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PLANT BIODIVERSITY AND CITY: APPROACHES FROM URBAN ECOLOGY

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I. INTRODUCTION

Globally, the process of urban expansion has accelerated in the last 60 years as more than 50 percent of the world population lives now in cities. In this context, urban ecology is presented as the science of studying urban ecosystems which improves on traditional ecology by incorporating human variables as the first agent of evolution and change (Alberti et al., 2003).

A field of particular interest to urban ecology is the study of green areas of the city and its relationship with the immediate socioeconomic environment. These environments play a fundamental role and serve different functions. They can provide intangible benefits such as social well-being, or even food and environmental services such as air exchange, noise reduction and overall urban temperature regulation (Costanza et al., 1997). A particular type of these green areas is private domestic gardens, which may occupy about one third of total urban surface areas in scattered residential zones (Gaston et al., 2005; Mathieu et al., 2007). An interdisciplinary approach is needed to understand the mechanisms shaping these ecosystems, not only affected by natural factors but a combination of different urban, historical, cultural and socioeconomic variables.

The objectives of this study are (1) to establish a framework for the application of the methods of urban ecology in the study of urban flora, (2) to analyze those patterns determining plant composition in urban green areas and describe their ecological and social importance, and (3) to claim the role of private gardens as an ecosystem to be explored by urban ecology.

II. METHODS

The first part of the study is based on the collection of relevant publications about urban ecology and plant biodiversity in these environments. This consisted mainly of a search of titles, abstracts and keywords in different databases. In the second part, an integrated analysis was used to systematize all the gathered information and divide it into four sections. The first one contains an analysis of the literature relating the principles of urban ecology to urban vegetation. The second part deals with urban plant biodiversity and its importance to overall ecological level. Then, the third section analyzes the case of domestic gardens within urban green areas. Finally, in the concluding section, all ideas from previous sections are integrated to elaborate a simple framework that allows the study of urban flora from the urban ecology perspective.

III. URBAN ECOLOGY: PRINCIPLES AND METHODS FOR THE STUDY OF URBAN VEGETATION

For many years, ecology has focused in the dynamics and processes of the natural environment without taking into account the realities of the urban environment (McDonnell and Pickett, 1990). Since the early twentieth century, the idea of including the human factor as an active element of urban ecosystems has increased in importance (Adams, 1935). Recently, and thanks to new technologies such as remote sensing, the processing of large-scale environmental data has accelerated this process (Mathieu et al., 2007). The framework for urban ecology should facilitate the integration of social and ecological components to describe urban areas as a result of the cultural and biophysical background.

One of the most useful techniques for urban ecology comes from traditional landscape ecology and is based on classification of the urban matrix. Using this procedure cities are broken into a mosaic of urban patches, vegetated patches and other land uses (Cadenasso et al., 2007). With this information, different landscape indices can be obtained to quantify territorial dynamics.

The use of patterns in urban ecology is also a widely used tool to quantify the relationship between ecological processes and the structure of cities. A type of pattern used in a large number of scientific papers is the gradient. According McDonnell and Pickett (1990) a gradient occurs when there is a change which varies in a regular and orderly manner in time or in space. The use of gradients in urban areas can help to better understand the interactions between urban development and the structure of ecological and social systems. One of the most successful is the urban-to-rural gradient. This gradient explains variations in plant and animal communities by organizing space according to urban density (McDonnell et al., 1997). Another particular case of gradients are those based on socioeconomic data. The inclusion of quantifiable social elements such as income level in the gradients can improve the results to predict urban biodiversity patterns.

IV. PLANT BIODIVERSITY IN URBAN AREAS

The diversity of flora and fauna in urban ecosystems play an essential role in the generation of benefits and environmental services. These uses are defined as «the benefits human populations derive, directly or indirectly, from ecosystem functions» (Costanza et al., 1997:1). One

example is the potential of plants for regulating temperature in urban areas. Large metropolitan areas tend to reach higher temperatures than rural areas adjacent to them. The carbon balance is also a significant element in the set of ecosystem services. Woody plants have a wider capacity to fix carbon than annual plants due to the storage capacity of its biomass (Jo and McPherson, 2002). For example, domestic gardens can store an average of $2.5x10^3$ g/m^2 of carbon, with 83% of that in the soil, 16% in trees and shrubs and only 0.6 % in herbaceous plant species (Jo and McPherson, 2002). Moreover, some plants, especially trees and shrubs, can liberate biogenic volatile organic compounds (BVOCs), which have a high potential to produce ozone when they react with nitrogen oxides resulting from human activities (Benjamin and Winer, 1997).

Water availability might become a limiting factor in sustaining biota in urban environments. Ornamental gardens are often associated with high water consumption, especially during dry seasons. However, urban ecosystems also play a significant role in the regulation of surface water runoff and flooding episodes. In addition, vegetation intercepts intense precipitation, reducing peak flow and easing demand on urban drains (Xiao and McPherson, 2002).

Moreover, according to Chiesura (2004), urban green areas are also used for relaxation, to relieve stress, to experience positive feelings and to have some contact with nature. These experiences have physical, psychological and social consequences as shown by several independent studies (e.g. Ulrich, 1981).

Finally, urban and periurban vegetation represent a great opportunity to increase subsistence agriculture. About one-seventh of all world food is produced through urban agriculture, including that occurring in private gardens (Olivier, 1999). This is particularly important in populous communities in developing countries (Shackleton et al., 2008).

V. DOMESTIC GARDENS AS A SIGNIFICANT PART OF URBAN GREENING

Domestic gardens are mostly managed by private owners, meaning that these ecosystems have been often excluded from the overall balance of green areas of the cities (Gaston et al., 2005). In England, it is estimated that private gardens account for almost a quarter of the total area of the five most populated cities (Gaston et al., 2005). In the city of Dunedin (New Zealand), the percentage increases to 36% (Mathieu et al., 2007), and in Baltimore (Michigan) up to 90% of the canopy grows in private gardens (Troy et al., 2007). Therefore, although individual gardens are just a small part of the territory, when considered as a whole they represent a significant part of the total urban estate.

Most studies in private domestic gardens have been carried out in developed countries and sometimes taking just a single garden as the main study unit to analyze its characteristics over an extended period of time (Owen, 1991). However, short-term studies of several home gardens are gaining importance in various research groups. It is important to highlight the BUGS project (Biodiversity in Urban Gardens in Sheffield), which includes samplings of the flora and fauna for more than 300 gardens in different cities of England (Gaston et al., 2005). Similar studies have been performed on other continents (e.g. Acar et al., 2007; Marco et al., 2008; Lubbe, 2011). In developing countries research has focused in the role of home gardens for food production and economic sustenance (Fernandes and Nair, 1986).

A specific topic of garden plant studies, and closely linked to biodiversity conservation, is the role of ornamental horticulture as the main vector for the introduction of invasive

alien species (Sanz-Elorza et al., 2004). In Spain, Sanz-Elorza et al., (2004) estimate that about 12% of the country's flora consists of exotic plants, 48% of which has been introduced through horticulture and gardening. Inappropriate management of uncontrolled garden wastes may increase invasive plant dispersion.

Furthermore, the protection of garden flora is important because it provides habitat and food for many different species (Kendle and Forbes, 1997). Public opinion is often skeptical of the value of conserving garden flora, and several NGOs in Britain and the United States try to highlight their ecological importance and promote wildlife-friendly management strategies (Goddard et al., 2009). Taking into account these approaches, conservation in urban areas should focus on improving the quality of life for inhabitants rather than promoting traditional conservation.

VI. CONCLUSIONS

Urban ecology has been described as an emerging science that includes the anthropic factor as the main agent of change of urban ecosystems. Its interdisciplinary approach allows the use of methods and principles from other disciplines such as landscape ecology, biology, geography, economics and urban planning. In particular for the analysis of urban flora we propose a preliminary framework which includes many of the concepts reviewed in this study (Figure 1).

In the first stage, and as a preliminary step, it is essential to identify the type of green area (or areas) to be studied according to the objectives of the research. This gives way to the second stage in which the researcher analyzes the disciplines and methodologies that fit best the purposes of their study. This initial approach should be interdisciplinary to capture relevant information from different areas not strictly related to urban flora.

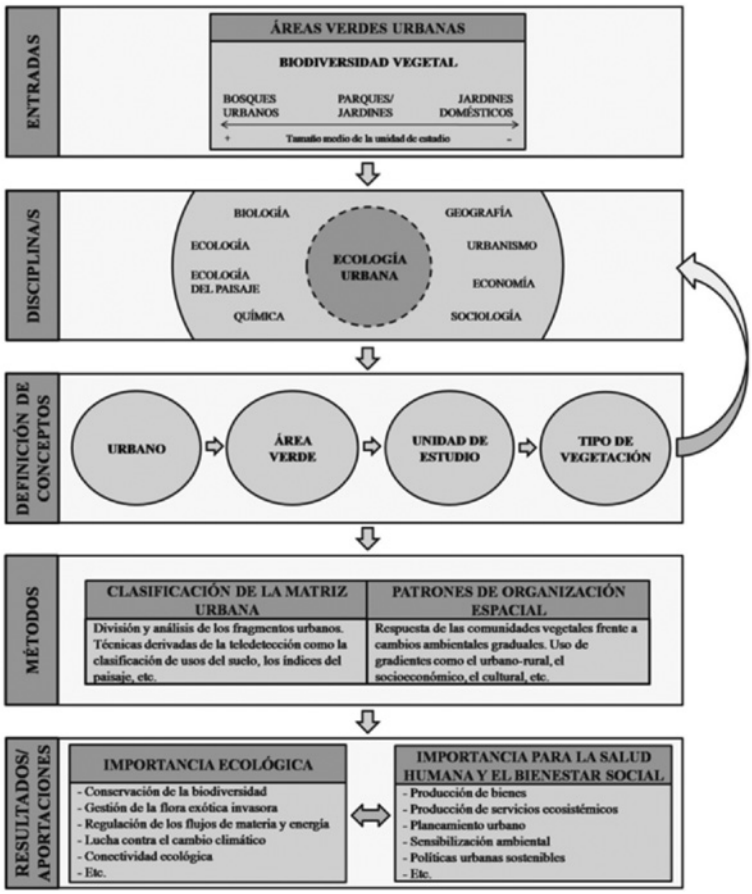
In the third stage, it is imperative to give a concrete description of the terms and concepts used in the study (e.g. urban, natural, green area, domestic garden). Moreover, the description of the type of vegetation to be analyzed is also required (cultivated, spontaneous, trees, weeds, etc.). At this point, it is recommended to revisit the previous stage, check the literature reviewed and expand the review of literature if necessary.

Stage four involves the use of various methods according to the selected scale of work. The classification of the urban matrix, on one hand, allows the breakdown of the urban mosaic in patches that can be analyzed through many landscape indices. On the other hand, the use of patterns and gradients analyzes in great detail the response of plant communities in front of environmental and socioeconomic gradual changes. Both approaches might complement each other in order to enrich the quality of the results.

Finally, in the last stage, the results and contributions of the entire process are classified according to their ecological and social relevance.

Studies on urban plant biodiversity from the point of view of urban ecology have addressed several issues in the recent years. A number of authors stress the use of gradients as a methodology to analyze the distribution and dynamics of urban flora. Private domestic gardens present an excellent opportunity to implement this approach. The interactions between plant dynamics and human preferences are stronger in these environments than in any other urban green area.

Figure 1
PROPOSED FRAMEWORK TO STUDY URBAN FLORAS THROUGH URBAN ECOLOGY



Source: Authors' own research.

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