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Mapping private gardens in urban areas using object-oriented techniques and very high-resolution satellite imagery

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Abstract

Gardens remain the least studied and least understood habitat in urban areas. With the recent exception of the URGENT funded urban domestic gardens project in the UK, there is a notable lack of research on the ecological character and contribution of gardens to the wider urban biodiversity. This is despite the fact that gardens usually comprise the largest vegetated component of the urban greenspace resource. In part this omission has been due to the difficulties inherent in obtaining ecological data on gardens and the lack of a methodology for classifying and analysing garden data. This paper presents data from a study undertaken in the city of Dunedin, New Zealand. The study developed a methodology using object-oriented classification techniques and very high-resolution multispectral Ikonos imagery to automatically map the extent, distribution and density of private gardens in the city. The focus was on the vegetated garden area which was calculated as comprising 46% of the residential area or 36% of the total urban area. Rigorous accuracy assessments were undertaken. When using the automated classification technique, a total of 90.7% of the private gardens were correctly identified. Discrimination of garden types (e.g. trees or grass dominated) was encouraging, but still requires improvement. Our results indicate the great potential that the methodology has in providing a quick method for obtaining good quality ecological data on garden habitats in urban areas.

Keywords: Vegetation mapping; Urban areas; Object-oriented classification; Ikonos; New Zealand

1. Introduction

It is only recently that ecologists have begun to direct attention at the urban environment challenging the long predominant view that urban areas were both devoid of wildlife and not worthy of serious ecological study. There is now a growing body of published research that addresses issues of urban biodiversity (Breuste, 2004; Moore and Palmer, 2005; Parsons et al., 2006; Pickett et al., 2001; Snep et al., 2006). Whilst this research demonstrates both the wealth of habitats and wildlife in urban areas and its value as a field of scientific endeavour, urban ecology and its relation, urban biogeography remain undervalued in the wider field of ecological study which continues to focus on the rare, the fragile and the pristine. Not only is the field of urban ecology as a whole undervalued but within urban ecology itself there are gradations of 'value'. The mapping of urban vegetation communities has generally been confined to mapping areas of known or potential conservation value; habitats typically found in parks, nature reserves, riversides, woodlands, meadows, scrub and shrubland (Acosta et al., 2005; Freeman and Buck, 2003; Pauleit and Duhme, 2000; Song et al., 2005). The predominant focus has been on areas that are usually in public ownership and that are of a size substantial enough to map fairly easily. As a consequence the one 'habitat' type that lies primarily in private ownership, has diverse and highly variable habitats usually on small land areas and that has remained largely unacknowledged in urban ecology is that of the private garden. Although the size and nature of the resource is poorly known, private gardens constitute a substantial part of the vegetated space within a city. In a unique study Gaston et al. (2005b) estimated that gardens cover approximately 33 km^2 or almost one quarter of the predomi-

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nantly urban area of Sheffield, UK. Recent research has begun to stress the role of private gardens in supporting biodiversity in cities (Cannon et al., 2005; Gaston et al., 2005a; Rudd et al., 2002; Thompson et al., 2005).

Large scale aerial photographs have been traditionally used to extract vegetation units through visual interpretation and manual digitizing (Freeman and Buck, 2003, Pauleit et al., 2005). This technique, although efficient for detailed mapping, is time consuming and may be largely impractical in extracting data on private gardens in medium or large size cities. Until recently, the spatial resolution of satellite sensors has been too coarse (e.g. 30 or 20 m for Landsat TM or SPOT) to be appropriate for application, given the small size of the average garden. The last generation of high-resolution Earth Observation satellites, e.g. Ikonos or Quickbird, provides images with a level of detail compatible with urban mapping (Jensen and Cowen, 1999), i.e. from 4 to 2.5 m spatial resolution and can thus provide data at a level appropriate to garden analysis. In addition multispectral sensors have the advantage, over colour aerial photographs, of recording near infrared light which is the most sensitive spectral domain used to map vegetation canopy properties (Guyot, 1990). However, problems have been experienced when using traditional pixel-based classification techniques to extract land cover data from very high-resolution data. Urban environments consist of a mosaic of small-scale features made up of different materials (De Jong et al., 2000; Hofmann, 2001), and thus most targets, including vegetation components, are on average larger than the pixel size. A high degree of spectral heterogeneity is not easily handled by per-pixel classification techniques which classify individual pixels by using only the spectral content of the images. As many urban land use types, such as roads, buildings, parking lots, or amenity pasture, are spectrally similar, spatial information such as texture and context needs to be taken into account to increase the classification accuracy (Shackelford and Davis, 2003). Object-oriented techniques recognise that important meaningful information is not represented in single pixels but in image objects and their mutual relations, that is with reference to their context (Benz et al., 2004; Blaschke and Strobl, 2001). These techniques have demonstrated great potential to improve the automatic extraction of information from very high-resolution imagery (Benz et al., 2004; Giada et al., 2003; Laliberte et al., 2004).

In the first part of this paper the existing and potential roles of gardens in the wider urban ecology are explored. The discussion then moves towards an examination of some of the reasons why gardens, despite being the largest area of green space in most urban environments, have been overlooked by urban ecologists. The second part of the paper discusses and presents the findings of a research project undertaken in the city of Dunedin, New Zealand. An original methodology based on object-oriented classification techniques and very high-resolution multispectral imagery was developed to map the extent, distribution and density of private gardens in urban areas. The potential of discriminating private gardens on the basis of their vegetation structure (i.e. trees, shrubs, and grasses) was also investigated. As part of this research this mapping technology was used to identify the significance of gardens to the wider urban ecology.

2. The contribution of gardens to urban ecology

The contribution of urban areas to biodiversity maintenance and conservation is being increasingly recognised. This recognition has been due in large part to growing interest in urban wildlife amongst the general population (Baines, 1986). There has been also emerging recognition amongst natural scientists of the value and role of urban biodiversity and its legitimacy as a focus of scientific study (Baines, 1986; Bradshaw, 1999; Gilbert, 1989; Hough, 1984, 2004; Laurie, 1979; Matthews, 2001; McHarg, 1969; Scott, 2004). Private gardens represent the largest single proportion of greenspace in many urban areas (Gaston et al., 2005b). They contribute to the biological integrity of the city by providing sources of food and shelter for wildlife, seed sources for regeneration, physical linkages between green spaces and green refuges in the midst of what can often be harsh artificial environments. To date the most significant and possibly the only noteworthy scientific study of gardens has been the ‘Urban domestic gardens research project’ funded under the URGENT programme of the Natural Environment Research Council in the UK. This study based on a sample of 61 gardens found that garden flora contained 146 plant families and 1166 species of which 30% were natives, with gardens on average containing 45% native plants (Smith et al., 2006). In Sheffield, UK, where most of this garden research has been undertaken, 23% of the built up area is private domestic garden (84% of the housing land is suburban in style) and included an estimated total of 175,000 private domestic gardens (Sheffield City Council, 2005). An earlier study in 1992, estimated that private gardens constituted approximately 20% of Greater London, equivalent to 31,000 hectares, a figure that includes many very small ‘pocket’ sized yards (London Biodiversity Partnership, 2006). Whilst many gardens may in themselves appear to be too small to be biologically significant, as a composite the total area is too large to be ignored. The key area of debate for many ecologists is around the biodiversity value of gardens (Gaston et al., 2005a; Thompson et al., 2003; Thompson et al., 2004). Prior to the Sheffield study indications of the richness of garden biodiversity came largely from individual reports usually from outside the scientific community. One of the best known is the record from Jenny Owen’s 740 m^2 garden in Leicester England which recorded a mean of 240spp of flora (in Thompson et al., 2003).

Apart from the debate around the value of gardens as a focus of scientific study there are a number of more pragmatic reasons that may explain why garden studies are so rare. Gardens represent micro-biotopes, each privately owned, with access for any study having to be repeatedly negotiated for each individual garden unit. Gardens are also immensely dynamic and subject to change on what can be an ongoing basis. Thus, the biological status of gardens will invariably be less stable than that of other habitats. Gardens are also unregulated habitats; there are no planning or other regulatory restrictions on the activities that can take place in gardens, with rare exceptions such as when a tree has a protection order on it. Neither are there any imposed or recommended management criteria to which owners have to adhere. As a consequence there are a wide range of active and