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«MARGINAL» URBAN VEGETATION – THE CASE OF LISBON

S. MACHADO DOESBURG, P. FARINHA MARQUES

Abstract

The capacity of cities to respond to the physical, social, economic and environmental reality in order to guarantee sustainability, identity, biophysical integration, social dynamics, mobility, diversity, security and comfort is being challenged. An ecological approach to urban planning and management is essential to maintain the long-term sustainability of ecosystem benefits, services and resources. The urban vegetation plays a key role in this process. While municipality plans identify and protect most green areas, a network of existing vegetation remains «marginal» in these plans and its contribution to the urban ecosystem remains unknown. In this study, by means of satellite images, the existing vegetation of the city of Lisbon is identified, quantified and compared to the Ecological Urban Structure Plan (EUS), as defined by the municipality. The amount of vegetation not considered by the EUS was defined as «marginal» Urban Vegetation. It consists of a considerable amount of areas, fragmented throughout the city and subjected to imminent pressures. This vegetation is investigated, evaluated and its evolution monitored with images of the past 7 years and finally, contextualized in the new urban plans for the city.

Key words:
Urban Vegetation, Remote Sensing, Urban Ecology, Urban Green Areas, Ecological Urban Structure, Lisbon

Introduction

In Portugal, urban development continues to reduce the amount of vegetation in the cities, resulting in the fact that most cities are perceived as lacking green areas and present levels of pollution and bio climatic discomfort that are deteriorating the quality of life of their inhabitants. Green infrastructure has been recognized as an important contributor in improving these urban conditions (Dale, et al., 2000), which affect surface temperature, hydrology, carbon storage and sequestration, biodiversity, while an inefficient urban planning, as well as insufficient green infrastructure, may result in raising environmental costs. Despite the efforts of Local Governments to implement green infrastructures in the cities, the presence of green areas, levels of pollution and bioclimatic comfort mostly remain inadequate.

Urban parks and gardens are considered green areas of the city, which – due to their identity – are part of people's everyday life. These spaces are classified in municipal plans as valuable ecological areas and are therefore protected from urbanization by the municipality, and especially, by the inhabitants. Another form of landscape value in the city is spontaneous vegetation, which covers slopes, vegetable gardens in empty plots and the vegetation in the inner-courtyards, which often have a negative image. These «marginal» spaces have their own dynamics, diversity, and often survive outside the municipal initiative, independently and without protection. They are the object of this study and are referred to as «marginal» vegetation, which is the vegetation that exists in the city that falls outside planning instruments.

Questioning the potential of existing resources of the city as a comprehensible structure, capable of generating better environmental conditions, require new dynamic tools. It also may provide understanding of existing processes and relationships at different scales. High resolution satellite imaging can provide accurate, economical and straightforward information to map, analyse and monitor urban vegetation because it offers a large and frequent temporal cover.

Through the analysis of data retrieved from Vegetation Indexes (such as the Normalized Difference Vegetation Index), information is gathered about how this vegetation works and aids in understanding (a) what this type of vegetation can contribute to the ecological matrix of the city and (b) how it relates to the formal Ecological Urban Structure. The spatial dimension of urban ecology can be a useful planning tool to facilitate the comparison of existing urban areas, which may help to predict the ecological impact of new urban developments (Botequilha Leitão and Ahern, 2002).

This paper will first present considerations about the process of developing the city as well as its ecological matrix in a Portuguese context, followed by defining what «marginal» Urban Vegetation is. Second, will be a description of the tools used in this study, namely «Very High Resolution Satellite Imagery», and an examination of the case-study of Lisbon. Finally, the «marginal» Urban Vegetation of Lisbon will be discussed and the conclusions of the study presented.

This study emphasizes the fact that, in Lisbon, there is a considerable amount of vegetation that falls outside of the city's planning instruments with no level of protection and that little is known about its potential and contribution to the urban ecosystem. It challenges the methods for implementing Green Infrastructures in the city by suggesting a broader approach to the urban ecological matrix.

Making City

Cities today are the engines of the world's economy, however, to be successful they have to be culturally resilient, socially robust, economically viable and ecologically sustainable.

In Portugal, the development of cities is defined by planning instruments, which determine how the city and its Green and Blue Infrastructure should progress. Urban plans, based on zoning with strict lines to regulate uses, dominate the current practise, and even though most Portuguese cities already have an Ecological Urban Structure Plan, these typically incorporate the green spaces of the city, such as parks, gardens, street trees and water surfaces. The method of planned green corridors, with ecological, cultural and symbolic systems (Magalhães, et al., 2007) is often used as can be seen in the example of the city of Loures. The city of Lisbon goes a step further with its new Municipal Urban Plan (2012), which provides active policies for the greening of the urban environment that go beyond the protection of more formal green areas. Furthermore, it defines dynamic strategies for storm and waste water management, energy savings, mobility, civic participation and land use. These strategies strive for a long-term sustainable development of the city, giving space for design innovations, cultural expression and ecological formation. However, the legacy from the modernist models of urban planning, based on rigid mechanisms of central planning, continue to lead planning practices in Portugal even to this day. The urban ecological matrix must be able to respond to the physical, social, economic and environmental changes in the city. A new sensibility about incorporating divergences between ecology and the urban development of the city has to guide the human role in its relationship to ecological needs. The underlying principle is that the process of urbanization is much more significant for emphasizing urban relationships than «particular» spatial forms of urbanism in and of themselves (Corner, 2006).

As Homi Bhabha said, timing and the significance of an event don't always go together and what we think we knew we don't know; what we think is new might or not might be so (Bhabha, 2010). The great question of urbanization is the capacity to consider the timing of interventions in the city. The timing of decision agents is very much related to governmental politics and bureaucracy, while the city develops with a temporary balance and interstitial possibilities. However, plans do not eliminate uncertainties, since they depend on opportunities and the price for not acting timely can result inthe loss of these opportunities (Portas, 2010).

The need for constant adaptation demands that urbanism does not take the form of fixed rules, but instead, promotes a series of flexible principles of ideas, systems and actions, which can be adapted to the given circumstances and opportunities. In the urban domain, the fragility of the ecosystem and the limits of resources should not be taken into account, but rather such conditions should be considered the essential basis for a new form of creative imagining (Bhabha, 2010).

The ecological matrix of the city

While in the past planners, municipalities, environmental organizations and ecologists were focused on conservation of wilderness areas, today, awareness of the importance of natural areas within cities where most of the human population resides, is increasing (Bryant, 2006). Natural systems are especially important in urban regions where they must serve many people by providing water supply, one-day recreation, flood control, farmland, wetland benefits, soil erosion/sedimentation protection, biodiversity, waste absorption/breakdown, and aesthetics or inspiration (Forman, 2010).

In the city, the urban landscape has the capacity to function as important cores or ecological arteries, and it has the ability to make scale transfers, placing urban areas into a regional scale and into a biotic context.Because the challenges of rapid urbanization and the limited global resources have become much more pressing, there is a need to find alternative design approaches that will enable us to consider the large scale differently than we have done in the past (Forman, 2010). The understanding of urban ecosystem processes in its territorial context will contribute to its survival and development. Furthermore, by providing ecosystem services within the city, it will not only improve the city's performance but also help protect the natural landscape around it.

To manage the dynamics of natural systems in the urban landscape, the ecological structure and processes need to be characterized and identified in order to understand the landscape system in terms of a) the structure, as the spatial pattern and the physical arrangement of ecological, physical, and social components, b) the functioning, as the way the components interact, such as the movement and flow patterns of animals, plants, water, wind materials and energy through the structure and c) change, as the dynamics or alterations of spatial patterns and their functioning over time. These organizations can be expressed at different scales and employed to interpret different functional spatial heterogeneity of urban landscapes (Zipperer, et al., 2000). The principles of landscape ecology apply to any land mosaic able to function equally in both, pristine natural areas and areas of intense human activity (Dramstad, Olson and Forman, 1996).

Defining a key of ecological principles, applicable to ecological research and land-use decisions in urban landscapes, is essential for maintaining the long-term sustainability of ecosystem benefits, services and resources. This framework includes principles such as a) content – the structural and functional attributes of a patch, b) context – the patch's location relative to the rest of the landscape, c) connectivity – how spatially or functionally continuous a patch, corridor, network or matrix of concern is, d) dynamic – how a patch or patch mosaic changes structurally and functionally over time, e) heterogeneity – the spatial and temporal distribution of patches across a landscape and finally, f) hierarchy – a system of functional units operating at different scales. These six principles, (content, context, connectivity, dynamics, heterogeneity and hierarchy) will help to simplify and understand the complexity of urban landscapes (Zipperer, et al., 2000).

The urban landscape should be seen as an ecosystem, with a functional and structural identity: a system with a series of elements and relationships, unitary in character, where changes to one part of the system affect the entire system. By evaluating the various components of identity of the city, it is then possible to understand the role of seemingly insignificant sites as actually being part of an important and valuable expression (McHarg, 1992).

Therefore, the ecological matrix is not limited to the formal components of the urban landscape, such as parks, gardens, green corridors etc., and much less to the citizen's perception of the city, but instead, consists of all the elements that are part of the ecosystem.

«Marginal» Urban Vegetation

In recent years, the potential of the existing resources of the city – understood as a structure that can generate a better environment – is being brought into focus through emerging fields such as Tactical Urbanism, DIY (*Do-It-Yourself*) urbanism, Guerrilla movements, temporary projects, and politics of space that were initiated by the Arab spring and other occupy movements.

While political agendas frequently plan large-scale transformative changes for the cities, small-scale improvements are increasingly seen as a way to enrich the liveability of cities. The city's existing resources are the base for these «marginal» interventions, which are its population, private initiatives, built structures and infrastructures, public and private open spaces and the biophysical conditions as well as themorphology of the city. This type of bottom up urbanism, developing «marginal» interventions in the conventional legal and regulatory frameworks, often produces novel and ingenious solutions for the city.

One very important resource of the city is its vegetation and the many benefits for the cities have been extensively studied. Areas covered with vegetation mostly indicate the existence of topsoil, and pervious surfaces, which have a negative correlation with the urban heat island effect, storm water floods, and other undesirable effects on environmental quality. Nevertheless, the cost of implementing new green infrastructure, and the time that it takes for its development to yield benefits of its functions, is too great.

The Ecological Urban Structure Plans are generally responsible for the establishment of ecological arteries that contribute to the connectivity between different systems of the landscape, contradicting the natural tendency for fragmentation in urban development. It also promotes the qualification, protection, conservation and implementation of green areas, mainly for public use, by restricting construction on these areas and specifying monitoring and execution strategies. In many cities there is a considerable amount of existing vegetation that falls outside of the domain of the Ecological Urban Structure Plan, which are under no or reduced protection policies, often resulting in being replaced by built or impervious areas.

These networks of «marginal» vegetation are based on areas that represent habitat fragments and open spaces. These areas may be important features for biodiversity (Mcintyre, Knowles-Yánez and Hope, 2000), and may also be valuable to function as corridors and stepping stones for species dispersal (Kirby, 1995). Therefore, they should be considered a key component of current ecological planning (Angold, et al., 2006).

In this study, the «marginal» urban vegetation is considered to be the vegetation that has established outside the Ecological Urban Structure Plan, and is, therefore, marginal to municipal policies. These spaces are not considered green spaces, nor does the municipality prioritize their preservation. This vegetation appears mostly spontaneously through natural succession, or through the care and maintenance of the local population. Yet, it functions as part of the ecosystem. These spaces are abandoned plots, wastelands, private gardens and inner courtyards among others (figure 1). For the purpose of identification of the areas in question, all types of vegetation identified in the satellite imagery are considered equally.

Figure 1
Representative photos of «marginal» urban vegetation in the city of Lisbon.

Since the ecological development of the city is not to be fully regulated by the municipality in all its complexity, or if so, the cost estimates would be too high, the ecological matrix of the city often relies, at least in part, on these «marginal» spaces. However, little information is available about the ecological structure and processes of these crucial spaces.

Like many other urban green areas, «marginal» vegetation appears in the city as patches of varying origins, different distribution, sizes and shapes. Their physical characteristics have a direct influence on their function and relationship with the Ecological Structure.

The interaction between patches and the matrix are numerous and often highly significant, creating fluxes that link ecosystems. Within the highly dense urban environment, the urban mesh can have a strong isolating effect, which could be compared to an island in the sea. By such comparison, a parallel could be drawn between the urban green areas and the Theory of Insular Bio-geography (Forman, 1995a). The edges of these patches mostly work as filters that determine the diversity of the patch, while the fact of being connected to the ecological network increases its diversity and dynamic potential. The disappearance of a patch can cause the loss of habitat, and reduces the number of meta-population (Dramstad, Olson and Forman, 1996).

The urban landscape structure and composition can change dramatically over time. The «marginal» vegetation, not being regulated by planning instruments, is very vulnerable to these changes. Understanding the process of landscape change, through change models at different times and scales, allows for defining the interaction of natural processes and evaluating the landscape.

There emerges a big challenge about learning how «marginal» vegetation influences the ecological matrix of the city. The following section will describe a methodology employed to tackle this challenge. This methodology makes it possible to identify, map and quantify the «marginal» spaces in a city, and thereby, can help to better understand the structure and the processes present in these spaces and their potential in relation to the Ecological Urban Structure. Following this section, the outcome of the case study of the city of Lisbon will be briefly addressed.

High resolution remote sensing and urban ecology

To understand the existing urban processes and their relations at different scales to the vegetation in the city requires new dynamic tools. The high frequency of urban spatial changes demands expedited ways of producing and updating spatial information. For this reason, high resolution satellite imaging can provide economical and straight forward information for mapping, analysing and monitoring urban vegetation, since it offers a large and frequent temporal cover.

While remote sensing is not able to replace field work and other procedures to gather information about the city, and also cannot identify single species, rarity and composition in the analysis of vegetation, it can, however, provide useful results in the form of such images and information, making the investment of image purchase and analysis a highly cost-effective solution (Langley, Cheshire and Humes, 2001).

In Portugal, one of the main instruments of urban planning and management, the PDM-Master Plan, is updated every 10 years. In highly urbanized and expanding cities, such periodicity is not suitable. Alternatively, high resolution satellite imagery, if weather conditions permit, can capture spatial data on a daily basis.

Even though high resolution satellite images present limitations in the urban context, such as the difficulty of classifying each pixel due to the high level and complexity of information (van der Sande, de Jong and de Roo, 2003), or the existence of shadows, these images contribute to a more general level of information that should be able to detect, more regularly, significant changes in urban environments.

Vegetation mapping through remote sensing

A satellite image is the registration by a sensor of the values of electromagnetic radiation reflected in the different frequencies of the electromagnetic spectrum. Vegetation has a very specific spectral behaviour. Chlorophyll strongly absorbs radiation in red and blue wavelengths but reflects green wavelengths, which is the reason why they appear «green». When the chlorophyll content is at its maximum, leaves appear the «greenest», and when there is less chlorophyll in the leaves, like in the autumn, there is less absorption and proportionately more reflection of red wavelengths, making the leaves appear red or yellow.

The photosynthetic potential is strongly related to a variety of ecosystem services, ranging from freshwater availability, biomass production to biodiversity (Field, Randerson and Malmstöm, 1995).

A vegetation index assesses the spatial texture of ecological quality and categorizes the image into non-vegetative and vegetative pixels with different values. Satellite-derived vegetation indices are excellent estimates of productivity and can also quantify spatial heterogeneity of vegetation; two important factors shaping biodiversity patterns (Mittelbach, et al., 2001; Tucker and Sellers, 1986).

The Normalized Difference Vegetation Index (NDVI) is an index calculated from reflectance measured in the visible and near infrared channels. It is related to the fraction of photosynthetically active radiation (Eidenshink and Faundeen, 1994).

$$NDVI = \frac{(NIR - NR)}{(NIR + NR)}$$

The NDVI value varies with absorption of red light by plant chlorophyll and the reflection of NIR (*Near InfraRed)* radiation by water-filled leaf cells. The outcome is a visual representation of the ecologically meaningful spatial structure, related to the production of chlorophyll and able to predict and assess vegetative characteristics, such as plant leaf area, total biomass, and chlorophyll content, the percentage of ground covered by vegetation and general plant stress and vigour.

Analyzing the vegetation mapping of the NDVI involves comparing different pixels based on visual elements, like tone (brightness, colour etc.), size, pattern (spatial arrangement), texture, shadow and association (relationship to other recognizable objects or features).

Case Study

The city of Lisbon is used as a case study in this research in order to understand and demonstrate «marginal» vegetation.

Study Area

The city of Lisbon, located near the coast on the North bank of the river Tagus, is the largest city in Portugal in terms of area (84 km^2) and population (547.631 habitants). Lisbon is characterized by its hills and valleys, which bring a dynamic and complex landscape to the city. It is dominated by two fundamental elements, which characterize the functioning of its urban ecosystem: in the west, the Monsanto Forest has a unique geological formation, and in the east and south are the Tagus River and Estuary.

The urban evolution of the city characterizes the urban morphology and the existing green infrastructure. The medieval period, up until the Discoveries (XV century), relates to the city's transformations, the organic distribution inside the city walls. This was followed by the «Maneirista» period (XVI to XVII century), that brought expansion of the urban fabric towards the west. In the XVII century, the city faced a major reconstruction after the great earthquake of 1755, in an orthogonal morphology. It was in the XIX Century, during the romantic period, that Lisbon occupied the central plateau with great avenues, gardens and squares. The planning approach of the «Municipal Master Plans» to design major accessibilities and land use patterns, was created in 1938. Two revisions (1958 and 1967) were approved over the following 25 years.

In 1993, a new revision of the Municipal Master Plan was approved, which introduced for the first time the Ecological Urban Structure Plan. Even though national regulation determines a 10 yearly revision of the Master Plan, it took almost 20 years to review this plan and finally, in 2012, the current Municipal Plan was approved.

This study analyzes the city of Lisbon within its administrative boundaries, taking into accountits regional and metropolitan ecological structure.

Data

Several spectral, altimetric, and planimetric spatial data sets were used for this study, specifically, Very High Resolution Satellite Images (VHR), topographic surveys and PDM – Masterplan maps (Plano Director Municipal) (PDM 1993 and PDM 2012). Strategic field visits and photographic surveys were also carried out.

Different data sets were used for the vegetation analysis; originating from different satellites, namely, Quickbird and Worldview from DigitalGlobe. The data sets used were pansharped to the resolution of the panchromatic band in PCI Geomatica, orthorrectified in order to reduce geometric distortions using the Rational Polynomial Coefficients (RPCs) and attributed to a national projected coordinate system (ETRS89-PT-TM06). The NDVI was derived from the bands of these images, and threshold changes were applied under the supervised classification method providing discrimination of vegetated/non-vegetated pixels.

Year	Day	Satelite	Panchromatic Sensor Resolution	Multispectral Sensor Resolution
2005	13^{th} April	QUICKBIRD	0.6 m	2.4 m
2010	24^{th} June	WORLDVIEW	0.5 m	2 m

Figure 2
Table with data specification of the imagery used for this article.

Methodology

Through the use of VHR, it is possible to analyse the vegetation at a specific moment in time and determine the relation between the total existing vegetation and Planning Instruments.

The produced data sets of NDVI from the available satellite images are overlaid with the vectorial data set of the PDM-Master Plans. Based on the NDVI imagery ofthe existing vegetation of the city, the NDVI imagery, which corresponds to the Ecological Structure of the PDM-Master Plans, is identified resulting in a) the existing vegetation incorporated in the Ecological Structure, and b) the subtraction of both images, consequently being the vegetation that is not included in the planning instruments: the «marginal» vegetation (figure 3). This vegetation represents urban spaces that have developed outside the established planning processes, and survive outside the municipal initiative.

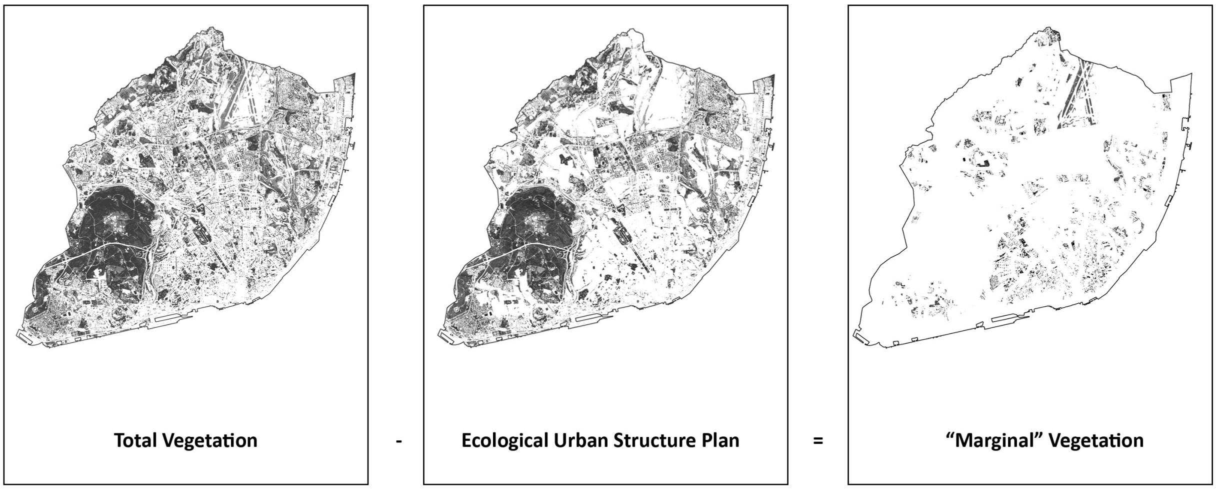


Figure 3
Definition of «marginal» vegetation for the city of Lisbon. The «Total Vegetation» image corresponds to the NDVI imagery of the existing vegetation of the city, the «Ecological Structure Plan» image corresponds to the existing vegetation incorporated in the Ecological Structure, and «Marginal Vegetation» image is the subtraction of the above plans, displaying the vegetation that is not included in the planning instruments.

Results and Discussion

The city of Lisbon presents a significant lack of different types of Green Areas for the wellbeing of its inhabitants, as well as unsatisfactory levels of air quality and noise (CML, 2002). In France, the «Protection et aménagement des espacesverts» (Protection and Development of Green Areas) recommends 35 m^2 of Green Area per capita as the minimum standard, while in England the «National Playing Fields Association» stipulates 52 m^2 per capita. In Portugal, the value was set to 40 m^2 per capita (Magalhães, 1992), which is based on the capacity of vegetation to produce oxygen. In 1994, the PDM-Master Plan reduced the Green

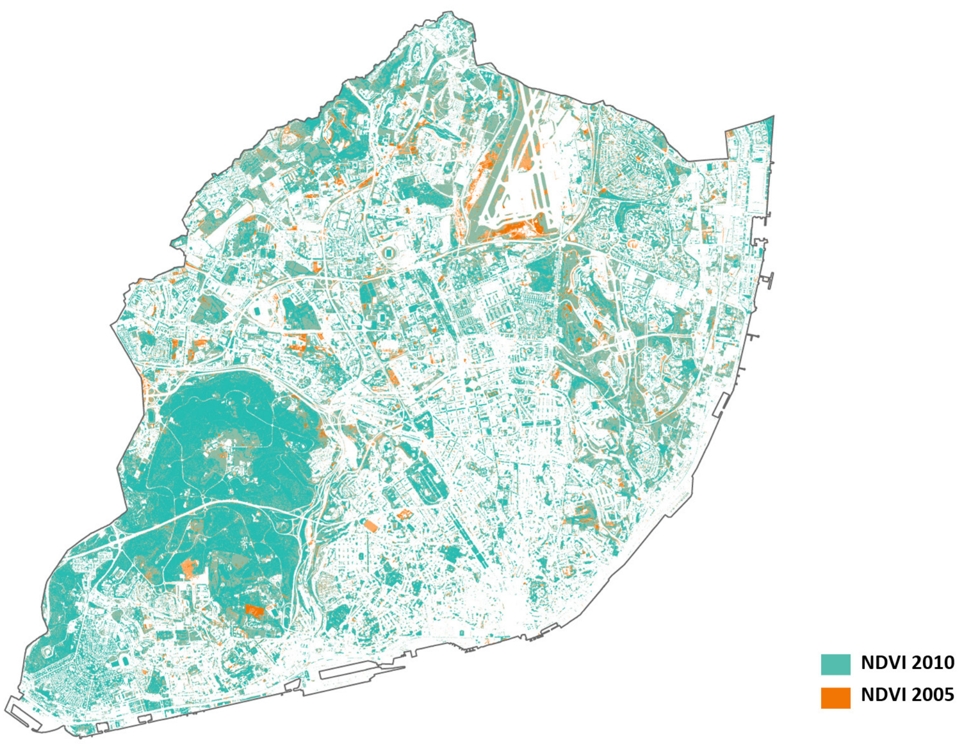
Area per capita to 19.4 m², and finally in 2007, it was raised again to 24 m² (CML, 2012). This increase, however, is also accompanied by the decrease of population in the city.

Study results of the NDVI image of 2005 and the former PDM-Masterplan of 1993, show that: a) of the total of 2. 370 ha of vegetation in the city of Lisbon, 740 ha corresponded to the Monsanto Forest and 860 ha corresponded to other parks and green corridors planned in the city; b) 770 ha of vegetation was left out and was spread throughout the city – «marginal» vegetation – which makes up 33 % of the total vegetation.

The City of Lisbon acknowledges having a lack of Green Spaces in the city, and yet only considers a part of the existing vegetation for its ecological structure. The interpretation and evaluation of the existing conditions, in terms of urban vegetation and its relation with the Ecological Urban Structure defined by the Local Government, can constitute the ecological, social and urban support for the city's development.

Looking at the evolution of these spaces, a lot has changed in the city of Lisbon over the past 5 years. Analysing the NDVI «marginal» vegetation image of 2010 and comparing it with a «marginal» vegetation image of 2005, we can see a reduction of vegetation values. Areas in orange highlight where some vegetation cover has disappeared and has been replaced with built areas. Furthermore, some areas have become more degraded and now present less vital vegetation (figure 4). From an

Figure 4
Overlay of the NDVI map of 2005 and 2010.



urban planning perspective, there are currently a lot of changes. For example the municipality is finally approving the new PDM-Master Plan in conjunction with its new Ecological Urban Structure.

Analysing the NDVI vegetation image of 2010 overlaid with the currently ruling PDM-Master Plan (1993), results in a considerable amount of vegetation that is not contained within the formally defined ecological structure – «marginal» vegetation (figure 5).

The future Ecological Urban Structure Plan is in general a big step forward towards the preservation of natural resources and the construction of green corridors. Analysing the NDVI image of 2010 overlaid with the Ecological Urban Structure of 2012, we can see that the «marginal» vegetation has become less (figure 6). This Plan goes beyond the protection of parks and gardens, but also introduces the protection of some inner-courtyards and empty plots. Further, it introduces new concepts such as the humid and the dry system (Magalhães, et al., 2007), which differentiate the functioning and the distribution of natural resources of the city. The humid system represents the areas of the watersheds: watercourses, floodplains, stilling basins, areas subjected to flooding and the transition system between these elements as well as the river flow and tide (CML, 2012). The dry system is defined by the areas of maximum infiltration, areas with erosion risks, soils with high ecological value and the protection of the ridge related to the watercourses (Magalhães, et al., 2007). This concept is carried out in the PDM Masterplan 2012 through the structure corridor system (CML, 2012), which integrates public and

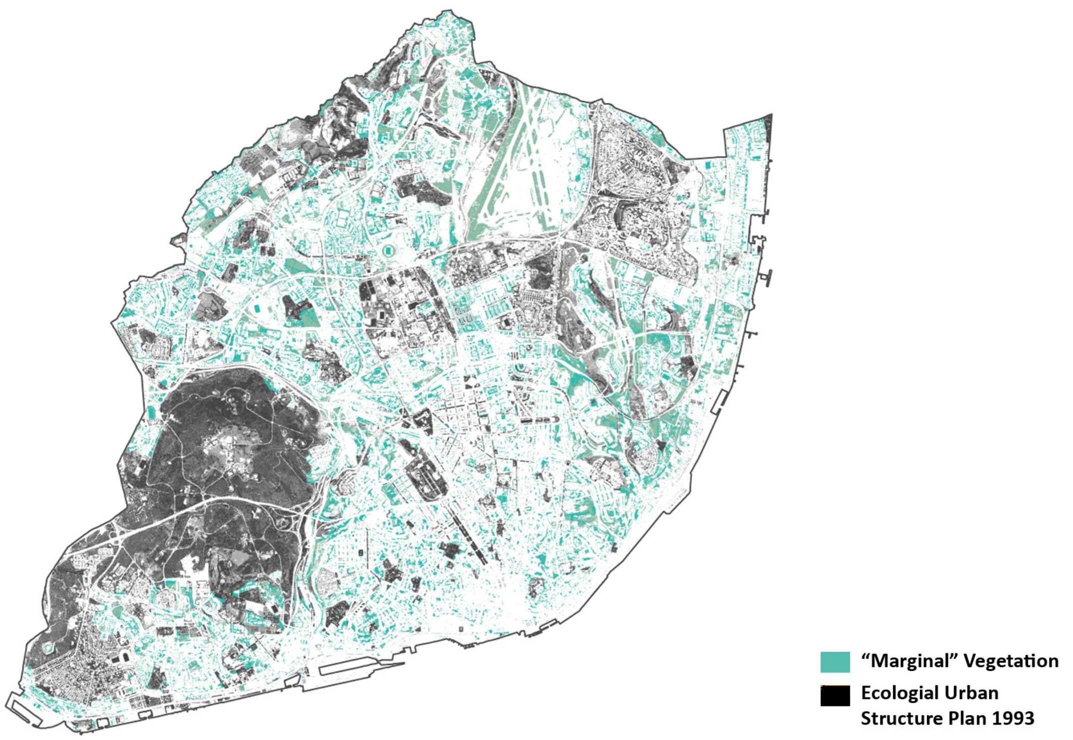


Figure 5
NDVI map of the Ecological Urban Structure of 1993 and the «marginal» vegetation.

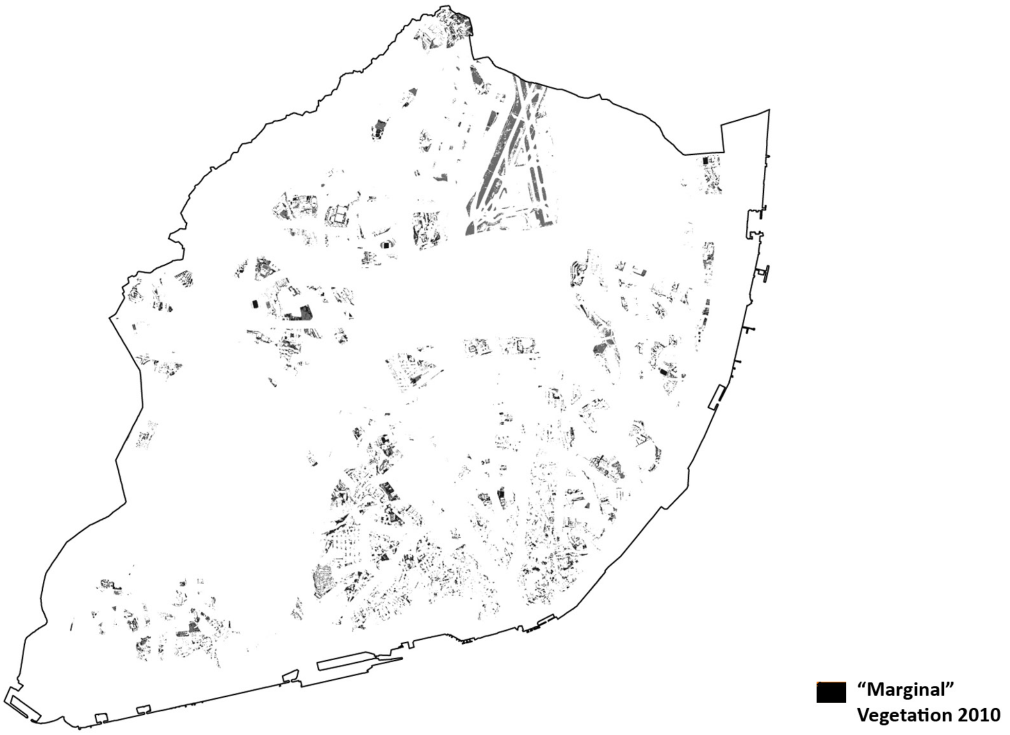


Figure 6
«Marginal» vegetation as a result of the 2010 NDVI map compared to the Ecological Urban Structure Plan of 2012.

private areas that establish connections or define reserves that promote an ecological structure. Most of the «marginal» vegetation of the PDM-Master Plan of 1993 included in this plan is integrated into the typologies of the structure corridors system and the humid system.

The image identifies vegetation that will survive outside this plan and shows a strong representation at the neighbourhood scale (figure 7). These spaces are mainly inner courtyards, gardens associated with public and private facilities and vacant plots.

Figure 7
«Marginal» vegetation as a result of the Ecological Urban Structure Plan of 2012 with the NDVI plan of 2005 and 2010.

Conclusions

Considering the environmental conditions that today's cities are facing, and the urban pressure on its ecological structure, green structures have been recognized as an important contribution to improve these urban conditions. However, the green structures implemented by the municipalities are mostly insufficient in responding to the challenges cities are dealing with, and more consideration is given to the existing resources of the city and bottom-up initiatives.

On the other hand, a network of vegetation within the cities has been identified, which shows an important expression and is distributed and dispersed with a more or less homogeneous form throughout the city and is found marginal to the planning instruments of the municipality – «marginal» urban vegetation.

These Green Areas are mostly not protected and ignored by Local Governments, suffering the changes and pressures from increasing urbanization. Since they are inserted into the urban tissue and have a greater contact and relationship with their surroundings, they have a great potential to reinforce the urban green structures.

Nevertheless, there is little or no information about this vegetation; not only in terms of location, quantity, content, structure or function, but also about its role and contribution to the ecological balance of the city.

This study identifies and quantifies the «marginal» urban vegetation of the city of Lisbon and concludes that there is a strong representation on the neighborhood scale, reaching 33 % of total vegetation in 2005. It also shows that the evolution of this vegetation overthe past 7 years has been a negative progression, resulting in many vegetation areas being replaced with built areas.

The knowledge provided by this study contributes to preserving and enhancing the existing vegetation, which is partly responsible for the quality of the city. Attention is drawn to the multifunctional capacity of spontaneous acts and processes, and to the fact that traditional planning instruments are unable to respond to the needs and dynamics of the city and its agents. It also opens a new way of looking at urban ecosystems and urban planning that is not only based on the ecological structure and planning instruments, but also considers the existence of a dynamic network of vegetation that establishes independently to these processes.

By acknowledging the existing «marginal vegetation» in the city of Lisbon and its dynamics and characteristics proposed in this study, alternative ways can be explored to articulate the existing urban vegetation with the ecological structure of the city. The potential of the existing resources of the city is questioned as a structure capable to generate better environmental conditions. This aim contributes to a framework that, by conjoining urban ecology, urban planning and remote sensing, can provide knowledge, methods, and clues as to what the urban city can become in future years.

More studies should follow, which evaluate the «marginal» vegetation of Lisbon with ecological principles, in order to understand its contribution to the ecological matrix of the city, and explore ways to enhance these existing spaces and promote the appearance of new ones.

The generalisation of the approach presented in this study, or its application in other case-studies, would be beneficial from multiple perspectives. It can serve as an instrument for policy makers to assess the impact of the «marginal vegetation» in their cities and create new policy making strategies. With the dynamic forces in today's urbanisation processes, the approach can also be used to study the unwanted consequences of interventions and existing monitoring instruments. Although the results of a general application of this approach to other cities are dependent on the methodology used in urban planning, different information at various levels can be extracted and used with the same methodology. This study shows that this approach provides a rapid and accurate ecological database to further inform the planning of ecological urban structures.

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