Green Infrastructure and Land Cover in Territorial Management
An Exploratory Approach

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Abstract - Urban and territorial planning and management have increased their presence at the center of political and technical concerns as a determining factor for economic and social growth. The introduction of the development of green infrastructure as an instrument for territorial management that seeks the creation of a continuum naturale[1], and whose main objective is the preservation and enhancement of ecosystems and their services, provides the opportunity to manage the territory in a sustainable perspective. However, in Portugal, the way the green infrastructure managing instrument is mapped and framed lacks regulation and effective management tool and guidelines for its implementation and monitoring.

This work, therefore, is created from the need to develop a new methodology for green infrastructure mapping, namely at the municipal level, due to a lack of vision and effectiveness in relation to the current use of this territorial management instrument. To better understand the practical outcome of the current mapping criteria for green infrastructure the mapping methods were analyzed and systematized to comprehend the weaknesses, strengths and challenges that the current approach faces. Following this analysis, a new mapping approach for green infrastructure was developed. The development of the new approach focuses on the use of land cover related to the potential of providing ecosystem services associated to each land cover type. The result of this approach is a green infrastructure with complementary information, provided by the ecosystem services, that can be used as starting point to develop measures and guidelines for managing the territory.

For full comprehension of the applicability, the approach was tested with a more updated land cover base to analyze the differences and the thematic of attributing weights to the ecosystem services was discussed. To conclude this study, some challenges and barriers that need tackling were identified, as well as, some recommendations for the future developments of the approach.

Keywords - Municipal Green Infrastructure; Territorial Management Tools; Land Cover; Territorial Planning; Ecosystem Services; Alentejo.

1. Introduction

The European Commission, with the EU strategy on Green Infrastructure (GI), establishes the development of GI as a key step towards the success of the EU 2020 Biodiversity Strategy. The development, preservation and enhancement of healthy green infrastructure aids to halt the loss of biodiversity and enables ecosystems to deliver their many services to people and nature. Mapping and assessing ecosystems and their services are the core of the EU Biodiversity Strategy as they are crucial if we are to make informed decisions.

The concept of green infrastructure, “an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to humans populations” (Benedict & McMahon, 2000:5) is rooted in much earlier concepts such as greenways, ecological networks or ecological corridors. The idea of developing a green infrastructure originates from the concern towards the connection between parks and other green spaces for the benefit of the population, the preservation and connectivity of natural

[1] Continuous system of natural occurrences which constitutes wildlife support and the maintenance of genetic potential that contributes for the stability and balance of the territory

areas to generate benefits for biodiversity conservation and the halt of habitat fragmentation (Benedict & McMahon, 2000; McMahon, 2010; Mell, 2008). In Portugal the concept was introduced in the form of *continuum naturale* by Caldeira Cabral and it has been integrated within the Portuguese legal framework since 1999 in the form of ecological structures. An ecological structure is a part of the municipal masterplan, a territorial management tool, with continuity in other legal documents. However, although the masterplan is a legal binding document, the question arises when it comes to the ecological structure since it is majorly composed by other legal documents, such as National Ecological Reserve (REN) and National Agriculture Reserve (RAN) (Cangueiro, 2005).

According to the decree for land classification and reclassification criteria, an ecological structure is composed, (i) within the urban perimeter, by green spaces of collective use along with other spaces needed to ensure environmental balance and protection of natural heritage (contributing areas for the regulation of the hydrologic cycle, bioclimatic regulation, improvement of air quality, biodiversity conservation) and (ii) within rustic land by areas that belong to the Fundamental Network for Nature Conservation, natural areas which are prone to risks and vulnerable, and soil areas selected due to municipal protection and preservation interest of natural and landscape heritage. The Fundamental Network for Nature Conservation comprehends the National Network for Protected Areas, Natura 2000 Network, Classified areas under international commitments, National Ecological Reserve, National Agriculture Reserve and Public Water Domain.

The term ecosystem services – the benefits that people obtain from ecosystems[2] - originates from a growing awareness with respects to environmental pollution, resource scarcity and subsequent notions of managing economic development under the concept of sustainable development. Its use demonstrates how the disappearance of biodiversity directly affects ecosystem functions that underpin critical services for the human well-being (Braat & de Groot, 2012; Costanza et al., 2017; Haines-Young & Potschin, 2010). In the year 2000, the Millennium Ecosystem Assessment, the first comprehensive global assessment of the implications of ecosystem change for people, introduced the term into the policy arena. Since then, the literature on ecosystem services and international projects have multiplied. A few examples are the project of The Economics of Ecosystems and Biodiversity (TEEB)[3] and CICES[4] – Common International Classification of Ecosystem Services – which was proposed in 2009.

The assessment of ecosystems and their services in a spatial manner occurs for a broad set of reasons including advocacy, awareness raising, decision support, priority setting and so forth (Burkhard & Maes, 2017; Maes et al., 2014). Different methodologies and tools have been developed for quantifying, valuing and mapping ecosystem services. A simple approach derives information directly from land cover type maps, the expert approach rellies on the knowledge of experts about the matter, the causal relationship approach is where an ecosystem service is estimated based on a known relationship between the ecosystem service and spatial information, an approach that extrapolates ecosystem services estimates from primary data and an approach that uses a quantified regression and socio-ecological system models to estimate ecosystem services (Burkhard & Maes, 2017; Grêt-Regamey, Weibel, Kienast, Rabe, & Zulian, 2015; Maes et al., 2014). The tiered approach is a type of generic mapping approach that differs according to the information availability, expertise and scale. Tier 1 maps ecosystem services using only available indicators, tier 2 links different indicator with land use data and tier 3 consist on a model-based approach (Grêt-Regamey et al., 2015; Maes et al., 2014). However rapid growing research for ecosystem services mapping generates inconsistency, which limits the use of ecosystem service information in policy and

[2] www.millenniumassessment.org

[3] www.Teebweb.org

[4] www.cices.eu

decision making (Burkhard & Maes, 2017; Crossman et al., 2013).

The clear existence of barriers regarding ecological structure mapping, implementation and regulation in Portugal result from the lack of scientific knowledge concerning the different components involved, the lack of clarity in the way the ecological structure is introduced in the legal framework namely the absence of guidance on how to regulate the instrument and how to articulate the different legal regimes and understanding the purpose of the ecological structure among them (Correia, 2012).

Therefore, there is the need to search for new mapping approaches that tackle these issues. This paper aims to understand if mapping green infrastructure having as a base a land cover map, reclassified by ecosystem services, has potential to be used as a new approach for mapping green infrastructures in context of the territorial management tools. The necessary steps are the following:

(1) Analyse and discuss the mapping practices of the municipal green infrastructures included in the second-generation masterplans;

(2) Create a reclassified land cover map;

(3) Create a map of green infrastructure having as a base the reclassified land cover map;

(4) Explore the possibility of proposing the new mapping approach.

2. Assessment Framework

The basic idea for this study is to explore a new approach for mapping green infrastructure. In a first step, which is about creating a base of comparison for the new mapped GI, the masterplans and other legal documents were submitted through a process of analysis and systematization of green infrastructure mapping criteria, objectives and management guidelines. Following that, with the information that was available, two green infrastructures from adjacent municipalities were aggregated.

The second step focuses on creating a reclassified land cover map to act as the base for the green infrastructure. The reclassified land cover map is the result of the application of a Burkhard *et al.* (2009) inspired matrix combined with the ecosystem services mapped by the PT MAES Study (Marta-Pedroso, C. & Domingos, T., Mesquita S., Capelo J., Gama, I., Laporta L., Alves, M., Proença, V., Canaveira, P., Reis, 2014).

2.1. Masterplan Analysis

The process of analysis was confined to 22 municipalities of the Region of Alentejo that had second-generation masterplans. After the analysis, a table was built to systematize the information. To build the table, information regarding what is included within the green infrastructure, how is it structured, what is the regulation if the green infrastructure and what is the concept followed for mapping the GI was collected.

2.2. Aggregation of Green Infrastructure

To build a base for spatial comparison with the reclassified GI, two of the analysed green infrastructures were aggregated into one so that the continuity between them could be accessed. The two GI belong to the municipalities of Grândola and Alcácer do Sal. The choice of these two, to aggregate, is because they were the only two continuous municipalities with vectoral information available. To aggregate, both green infrastructures were harmonized to create a more coherent GI in terms of layers and representation.

2.3. Reclassified Land Cover Map

The first step of the development of a reclassified land cover map is the harmonization of the ecosystem services scales.

PT MAES Study mapped five ecosystem services – Soil Protection, Carbon Sequestration, Fibre Production, Crop Production and Fodder Production – each with their own units. Therefore, each ecosystem service scale was transformed into capacity of providing ecosystem service levels.

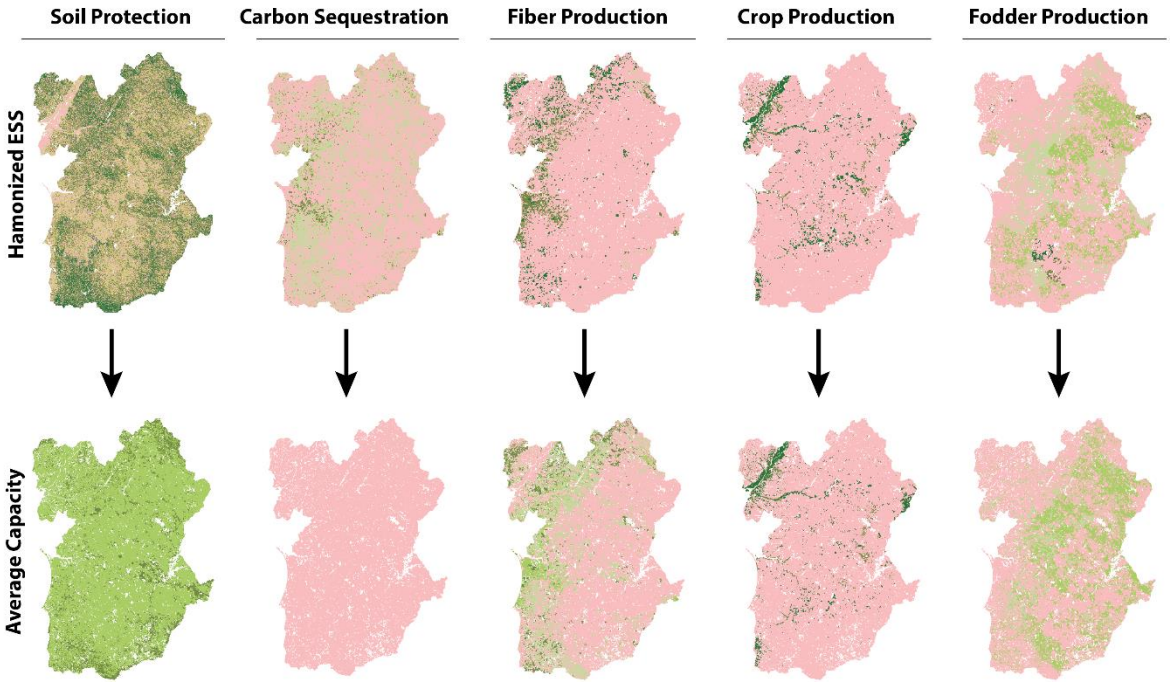

Figure 1: Comparison between the harmonized ecosystem services map and the average ecosystem services map

Burkhard *et al.*, (2009) suggests 6 levels of capacity – 0 no relevant capacity; 1 low relevant capacity; 2 relevant capacity; 3 medium relevant capacity; 4 high relevant capacity; 5 very high relevant capacity. To build the matrix, the average capacity value for each land cover class was calculated. In both instances, the result was mapped to understand the impact of calculating the average (Fig.1).

The matrix was built using the land cover map from 2007 (COS 2007) due to that being the base, used by the PT MAES Study, to map the ecosystem services.

After building the matrix, the total capacity value for each land cover class was calculated and mapped. Due to the low number of ecosystem services, compensation between the services may occur and so, a map with only the number of ecosystem services in a land cover class was made (Fig. 2).

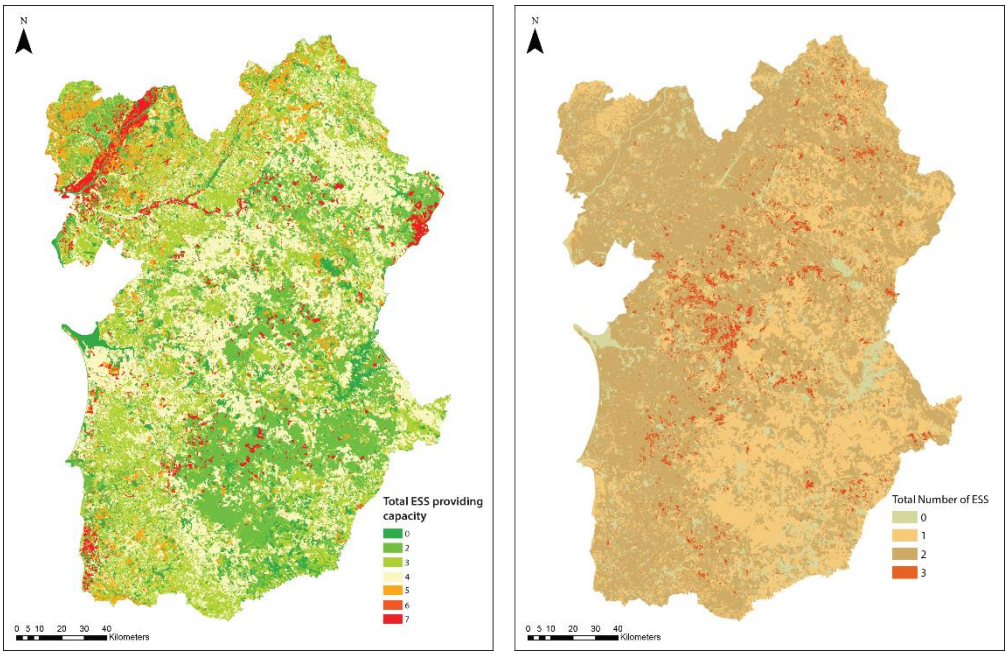

Figure 2: Total ES and Total number of ES Maps

2.4. Green Infrastructure Mapping

Having the base, the reclassified land cover map, it was necessary to decide what would be the criteria to map the green infrastructure, in other words, what is the minimum average capacity of providing ecosystem services that a land cover should have to be included in a green infrastructure? After analysing the spatial expression of each capacity level, it was concluded that, in the case of a scale of 0 to 7 of total capacity of providing ES, the minimum should be 4 (Fig.3).

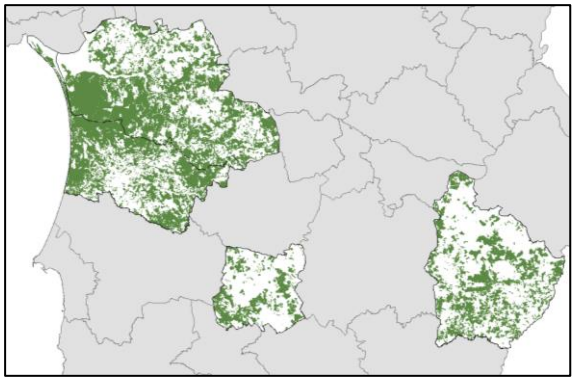

Figure 3: Reclassified land cover green infrastructure

3. First Results

The analysis of the masterplans allowed to comprehend what was done by the municipalities and if there was compliance with was established at national and regional scale.

Although most of the municipalities included the Natura 2000 Network and the Public Water Domain, many of the municipalities did not explicitly include the National Ecological Reserve and the National Agriculture Reserve.

Regarding the regulation applied to the GI, the municipalities tend to re-direct toward the already established legal regimes, whether that is a public restriction regime, or the existing regimes for each category of space. Some municipalities do add recommendations of use and activities that should be developed as well as additional specific restrictions.

An additional analysis focused on the spatial representation of the municipal green infrastructures. From the data available it was possible to conclude that large differences regarding the representation of the different component's elements (Fig. 4).

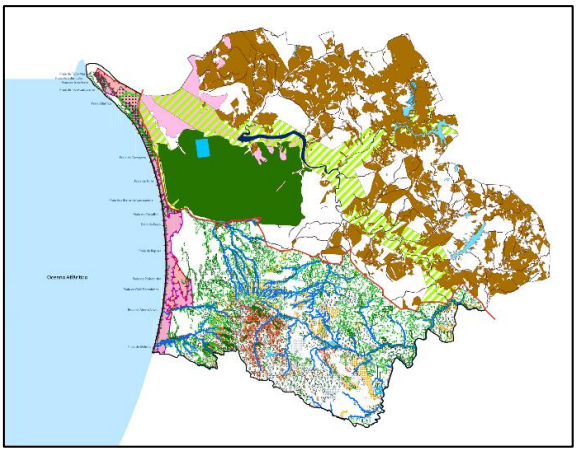

Figure 4: Non-harmonized municipal green infrastructures

This difference is mainly due to, first, the nonexistence of mapping representation guidelines and, second, the use of different teams, some hired, some belonging to the municipalities, to perform the task. Due to the representation and structure differences, the green infrastructures were harmonized, resulting in a cohesive base of comparison for the reclassified land cover green infrastructure.

When comparing both structures (Fig.5), it is evident that the natural park and priority habitat areas are not comprised by the reclassified land cover GI and neither are the areas belonging to water courses and other water bodies and urban spaces.

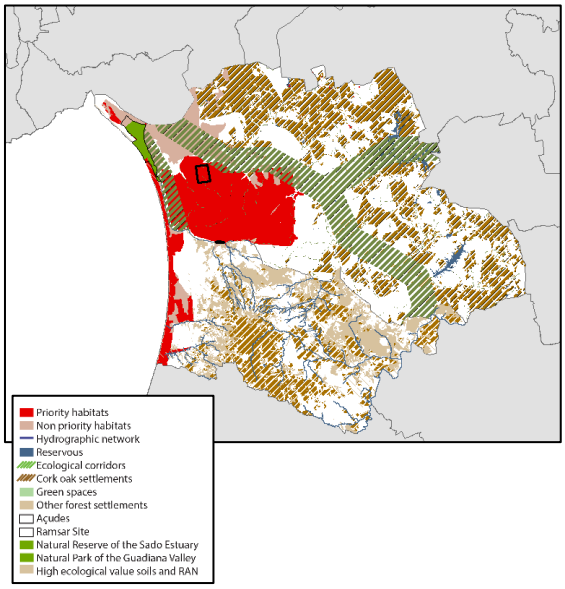

Figure 5: Harmonized municipal green infrastructure

The lack of representation of these areas is explained by, one, the non-consideration of those land cover classes in the evaluation and

mapping done by the PT MAES Study and, second, the ecosystem services considered for the approach do not represent properly the benefits that those areas provide to humans.

However, to develop a green infrastructure that proper represents the needs of the territory, the amount of considered ecosystem system services must be higher and take in consideration all aspects of the benefits an ecosystem can provide. Furthermore, all relevant land cover classes should be included in the approach, as well as, the application of weights to the matrix to differentiate the ecosystem services in terms of prioritization of measures or in terms of interest of policies or stakeholders.

4. Testing the approach

The applicability of the approach was tested by evaluating the level of compliance between the reclassified land cover GI and the municipalities GI. The municipalities GI have a 53% of non-compliance with the reclassified land cover GI.

When testing the approach, it was used a land cover base from 2015 (COS 2015), which offers a more accurate representation to compare with, since the green infrastructure from both municipalities is from the year 2017. In this case, the percentage of non-compliance was 65%. The increase of non-overlapping area is a consequence of land cover changes that occurred over the years. Nevertheless, there is still more than half of the municipalities GI that does not match, which does not mean that the approach doesn't have potential. It means that the approach needs to be further developed. In fact, both municipalities include water courses, water bodies and urban green spaces into their green infrastructure, which are land cover classes that are not considered in this case and, therefore, offer room for improvement.

The application of weights in the matrix was also tested, to highlights the importance that the integration can have when it comes to managing the territory (Fig.6).

According to the analysis of the masterplans there is a serious gap when it comes to the regulation of the green infrastructure, mainly because it is already integrated in other public restriction regimes. By integrating the use of weights into the approach matrix it is possible to prioritize deficient services and enhance or maintain thriving ones. For example, the weights of 1;2;3;4;5 were assigned randomly to each ecosystem service. To the ecosystem service that shows the lowest values – Carbon Sequestration - the weight of 5 was attributed, meaning that it is the most important service. If the most important service shows the lowest values, then in terms of management, it is a service that requires prioritization and perhaps special measures to enhance its performance.

5. Conclusions

This paper presents a new methodologic approach to map green infrastructure with the purpose of creating an effective territorial planning tool. One must bear in mind that the approach applied here is dependent on the information available, mainly regarding the mapped ecosystem services. However, even with only five ecosystem services this approach seems to be very promising.

The analysis done to the masterplans raise the question of the purpose of the green infrastructure.

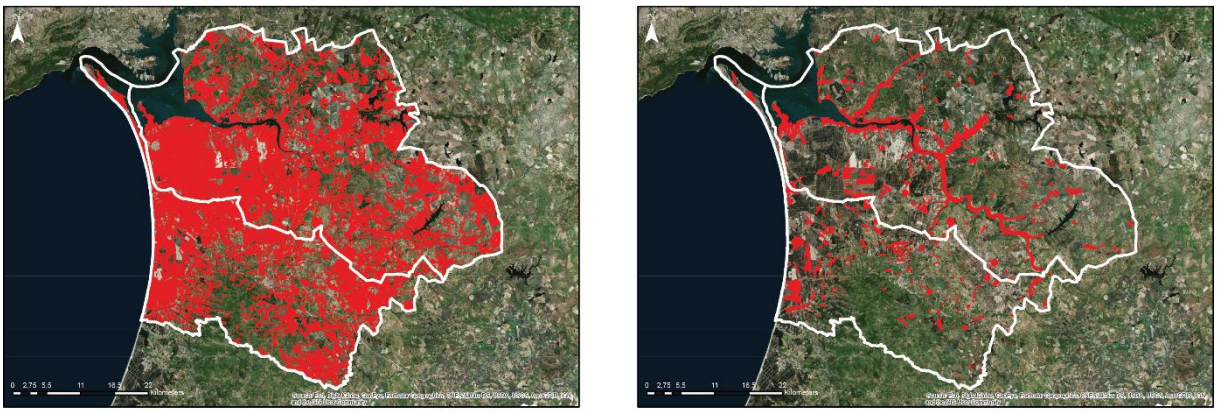

Figure 6: Comparison between the non-usage of weights and the use of weights when building the matrix

Is it more than an overlapping of other components? How should it be managed? And, taking in consideration the obtained results, why does it exist since in terms of implementation and management it has become redundant?

The use of the proposed approach offers a more comprehensive green infrastructure which is intuitive when it comes to managing. It protects the areas that provide the most ecosystem services, as well as, targets the ecosystem services that are more beneficial to society but need improvement.

The next trial phase would be applying this approach considering a larger sample of ecosystem services, all the relevant land cover classes and the introduction of weights in to the matrix.

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