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THE ROLE OF VEGETATION COVER INDEXES IN URBAN AREAS: A CONTRIBUTION BASED ON LANDSCAPE ECOLOGY USING SENTINEL-2 SATELLITE IMAGES

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RESUMO

O artigo defende a importância do acesso livre a dados, como o Projeto Copernicus que permite que os cidadãos usem imagens de sensoriamento remoto Sentinel para mapearem o uso do solo. Destaca o mapeamento da cobertura vegetal e o uso de métricas da Ecologia da Paisagem, principalmente o efeito de borda, para medir a relação entre áreas verdes e áreas edificadas urbanas. Como resultados, ilustrados por algumas cidades da Europa, critica os tão usados "rankings", que não consideram condições locais específicas. Ressalta as possibilidades de usar algumas métricas com base na Ecologia da Paisagem para analisar o equilíbrio entre paisagens construídas e verdes, como suporte para propor novos índices urbanos que considerem valores relativos que estejam mais a tom com as características e valores locais.

Palavras-chave: Áreas Verdes Urbanas, Sentinel-2, Ecologia da Paisagem, Métricas de Paisagem.

ABSTRACT

The paper defends the importance of free access to data, as Copernicus Project that allows citizens to use Sentinel remote sensing images to map land use. It puts emphasis in vegetation cover, using metrics of Landscape Ecology, mainly the edge effect, to measure the relation between built and green landscape in urban areas. As results, illustrated by some cities in Europe, it criticizes the possibilities of producing rankings, that doesn't consider specific local conditions. It points out about the possibilities of using some metrics based on Landscape Ecology to analyze the balance between built and green landscape, as a support to propose new urban indexes, with relative values according to local characteristics.

Keywords: Urban Green Areas, Sentinel-2, Landscape Ecology, Landscape Metrics.

1- INTRODUCTION

The act of measuring built and natural land uses to arrive to indexes is part of the main studies that researchers do, with the goal to characterize, compare and define vulnerabilities and attractiveness in space. Theories related to modeling are based on that, on studies of decomposing (to define main variables) to compose (to apply methods of combining main variables) and to decompose (to do the interpretation of the results) and then recompose (to propose alternative futures). The definition of limits from adequate to inadequate and all the steps to work with models are in the interest of GIS users.

The working with analysis and synthesis was proposed by McHarg (1969) in "Design with nature", while the logic of constructing models based on the acts of decomposing, composing and recomposing was explored by Chorley and Haggett (1967) in studies about models in geography. The importance of integrating parts into systems to understand connections in a dynamic condition composed the theory of System Approach, presented by biologist Bertalanffy (1968).

With the support of IT tools and GIS science, with conditions to propose and test models, we are always producing or using indexes. With the goal to understand the relation between variables in a systemic approach, we produce analysis and synthesis, with methods based on decompose, compose and recompose.

Access to spatial data is becoming more and more possible, although with huge territorial differences related to economic inequalities, lack of policies and awareness of the role of data in planning. Data can be transformed into information using models, based on representation of vulnerabilities and attractiveness of the places. The construction of knowledge is base to the societal development because people of the place will be able to recognize their reality and to be more critical about plans and policies, in a process of education with the use of data and information.

In the field of vegetation cover, there are some classical references mentioned by most of the researchers. A rooted and widespread index in Brazil is the value of 12 m² of green area/inhabitant, considered ideal, assigned to the UNO, OMS or FAO. Cavalheiro and Del Picchia (1992) put in discussion if this index was really proposed by any institution, and if they are to be applied, they must refer only to categories of parks or public areas for outdoor recreation.

In face of those values, Brazilian Society of Urban Arborization (SBAU) proposed a minimum index for public green areas for recreation of 15 m²/ inhabitant (SBAU, 1996), but separating these specific areas with infrastructure to recreation from general vegetation cover and free empty spaces. So, there's something more to put under discussion: the definition of green infrastructure and the mapping of vegetation cover.

It's also very common, from the begging of the use of spatial models up to recent possibilities in GIS science, the use of ranks to compare situations around the World. Among several studies in that field we can mention some that produced rankings of cities, like "Green City Index", developed he Economist Intelligence Unit, sponsored by Siemens (DENIG, 2012) and the "Treepedia's Green View Index", developed by MIT's Senseable City Lab and conducted by Ratti (SEIFERLING et al., 2017, LI et al., 2015).

In the studies about "Green City Index" they arrive to general rankings in each continent, as the goal is an economic study, but at least they use different variables according to local conditions and classify the performances of each variable according to local references. Each city receives an overall index ranking and a separate ranking for each individual category. To countries that they had good data, they present the results numerically, but to other countries, they classify it in five performance bands from "well above average" to "well below average" (for the Asian, Latin American and African Indexes). The study is an example of the importance of data in analysis, as inequalities of basic information results in comparisons that can be questioned. They also recognize that classifications and rankings must follow local references.

In studies of "Treepedia's Green View Index" the goal is to define which cities have the greenest streets, using data collected from Google Street View. It quantifies how green a street view looks, according to the number of trees it contains. They say the result is a scalable and universally applicable method to analyses the amount of green perceived while walking down the street. We question the concept of "universally" that don't consider cultural values and specificity.

Urban planners are always searching for parameters that can provide a reference to quality of life. This is the base of a Master Plan: to recognize values from a society, as a collective goal or limits of what can be accepted, according to a shared decision. From necessity of searching for parameters, there is the tricky of comparing what is nor comparable. Rankings can be very generalist, and serve to specific purposes. But, in another hand, we must recognize that they can call attention to problems that must be faced.

This paper her the goal to show the importance of free access to data, as support to construction of information, based on models. It defends that the production of information and the promotion of knowledge must review the way we work with indexes. It tests and presents some general indexes, to criticize the indiscriminate use of comparisons between very different realities. Classifications must be more relative than absolute, considering different realities and avoiding basic spatial mistakes, like the use of administrative limits in model's analysis or generalized indexes that uses rigid limits as references.

Using satellite imagery and producing NDVI (Normalized Difference Vegetation Index), it`s possible to analyze the relation of the main built fragment and its surroundings, comparing to vegetation cover, according to local reference, avoiding indiscriminate rankings.

2- INTERPRETATION OF FORMS ACCORDING TO LANDSCAPE ECOLOGY

Studies about land use metrics in Landscape Ecology have the goal to apply measures and to propose limits and references, searching for the ideal conditions of each reality. The measurement of metrics aims to select the most appropriate fragments for environmental preservation and to compose the spatial arrangements to achieve biodiversity, the balance of species and the gene flow, involving the study of patterns and the interaction between patches within the landscape mosaic (FORMAN & GODRON, 1986; METZFER, 2001; COUTO, 2004; ROCHA et al., 2016).

According to Landscape Ecology, the ideal fragment has a good shape index, big enough to present a protected core, and not far from other fragments to conform an ecological corridor. Some fragments don't satisfy all conditions but may play a specific role in fragments network (FORMAN & GODRON, 1986).

The main metrics for urban studies are core area, inscribed circle, border effect, size, shape index, the degree of isolation and connectivity between fragments (ROCHA et al., 2016).

For this study, we used the metric "edge effect", that makes possible to calculate the shape index of the fragment: whether if it has many branches or it is more compact. It is measured by the relation of perimeter/area, to indicate the complexity of the shape. The bigger the relation perimeter/area is, the more significant is the contact between different uses in the borders (Fig. 01).

Fig. 01. Edge effect metric. Source: The authors

3- MATERIALS AND METHODS

To illustrate the discussions, it presents the case studies of Nice (France), Cagliari (Italy), Athens (Greece), Prague (Czech Republic). Cases with different urban conditions, from metropolitan to medium size areas, from very dense to spread, from large to medium population, with different proportions of green areas.

It was used Copernicus Sentinel data, from the European Space Agency's (ESA) Sentinel-2 mission. Copernicus, named after the astronomer Nicolaus Copernicus, is the European Union's earth observation and monitoring program that provides global satellite, ground-based, airborne and seaborne data, in near real time. All data is free and open through its European public funded services, developed, among others, to serve urban and regional planning through support for sustainable management and resilience. Sentinel-2, consisting in twin satellites phased at 180^o and a revisit frequency of five days at the Equator.

Sentinel-2 images are captured by a satellite equipped with an MSI (multi-spectral instrument), a sensor which generates data in 13 spectral bands, from which the bands of 10 m resolution were used: 2, 3, 4 and 8. They were worked in visual composition (RGB432) and near infrared composition (RGB843) to highlight vegetation cover.

NDVI (Normalized Difference Vegetation Index) was calculated and classified according to 4 types of land use, using local references for the value ranges: (a) Without vegetation, composed by exposed soil, buildings or water; (b) Buildings and/or low occurrence of vegetation, grass; (c) Buildings and/or occurrence of medium vegetation, scrubby; (d) Dense vegetation, mainly woody, robust.

Once produced land use maps, studies about metrics were applied, beginning from identifying the main built fragment. It was calculated the metrics of each fragment, total area of each typology of land use, perimeter of main built fragment, relation perimeter/area of main built fragment, area of the administrative limits, relations between built and green fragments, relations of population density.

The main discussion was about the problems of using general indexes to construct rankings, questioning in which conditions some of those indexes could be used, and what are the main problems related to indexes. Even criticizing some general indexes and the logic of rankings, it was possible to understand that studies about the relation between built and green landscape must be done, to develop some specific urban indexes that could be included in Master Plans

As future developments, the research points out to the importance of separating vegetation cover according to uses, as green infrastructure used as recreational areas, or even as areas to be protect due to environmental fragility due to risks and clime changes.

4- CASE STUDIES

We decided to work with cities in Europe with different dimensions (from media to big cities), different type of urbanization (from spread to concentration) and different area compositions (from cities with very big municipality areas and empty sectors without urban use, to those that urban use corresponds to the totality of municipality area).

The idea is to take different conditions to be analyzed and to defend that if we were using rankings, we could lose important information and we wrongly compare incomparable conditions. But also, to defend the use of metrics of edge factor (perimeter/area) of main urban fragment compared to distribution of vegetation fragments.

Observing the first case study, Athens, in Greece, we understand that the city has high dense urban area with lack of green areas. But the case study helps us to understand the problem of working with administrative boundaries in the analysis. If Athens had a bigger delimited official area, in a result about the relation of green areas per municipality, the numbers could change completely. The position of Athens in a rank could be according to a reference that is not spatial analysis, but a line defined by administrative decisions. To understand Athens, we must study it as a conurbation area, in metropolitan territory. (Fig. 02).

In the case study of Cagliari, in Sardinia, in Italy, we observe that urban morphology resulted in very interesting landscape quality. The main urban plot, that means the conurbation urban area, is very irregular and has a very high relation perimeter/area. This means that there are more surfaces of contact between urban land use and other uses, creating a more heterogeneous landscape and allowing people to have more contact with green and blue areas in their daily life. The case study was important to understand the role of edge effect. (Fig. 03).

The case study of Nice, in France, was important to understand the meaning of analyzing main urban fragment. Nice urban area, due to geographic definitions by topography and the sea, was constructed in two parts, almost with the same dimension. We took the oldest plot to analyze, because it's a little bit bigger. Different from Cagliari, the urban main fragments are very compacted and not spread, with low values in the report of edge effect. As a result, green areas are not so present in daily life, but in borders out of main urban plot. This case study was interesting to prove that if a rank was constructed, we could not see this condition, because when using the limits of the municipality, the report though total green area and urban area is positive, even thought people are not served by green areas in contact with urban areas. (Fig. 04).

Finally, the case study of Prague, in Czech Republic. Prague has a huge municipality area, what interferes completely in any index or ranking that can be constructed. The proportion of urban area and green areas in the municipality is conditioned to this very big territorial dimension. But it's also true that the main urban plot has a very complex form, in a good relation perimeter/area that tells about the edge factor. And inside the main urban fragment, there are many fragments of vegetation cover, what means that people have access to green areas in their daily life. (Fig. 05).

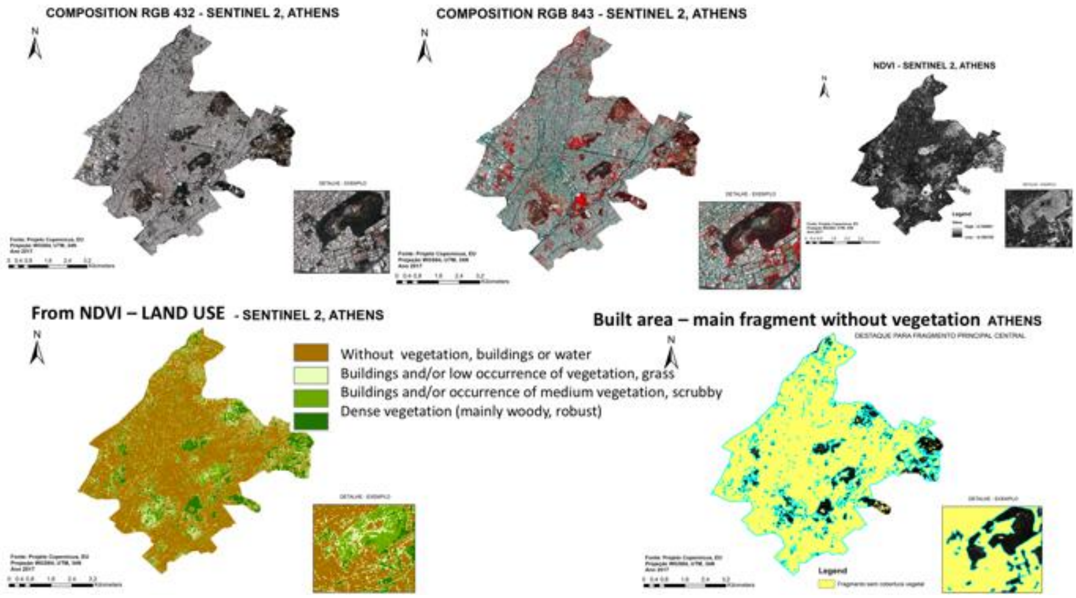

Fig. 02. The case study of Athens, in Greece.

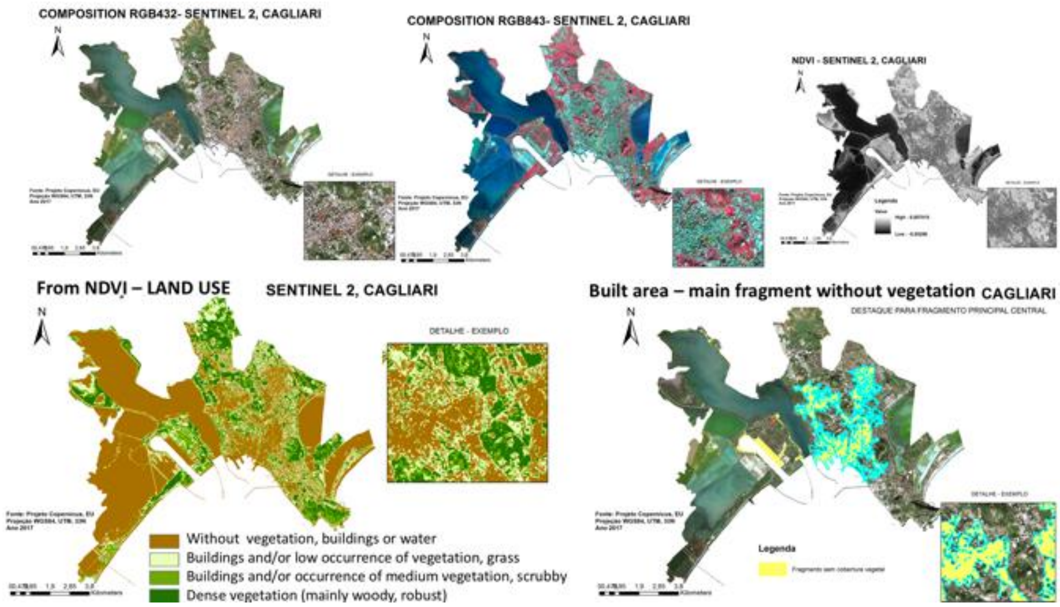

Fig. 03. The case study of Cagliari, in Sardinia, Italy.

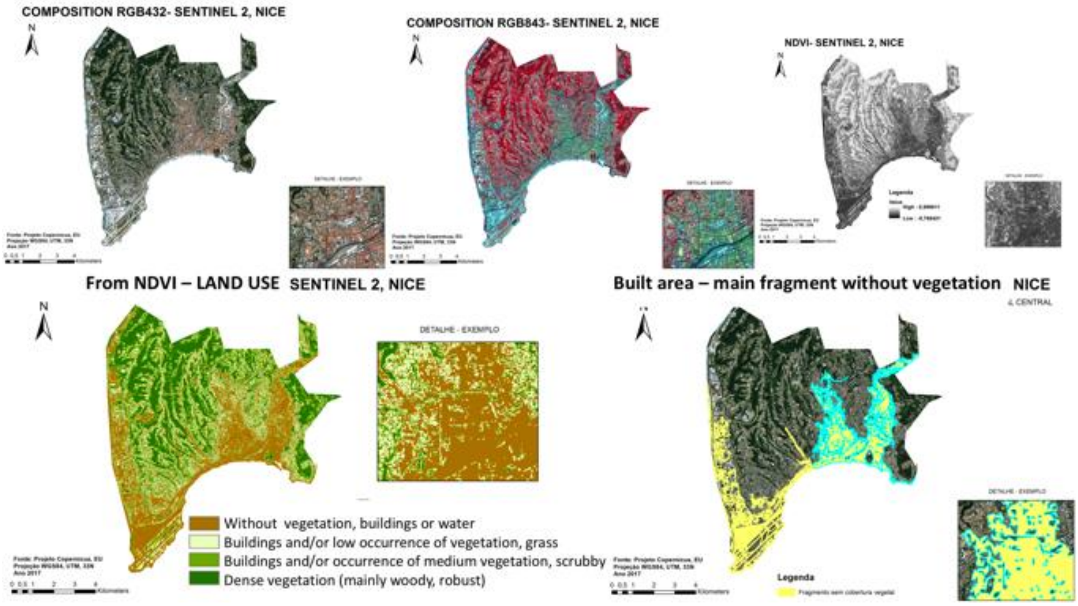

Fig. 04. The case study of Nice, in France.

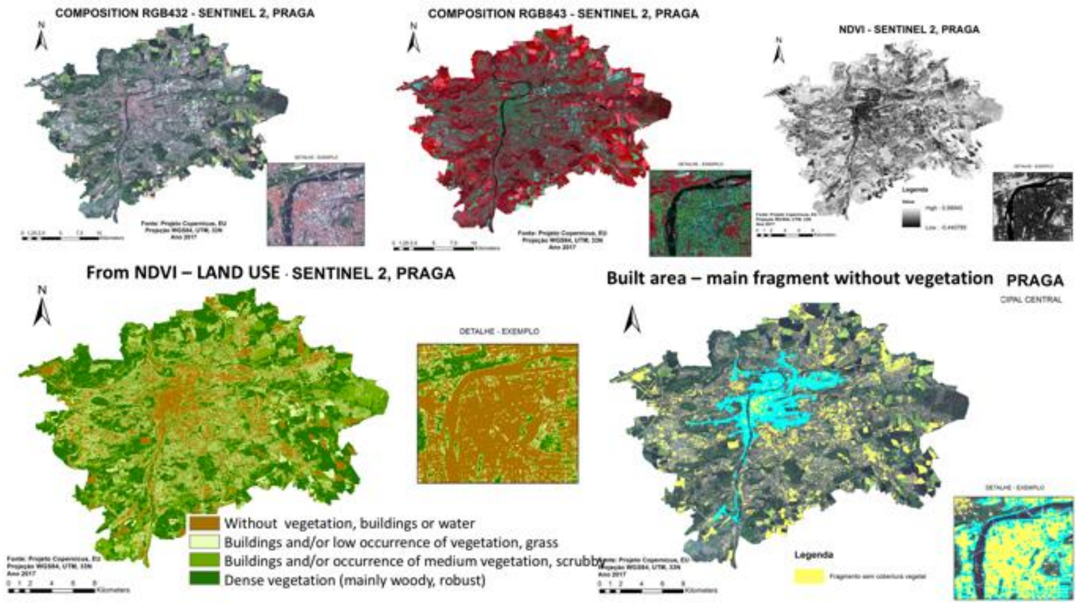

Fig. 05. The case study of Prague, in Czech Republic

5- RESULTS

Comparing the graphics with values from the 4 cities, the first surprise is that Prague has an urban area bigger than Athens, but Athens has a main urban plot bigger than Prague. The perimeter of main fragment and urban area in Prague is much bigger that the perimeter from Athens. In the relation perimeter/area, Prague has a much more expressive condition than Athens, but Cagliari appears almost as good as Prague. The result is the importance of an urban area not so concentrated, but spread in the territory and in contact with different land uses, so that green areas are not just outside the city, but part of daily life. (Fig. 06).

Analyzing the graphics about the dimensions of the municipality and the population, we confirm that the territory of Prague is huge, while the population of Athens is huge for a much smaller area, in a very dense urban land use without green areas. The numbers of Athens are so different that we had to construct another graphic taking Athens out, so that we could compare the 3 other cities When analyzing just Cagliari, Nice and Prague, we see that they are not so different from each other, but the surprise is that Prague has the worst condition in the report population/green area and Nice appears with a better condition in population/green area and population/municipal area. This is a result that is generally published when studies applies indexes, because they use administrative boundaries, without taking account on the real use of the space. (Fig. 07).

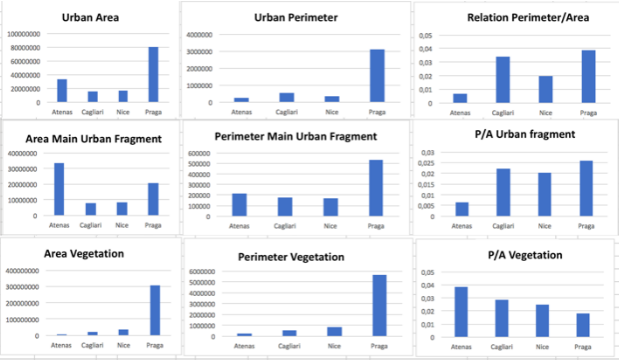

Fig. 06. Urban Area, Urban Perimeter, Edge factor in urban areas, Main Urban Fragment, Vegetation values. Graphics about Athens, Cagliari, Nice and Prague.

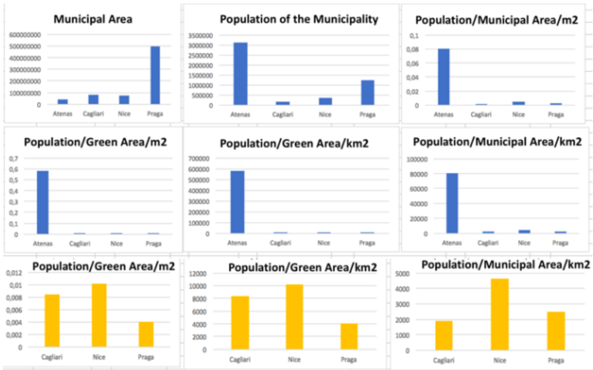

Fig. 07. Municipal area, Population and Green Areas. Blue graphics with Athens, Cagliari, Nice and Prague. Yellow graphics with Cagliari, Nice and Prague.

6- CONCLUSION AND DISCUSSIONS

Discussing the results, we emphasize the difficulties in making comparisons and the risks of indexes. Rankings must be avoided, but if indexes are proposed, it's absolutely important that they make clear they are models. Models are simplifications of reality, defined according to specific goals and approaches. It was also very important to see that in most case studies we cannot work with administrative definitions, borders or references, because they may have reasons that are not related to spatial analysis.

It's time, with all the conditions allowed by technologies of geoinformation, to test new indexes, but to avoid rankings. A ranking can only be accepted if it considers local specificity and justified by a clear reason. A rank cannot be a reductionist, but may produce "alternatives", in plural, according to different points of view. It's time for more than one answer instead of a single map. It's time for plurality in cartography.

It's import to defend the free access to data, as the example of Copernicus project, and the possibilities allowed by Sentinel Imagery. Data can be transformed into information, which can result in knowledge.

We could also see that studies based on the metrics of Landscape Ecology can be very useful, and they are much more robust then simplifications generally used. Future studies must go deeper in discussing the importance of taking into account local references, to perform relative and not absolute studies about green areas. In next steps we must discuss the role of vegetation cover and analyze it according to typologies of uses.

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