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The value of vegetation cover for ecosystem services in the suburban context

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ABSTRACT

Latin-American cities can be characterized by dynamic processes of urbanization that encroach upon the natural and semi-natural surrounding landscapes. Our study presents the effects of landscape development, transformed from semi-natural conditions into a mostly disperse suburban settlement. We explore the impact that this transformation has had on this context by three ecosystem services that regulate rainwater runoff, enhance microclimate conditions and help to improve air quality by monitoring vegetation cover. We have designed a spatio-temporal hierarchical analysis which employs remote sensing techniques to capture the structural changes of this landscape over long, medium and short term scales on two spatial levels. This methodological approach was tested in the Metropolitan Area of Santiago (MAS) as case study area. Despite of the increase in impervious surfaces due to urban processes, there has also been an increase in vegetation cover, which has led to an improvement in the provision of the above-mentioned ecosystem services. Hence, if diverse urbanization processes continue and they are coupled with an increase in vegetation cover, the provision of ecosystem services could also expand. This phenomenon can be observed in some areas, where public and private green spaces are created and maintained. Our data analyses give evidence that certain types of suburban areas which increase the share of vegetation cover can provide daily ecological benefits for urban neighborhoods, and beyond, for adjacent areas. Moreover, suburban development can successfully provide ecological benefits to citizens. Such processes can only be ecologically sustainable if the composition of vegetation is well-adapted to the regional climatic conditions.

1. Introduction

1.1. The impact of urbanization on ecosystems

Urbanized areas are human-dominated landscapes. Urbanization has a myriad of implications for the environment. During the 19th and early 20th century these implications were considered negative. More recently, the multifariousness of human effects has created various types of urban environments. This cultural and biological diversity adds to resilience against severe disturbances to boosts urban sustainability (Berkes et al., 2003; Andersson, 2006). Urban expansion influences a landscape's structure and function, covering soils, destroying natural vegetation and disrupting hydrological systems (Alberti and Marzluff, 2004; Farina, 2007:244). However, Pickett et al. (2008) also see cities as spaces with high biodiversity. As a consequence, we comprehend cities as a mixture of dense urban built structures and biodiversity, as places with various land cover types. The major problem is that due to urban development rapid land cover changes have a negative impact on the close-by semi-natural region. These changes occur in the urban and contiguous rural landscape for which the delimitation becomes more and more fuzzy. This boundary use is dominated by a suburban landscape, as part of the urban–rural gradient, and has strong and complex social and biophysical feedbacks (McDonnell et al., 1997; Pickett et al., 2008). The maintenance of the (sub)urban vegetation, for instance, will be unsustainable if the composition of that vegetation is not well-adapted to the regional climatic conditions. As a consequence, the selection of species to be planted in this area is a critical matter and the preference should point to

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native species adapted to the regional climate (Roloff et al., 2009; Asgarzadeh et al., 2014). The integrated study of ecological and social systems and phenomena in cities is of particular interest in suburban areas where highest urban dynamics are found. Here, we test the general hypothesis that more urbanization means less biodiversity and, especially, a loss in ecosystem services. Our specific hypothesis for metropolitan areas is that newly developed suburbs can foster ecosystem services if the neighborhoods are designed in a disperse structure.

Mosaics of residential, commercial and industrial sites are interlinked by road networks and railway systems, and vegetation cover, e.g. parks, green spaces, gardens, street trees. However, these spatial patterns vary across space and time, and there are research gaps in the knowledge on their effects on processes and functions of ecosystems. Particularly, with respect to expanding cities, such knowledge could help in gaining an understanding of the link between the provision of ecosystem services and socio-spatial differentiation (Breuste et al., 2008).

To deal with those gaps, it is important to gain an understanding of how human social systems can become part of the ecological system, or even enhance the ecological system toward a sustainable urban growth. As a consequence, a central question addressed in this paper is how socio-ecological interaction in suburban landscapes can be beneficial for the human and the ecological systems? Specifically, we ask if and how the diversity of suburban residential settings (e.g. disperse complex of houses with large gardens, high buildings or compact clusters of houses) have impact on the provision of ecosystem services, and consequently on urban quality of life? Ecosystem services are generally understood as the biophysical structures and processes through which natural ecosystems can contribute to human wellbeing (Müller et al., 2010). In addition, we believe that humans need to care for ecosystems to be able and profit from their services. Our goal is to investigate the effect of suburbanization on the provisioning of ecosystem services by analyzing and modeling from historical to up-to-date changes in land cover as types of ecosystems and their ability to provide ecosystem services in the suburban area.

1.2. Vegetation cover as a contributor to ecosystem service provision

The multi-dimension of urban areas is a comprehensive composition of natural, built, and social components. Urbanization processes are related to urban growth patterns of population increase and land-use changes as the major driving forces. Land-use changes include how the land previously covered by vegetation has been changing in its spatial coverage as well as types, density and functions. The structural pattern of vegetation cover is diverse. It comprises of root penetration, ramification, foliation, and adheres to different types of grass, flowers, shrubland, and trees. Vegetation cover is especially important for urban ecosystem services in terms of heat island mitigation, water infiltration, reduction of PM10 and NOx, etc. (Tyrväinen et al., 2005). At the local and regional level, urban landscape structures of the built and natural environment are investigated in order to identify the impact of land cover change, on socio-ecological activities and the types of ecosystem services generated as a result. Social components add to the urban diversity, spatially illustrated by various built and green structures. All these urban components influence the urban ecosystems.

Generally speaking, ecosystem services depend on ecological processes which are quantifiable by their structures, (i.e. the amount or cover of landscape elements that provide such ecosystem services), and by functions, (i.e. magnitude or rate of processes). There are different approaches which can be employed to quantify the provision of ecosystem services (see Seppelt et al., 2011). This paper uses the method of measuring the landscape structure to derive the potential provision of the ecosystem services (e.g. Burkhard et al., 2012) for an urban area. Therefore, our study contributes to research on urban vegetation cover, and its impact on urban ecosystem services at the suburban fringe. Previous research in this subject has evaluated the contribution of ecosystem features (e.g. vegetation cover and building density) and their role in the provision of ecosystem services in metropolitan areas (Moreno, 1994; Arnold and Gibbons, 1996; Moreno, 1999; Nowak and Crane, 2000; Pauleit and Duhme, 2000; Whitford et al., 2001; Romero and Vásquez, 2005; Tyrväinen et al., 2005; Peña, 2008; Sarricolea et al., 2008). In this paper we focus on three urban ecosystem services associated with changes in vegetation cover over space and time to understand how to improve environmental quality in the suburban landscape. Improvements to environmental quality include the prevention of landslides and floods during extreme rainfalls, improvement of air pollution caused by exhaust fumes (especially during inversions), and mitigation of high air temperatures in summer.

The metropolitan areas of Latin America are characterized by very rapid development. Urbanization processes started around 200 years ago (De Ramón, 1992). However, their major expansion occurred in the second half of 19th century (Ducci, 2002). At present, the major metropolitan areas expand very rapidly into the non-urbanized environment, thus changing agricultural or natural landscapes into urbanized areas. Such urbanization processes do not occur uniformly across space and time or result in the same configuration of densities, but rather result in very heterogeneous and unpredictable patterns which influence the changes of landscape character and structure in different ways. According to Borsdorf et al. (2007) this type of urban development can be defined as a Latin American development model which is made up of dense central settlements and disperse gated communities with individual family homes in suburban areas. The Metropolitan Area of Santiago de Chile (MAS) is an example of such a city. Its spatial expansion and rapid urbanization processes have experienced environmental implications such as reductions in regional natural ecosystems (De Ramón, 1992:116; Pavez et al., 2010; Schulz et al., 2010). Generally speaking, the highly dynamic urban growth has influenced the MAS in a variety of ways. For example urban in-migration has led to an increase in population figures, and to an accelerated urban development, oriented toward suburban areas and, additionally, toward urban sprawl in form of a spatially discontinuous, so-called "leap frog" style of development (Vidal, 2002). This paper argues that this style of development leads to environmental problems that could be reduced by the appropriate provision with ecosystem services. As a result of urbanization processes which have been occurring since the 19th century, anthropogenic activities have replaced natural sclerophyllus and xerofitic vegetation with a spiny savannah, which has resulted in low ecosystem service provision (Fuentes et al., 1984, 1989; Holmgren, 2002). The suburban landscape has become a dominant feature of the region, particularly over the last 70 years (Vidal, 2002; Heinrichs et al., 2009). The aim of this research is to develop a methodological approach to quantify structural landscape changes and to estimate the consequences of those changes on the provision, regulation and support of ecosystem services in a newly developed neighborhood. Urban development can increase the provision of ecosystem services through increasing vegetation cover. Although vast urban expansion in the past has led to a rise in sealed surfaces and the loss of natural vegetation cover in central areas and outskirts (Romero and Vásquez, 2005), this study on land-use developments and their impact on urban ecosystems will show a more differentiated picture on the structure of urban processes and potentials to increase vegetation cover. Such ecological provisioning should not only cover the areas in which the ecosystem services are produced, but it will be investigated how the local provisioning would even could benefit other settlements.