tested both, and the results were quite similar, that's why we decided for the first method.

<u>SLOPE MAP</u>

To produce the slope map, SRTM elevation data were used (NASA Shuttle Radar Topography Mission, Global 1 arc second data, V003 at 30 meters of resolution) to extract contour lines at 5 meter levels (Fig. 5). After that, we classified the contour according to the ranges of slope as 5%, 13%, 30%, and 47% according to Brazilian reality (Fig. 6).

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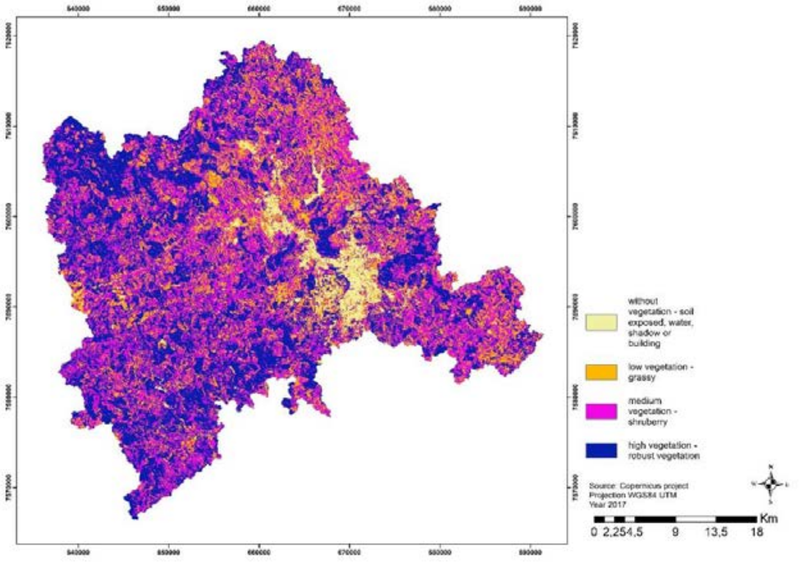

Fig. 4 Land use map, Juiz de Fora municipality, Brazil. Source: Authors

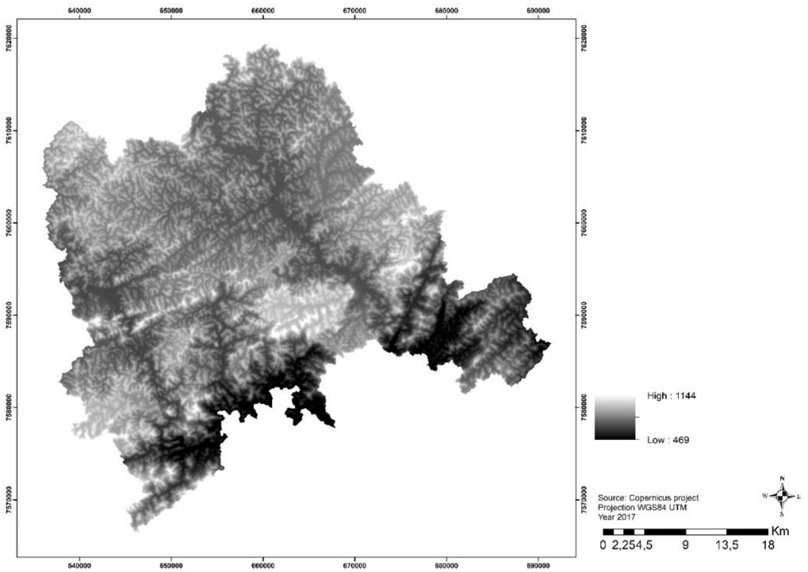

Fig. 5 SRTM elevation map from case study. Source: Authors

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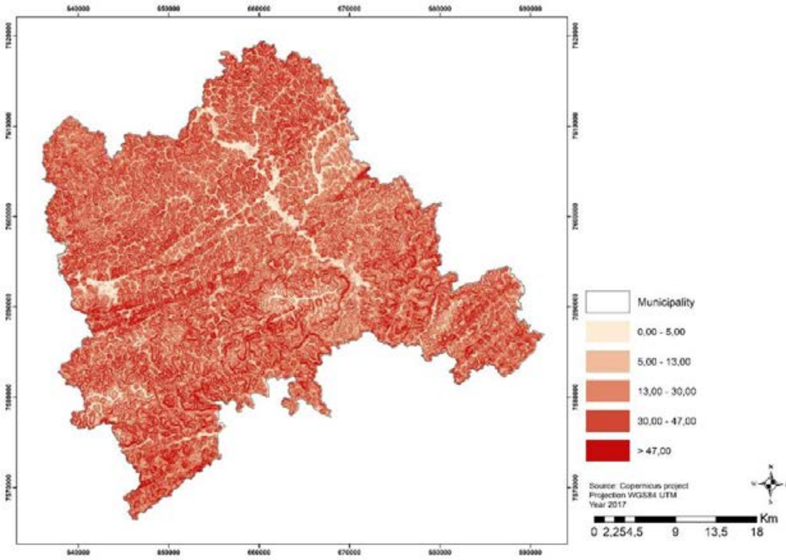

Fig. 6 Slope map derived from SRTM. Source: Authors

<u>STREET Network</u>

To produce the street network map, we downloaded data from "OpenStreetMap" (https://www.openstreetmap.org/) and selected the lines referring to the street, according to the case study (Fig. 7).

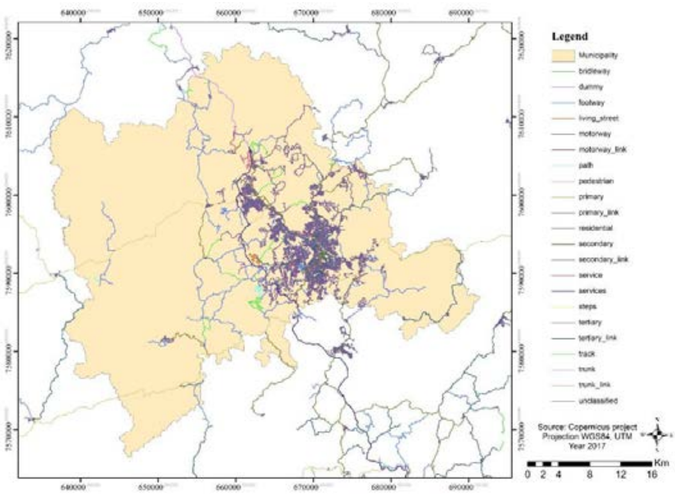

Fig. 7 Map of street network. Source: Authors

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Hydrological map

To produce the required hydrological map, it was necessary to consider the existent data according to the researcher's decision or the local conditions. In Brazil, using open access data from ANA (Brazilian National Water Agency), we downloaded these data and selected all the watershed and rivers from the municipality of Juiz de Fora (case study). After that, we calculated the watershed area and river area in square meters added to the length to discovery the density. The result was classified in three ranges: low, medium and high (Fig. 8).

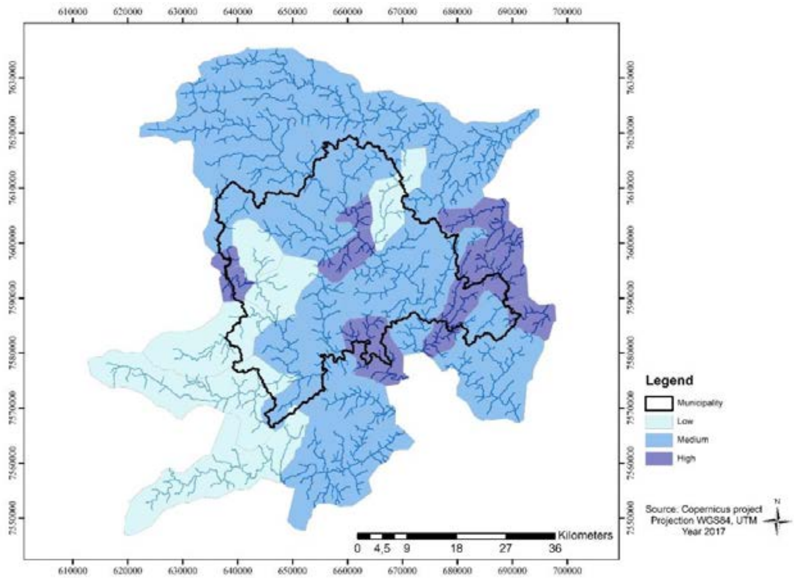

Fig. 8 Water map. Source: Authors

Combinatorial analysis

To apply the Combinatorial Analysis, we will use as an example the Urban system (Fig. 9). According to Oliveira Groenwald et al. (2009) combinatory analysis "... is the part of Mathematics that studies and develops methods for solving problems involving counting or existence, in general, it can be said that it is the part of Mathematics that analyzes discrete structures and relations". This method allows adequate aid for the analysis of the study with the combination of different variables (Rocha et al., 2016). It is important to highlight that each researcher can make their variable combination according to the feature of their research and this matrix serves as a guide to maps with algebra logic.

In the combinatory analysis result, we will use the colors by Steinitz's geodesign framework to produce an automatic algorithm to be applied to the evaluation maps in the GeodesignHub©, however, according to the need of each map, there will not always be the five colors indicated.

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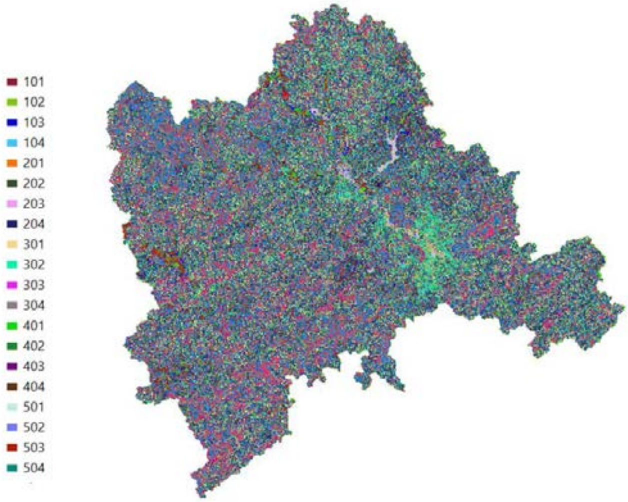

- Existing impervious area: 101, 201, 301, 401, 501
- Not suitable/inappropriate to urban growth: 502, 503, 504, 104, 204, 304, 404
- Capable to urban growth: 402, 403
- Suitable to urban growth: 102, 103
- Feasible to urban growth: 202, 203, 302, 303

SLOPE	LAND USE	Impervious areas/ Land exposed/ water and shadow	Grassy	Shrubby	Robust
		1	2	3	4
0-5 %	100	101	102	103	104
5-13%	200	201	202	203	204
13-30%	300	301	302	303	304
30-47%	400	401	402	403	404
> 47%	500	501	502	503	504

Fig. 9 Combinatorial analysis the Urban system. Source: Authors

2.2 WEBSERVICES MAPS

Sentinel data is a publicly available from a number of data sources such as Google Cloud[5], Amazon AWS[6] or Sentinel Hub[7]. Traditionally, imagery from these sources is downloaded on desktops and processed in Desktop GIS. The dataset from Sentinel is large and one scene is almost 650MB in size and the data is being updated daily. The pace at which the data is growing, and the size of data necessitates a new way to access and process them. This is where GIS as a service in modern cloud computing infrastructure is useful. Instead of using downloading and processing imagery on desktop GIS, commands are run in the cloud-based GIS system for a remote and fast processing. Here the outputs can either be downloaded after processing or accessed as Web Services.

[5] https://cloud.google.com/storage/docs/public-datasets/sentinel-2
[6] https://registry.opendata.aws/sentinel-2/, since May 2018 access to be paid
[7] https://scihub.copernicus.eu/

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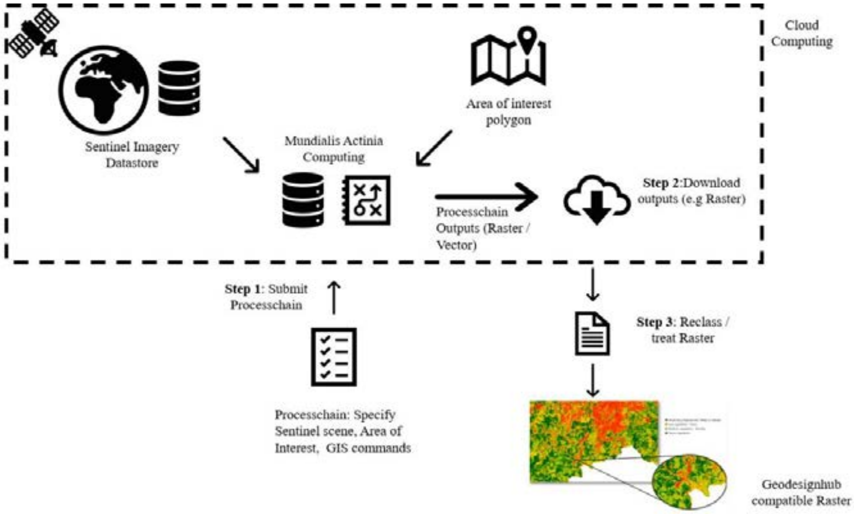

Fig.10 Diagram of webservices applications. Source: Authors

This method of working provides a number of advantages (Fig.10):

- it utilizes the greater computing capacity of servers and cloud computing;
- advanced caching and optimizations can be performed in a networked environment;
- it enables use to "chain" different commands together automatically, submit the job and then download the job once the steps are completed.

Mundialis[8], a company based in Bonn, Germany has built such a cloud computing system that enables "GIS as a service" in the cloud software. This innovative platform is called Actinia[9] and supports a wide array of geoprocessing. The Actinia platform leverages the vast experience that Mundialis has on GRASS GIS and cloud computing. It is cloud-vendor agnostic and provides a programmable interface (REST API). Through the EU H2020 project "openEO"[10] the backend development for the Sentinel data processing is further developed.

Geodesignhub partnered with Mundialis to develop an open source processing chain to build these evaluation maps using cloud computing. The open source code is hosted here: https://geodesignhub. github.io/Sentinel-Evaluations-Generator/. The software has two major components. The first component is to utilize Actinia to process Sentinel imagery in the cloud using "Actinia Processchains". Once the cloud computing operations are completed, the software downloads the generated images to the desktop and further processes them to perform operations like re-classing etc. to make them compatible with Geodesignhub taxonomy and classes. The second component of desktop processing can also be done on the cloud but for this initial trial, the authors decided it would be better if it was done after downloading to enable easy testing and debugging. The software

[8] www.mundialis.de
[9] https://www.mundialis.de/en/actinia-geoprocessing-cloud/
[10] http://openeo.org

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uses open source libraries to do this reclassing and post cloud treatment. The primary inputs to this software are a polygon denoting a "Area of Interest" and a ID of the sentinel scene. Finding the appropriate sentinel scene can be quite tricky given the cloud cover limitations. The appropriate scenes can be selected by using the Sentinel Hub or any of the services mentioned above. Processchains are an innovation of the Actinia platform that enables a whole range of Geo-processing operations on the cloud. These JSON based commands are understood by the GIS software (GRASS GIS; Neteler et al., 2012) in the cloud and uses them to chain different operations using outputs from one operation as a input to the next operation. In addition, detailed logging and debugging can be undertaken using this technique. When coupled with other web / service based tools like Geodesignhub dynamic on demand geo-computing can be performed. In a design environment like Geodesignhub this means that impacts of design interventions and design synthesis can be computed in realtime using advanced models and the results can be generated and transmitted in near realtime.

3 RESULTS

After applying the combinatorial analysis, we got to the systems, the evaluation maps. To show the results we used the colors indicated in the evaluation map used in Steinitz's framework geodesign. In the Urban System (Fig. 11), it was applied the combinatorial analysis between the NDVI map with the slope map. In this system, it was observed the best areas to urban growth without harming the existing main wooded areas (robust vegetation). The label "existing", in red, indicates the impervious areas, occupied areas with buildings, water or exposed soil, that is, to where a consolidated urban area already exists; the "not suitable" range (in yellow), indicates the robust vegetation existent and/or slope with more than 47% of protected areas, so this range is not indicated to urban growth. The "capable" range (in light green), indicate the areas that can accept urban growth, but they are conditioned to a favorable report geotechnical control because they are areas of risk of landslide. The "suitable" range (in medium green), indicates the areas that can accept urban growth, as long as precautions are taken, because it is located at the flood risk areas. The "feasible" range (in dark green), indicate the areas with a favorable slope without compromising the existent robust vegetation to the detriment of urban growth. In terms of combinations, the Agriculture System (Fig. 12) is the most complex system. It was applied the combinatorial analysis to understand the relation between the land use map, slope map, and hydrologic map. In that system, there is not the red range (that indicates the existing areas) because there are not restricted areas to agriculture, but rather areas conditioned to the existence of water resources, adequate slope, and next to existent urban areas, allowing the mechanization of agriculture, and the family farming without damaging the protection areas. The range "not suitable" (in yellow), indicates the areas with low potential to agriculture development; the "suitable" range (in medium green), indicates the areas with the medium potential to development of agriculture; and the "feasible" range (in dark green) indicates the areas with high potential to development of agriculture. The transport system is the only system that is elaborated from the street map (Fig. 13). In that system, it was classified the types of the existent roads according to capillarity and accessibility.

(1) Extremely important roads to capillarity and accessibility ('primary' or 'primary_link); (2) Very important roads to capillarity and accessibility ('secondary' or 'secondary_link'); (3) Important roads to capillarity and accessibility ('tertiary' or 'tertiary_link'); (4) Medium important roads to capillarity and accessibility ('motorway' or 'motorway_link'); (5) Medium to low important roads to capillarity and accessibility ('living_street' or 'residential'); (6) Low important roads to capillarity and accessibility ('track' or 'unclassified'); (7) Very low important roads to capillarity and accessibility ('bridleway' or 'footway' or 'path' or 'pedestrian' or 'steps'); and

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(8) unimportant roads to capillarity and accessibility ('service' or 'services'). According to this classification, the capillarity and accessibility received numerical values (100, 70, 50, 25, 10, 5, 3, 1).

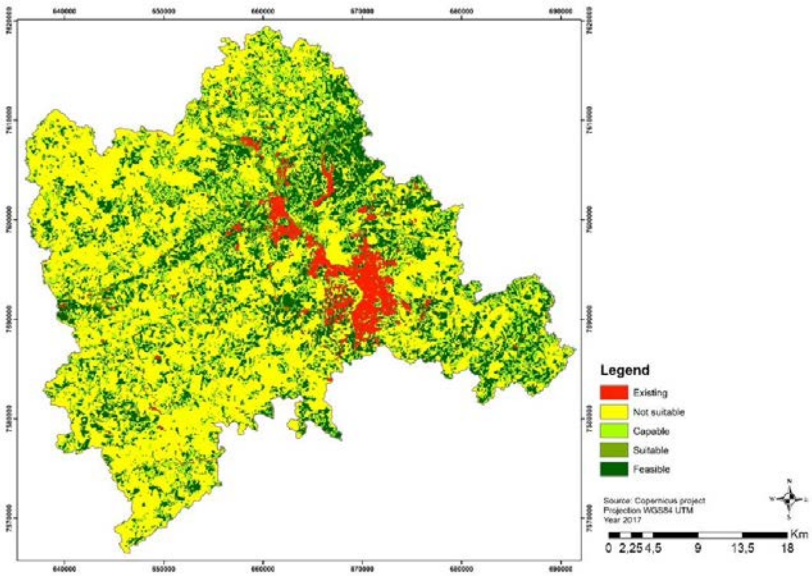

Fig.11 Urban system. Source: Authors

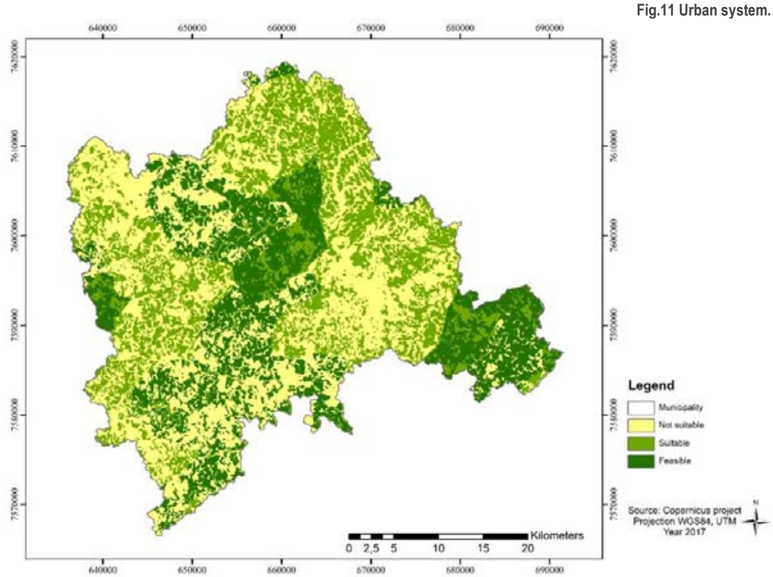

Fig.12 Agriculture system. Source: Authors

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After that, we used the Kernel Density to calculate capillarity and construct it an algebra weighted according to the value given in each classification mentioned above. The result of Kernel Density is divided into 5 ranges, using "natural break" distribution. The result was classified as "feasible" where there is low potential of capillarity and accessibility and needs to be improved a lot. The "suitable" label - where there is low to medium potential capillarity and accessibility - needs to be improved. The "capable" label - where there is medium potential of capillarity and accessibility - needs to be improved; the "not suitable" label - where there is medium to high potential capillarity and accessibility - does not need much improvement; the "existing" label where exists the high potential of capillarity and accessibility – does not need to be improved at all.

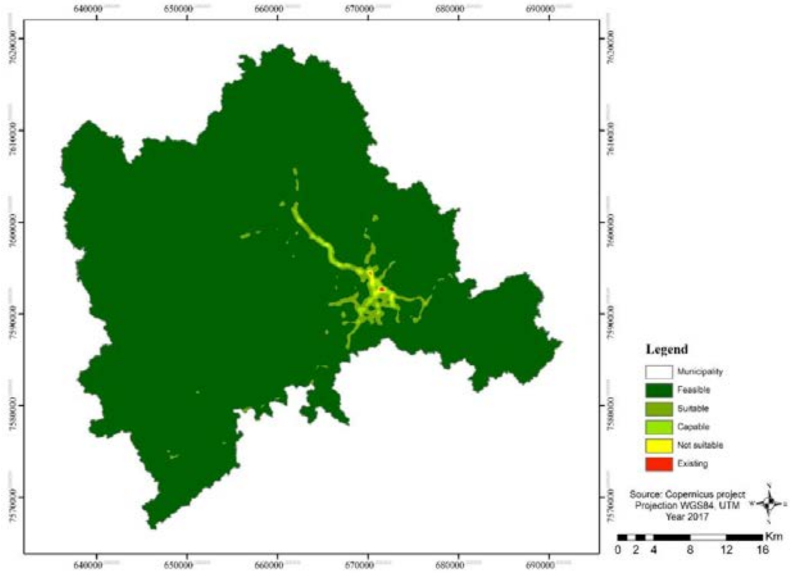

Fig.13 Transportation system. Source: Authors

In the Green System (Fig. 14), it was applied the combinatorial analysis between the NDVI map with the existent protection green areas map. The purpose of this system was to analyze the relation between the existing green cover and the protection green areas, that is, areas with potential for protection of green areas. The "existing" range (in red), shows the areas already protected in the city and that it does not need protection tools. The "not suitable" (in yellow) range shows the areas where it does not make sense to protect because it is a consolidated impervious area. The "capable" range (in light green) is where it is necessary to promote the protection of green areas. The "suitable" range (medium green color) is where it is interesting to promote the protection of green areas and the "feasible" range (dark green) is where it is necessary to protect the green areas.

The results obtained with the system maps using desktop applications method are the same produced by the webservices maps, however, the second method allows reducing the time, optimizing the production of evolution maps and using more updated data.

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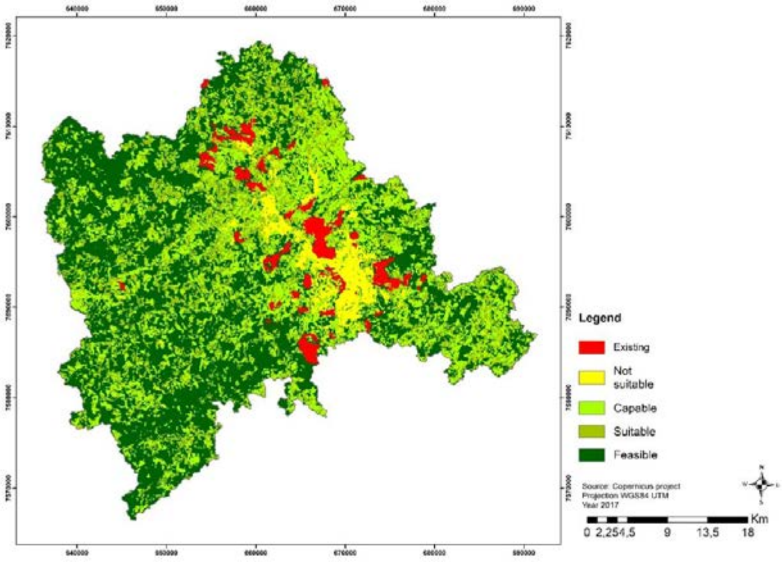

Fig.14 Green system. Source: Authors

4 CONCLUSIONS

The purpose of this paper was to construct scripts to be applied in geodesign meetings, to be offered by webservices map and to give support to Master Plans the city halls, once that the final product is already ready to be analyzed and discussed by the user. To produce the first data and evaluation systems, allowed the user's analysis of territory and identification the areas with sustainable urban growth potential for cities through a consensus between decisions. When we proposed the scripts of systems, the idea was to make dynamic data accessible to all users produced by demand, using the most recent information available in data warehouses. In this sense, users do not need to be GIS experts, but only GIS consumers, once only free access data will be used, and the municipalities will be able to have a minimum collection of dynamic evaluation models about their realities. The scripts showed good results when applied to NDVI map (land use), slope map and street map. However, they were still limited in the agriculture system and urban system to the desktop steps process, although there are studies in progress to apply the web map to solve these steps. The script is still limited about some water data because it depends on the country database, although there are indexes to analyze the water existent like NDWI (Normalized Difference Water Index). However, when this index was tested by the researchers in the urban context, it did not show good results. Perhaps, it would be interesting only applying the methodology to the rural context. The scripts showed good results of application to produce the NDVI map (land use), slope map, hydrologic map and street map. But limited to produce the systems maps, because exist some steps produced on desktop which still need more time to be worked out, although exists studies in progress to apply the webmap services to resolve these steps. Regarding methodologies, the web service method showed more interesting in relation to the traditional method, because it uses the most current data available at the platform, producing maps in a short time, allowing the production of a dynamic

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cartography without temporal clipping, which enables us to make comparisons. Thus, releases the user who is not an expert in the production of maps of analyzing and interpreting the existent data.

However, the web service method does not exclude the expert user in GIS from selecting territory data and knowing specificities about the place, being responsible for selecting consistent data for each reality. For example, slope percentage feasible with the Brazilian reality according to the ranges of slope 5%, 13%, 30%, and 47%. Because, it is important to understand that the judgment for a given data, is relative to the concept of what is acceptable or not, being able to have intrinsic cultural values of each locality.

The next steps to be developed in the tool is to allow the user to choose ranges and judgment classifications according to their values and ideals, through the dynamic cartographic, using interface windows, to allow the user to make adaptations they judge necessary.

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Markus Neteler, Ph.D., is cofounder and managing director of mundialis. He is a Geographer and GIS professional since 1999. After having worked as a researcher in Italy for 15 years he moved back to Germany in order to join mundialis GmbH & Co. KG in Bonn as a partner and general manager. His main interests are remote sensing, analysis of big geodata and Free Software GIS development. In his years in Italy, he worked on risk mapping in EU and Italian projects related to eco-health and biodiversity with a focus on the extraction of environmental indicators from spatial time series. He is author of a highly cited book, various book chapters, and over 70 peer reviewed publications. Markus Neteler is project coordinator of GRASS GIS (https://grass.osgeo.org/) since 1997 and founding member of the former GRASS Anwender-Vereinigung e.V. (Germany, now FOSSGIS.de), the Italian GFOSS association, and the Open Source Geospatial Foundation (OSGeo.org, USA). In September 2006, he was honored with the international Sol Katz Award for Geospatial Free and Open Source Software (GFOSS). Markus Neteler has been participating as task leader in several European projects (FP6 EDEN, CEP Eulakes, FP7 Edenext, FP7 Eurowestnile, LExEM, H2020 openEO), and was leading several national and international projects. In mundialis he overlooks a series of remote sensingi, GIS and cloud related projects.

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