Applied Geography 82 (2017) 1–10

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Redevelopment and the urban forest: A study of tree removal and retention during demolition activities

Justin Morgenroth [a, *], Jarlath O'Neil-Dunne [b], Luis A. Apiolaza [a]

[a] New Zealand School of Forestry, University of Canterbury, Christchurch, New Zealand
[b] Spatial Analysis Laboratory, University of Vermont, United States

ARTICLE INFO

Article history:
Received 9 January 2016
Received in revised form
20 February 2017
Accepted 21 February 2017

Keywords:
Green infrastructure
Greenspace
Landscape ecology
Object-based image analysis
Sustainable urban development
Urban consolidation
Urban planning
Urbanization
Teardowns

ABSTRACT

Though relationships between urbanization and tree cover are generally well studied, the effect of redevelopment on urban trees, at the scale of the individual property, is not well understood. Developing knowledge in this area is important in order to limit tree loss during redevelopment and thus, ensure sustained ecosystem services. Here, we explore the removal or retention of trees adjacent to building demolition in Christchurch, New Zealand. We mapped the presence or absence of individual trees on 123 properties prior to, and following, building demolition. Using a classification tree (CT) analysis, the presence or absence of 1209 trees was modelled as a function of: tree-related variables, property-related variables, and economic variables. The CT model estimated tree presence/absence with overall accuracy of 80.4%. Results show that 21.6% of all trees were removed as a consequence of building demolition, resulting in a tree canopy cover reduction of 19.7% across all 123 properties. The CT showed that tree crown area was the most important variable for predicting the presence/absence of trees, whereby trees with small crown areas (<7.9 m^2) were most frequently removed, especially if they were within 0.7 m of a demolished building. Land value was also an important determinant of tree presence/absence, such that tree removal was more prevalent on properties with higher land value ($/$m^2$). The results provide important new insights into some of the reasons for tree removal or retention during redevelopment at the scale of the individual property where most tree-related decisions are made.

1. Introduction

More people currently live in cities than ever before, with more than half the world's population (54% in 2014) living in cities (UN DESA, 2014). To satisfy rural to urban migration, city morphologies respond through urbanization (conversion from undeveloped to developed land cover), redevelopment (replacement of structures on site, amalgamation or subdivision of existing property boundaries), and densification (also known as intensification or compaction; (Williams, 2000)). Together urbanization, redevelopment, and densification put pressure on the growth and survival of trees in urban ecosystems (McKinney, 2002).

Tree cover response to urbanization has previously been studied via conceptually simple urban-rural gradient models (Berland, 2012), but these fail to consider development density, which is rarely linear from the urban core outwards (Tratalos, Fuller, Warren, Davies, & Gaston, 2007). Nonetheless, development of land at the urban-rural interface is generally believed to cause initial tree cover decline (Sharpe, Stearns, Leitner, & Dorney, 1986), then rapid increase following development (Berland, 2012). But the impact of property redevelopment on trees within the urban boundary remains understudied.

Redevelopment and densification's impact on urban greenspace was recently reviewed (Haaland & Konijnendijk van den Bosch, 2015) and the specific impact on urban trees has previously been reported at the scale of the city block, neighbourhood, city and metropolitan area. Koeser, Hauer, Norris, and Krouse (2013) found that city block redevelopment activities nearly doubled the probability that street trees would die in Milwaukee, while densification reduced tree canopy cover in neighbourhoods in Toronto (Steenberg, Millward, Duinker, Nowak, & Robinson, 2015), the city of Sheffield (Davies et al., 2008) and Minnesota's Twin Cities Metropolitan Area (Berland, 2012). While these studies provide valuable insights, property-scale research is rare, which is

* Corresponding author.
E-mail addresses: justin.morgenroth@canterbury.ac.nz (J. Morgenroth), Jarlath.ONeil-Dunne@uvm.edu (J. O'Neil-Dunne), luis.apiolaza@canterbury.ac.nz (L.A. Apiolaza).

http://dx.doi.org/10.1016/j.apgeog.2017.02.011
0143-6228/

problematic as tree-related decisions are generally made by individual property owners (Shakeel & Conway, 2014). In the absence of property level research, fundamental questions about the relationship between redevelopment and city trees remain (Haaland & Konijnendijk van den Bosch, 2015). What happens to trees on a property when it is redeveloped – are they removed or retained? Further to that, why are trees retained or removed during redevelopment? Answers to these questions are necessary given the ecosystem services provided by urban forests (Dwyer, McPherson, Schroeder, & Rowntree, 1992), many of which are relevant at the scale of the individual property (e.g. fruit production, aesthetic value, mental health amelioration).

In this study we explore the relationship between trees and redevelopment at the scale of the individual property. We specifically investigate whether trees are retained or removed during building demolition, the first stage of property redevelopment. We begin by quantifying the impact of demolitions on tree cover and then explore the reasons for individual tree removal during demolition, inclusive of tree-related (e.g. tree size), property-related (e.g. building cover), and economic (e.g. land value) explanatory factors.

2. Methods

Opportunities to collect data to study the dynamics of property-level redevelopment and tree cover are rare, perhaps because data collection would need to occur over long time periods in order to generate a sufficiently large dataset. In this study, an opportunity to collect the necessary data within a short duration was presented by the wide-scale demolition occurring in Christchurch, New Zealand following earthquakes in 2010–2011 (Bray, Cubrinovski, Zupan, & Taylor, 2014; Moon et al., 2014).

2.1. Study site

The study was conducted in Christchurch, located on the east coast of the South Island of New Zealand (Lat: −43.53, Long: 172.62). Buildings were identified for demolition by the Canterbury Earthquake Recovery Authority (CERA, 2012), with an evident concentration in Christchurch's city centre (Fig. 1). At the time of field data collection for this study, buildings on 854 properties were listed to be demolished; this represents a small proportion (0.005%) of Christchurch's approximately 165,300 properties (LINZ, 2013). All 854 properties were visited during July and August 2012 and a subset of 123 properties was selected for inclusion in this study. Conditions for inclusion in the subset included: 1) all structures on the property were fully demolished (and rubble cleared off site) at the time field-based tree inventory was undertaken; and 2) properties were residential, commercial, or industrial. The first condition was instated to ensure that the field work accurately detected tree presence or absence after demolition was completed, rather than part-way through, while the second condition was designed to include only privately-owned properties. The vast majority ($n = 95$) of properties studied here were within the ‘4 Aves’. This area is considered Christchurch's central city and is bounded by Bealey Avenue, Fitzgerald Avenue, Moorhouse Avenue, and Deans Avenue. The remaining properties studied were scattered throughout the surrounding suburbs (Fig. 1).

2.2. Data

In order to determine the effect of demolition on tree canopy cover, we compared the presence and absence of individual trees on properties before and after demolition had occurred. We used a hybrid approach to data collection including remote sensing and field surveys. Remote sensing was used to map individual trees prior to building demolition, while field surveys were used to confirm tree removal or retention following building demolition. It was not possible to use a remote sensing approach following demolition as no remote sensing imagery of sufficiently high spatial resolution was available.

2.2.1. Remote sensing data acquisition

Individual tree crowns were mapped to establish baseline values for tree canopy cover, as well as the location and size of individual trees on properties prior to demolition. The data used included high-resolution aerial photography and aerial LiDAR data. The true-colour aerial photographs were acquired by New Zealand Aerial Mapping (NZAM) on 24 February 2011, two days after the 22 February Christchurch Earthquake and before any of the demolitions had occurred. NZAM used an UltraCamXp sensor (Microsoft Corporation, Photogrammetry Divison, Graz, Austria) at 1700 m above ground level to produce very-high resolution (10 cm) true colour photographs. The aerial photography was obtained for this study from NZAM in orthorectified form and projected into the New Zealand Transverse Mercator projection based on the NZGD2000 spheroid.

The LiDAR data were also supplied by NZAM. The LiDAR acquisition flights occurred between 8–10 March 2011, prior to any demolitions occurring. Data were captured from 900 m above ground level using an Optech Gemini sensor (model # 07SEN211) with settings of 100 KHz PRF, 48 Hz scan frequency, and 40° field of view. Average point spacing for all returns was 0.57 m. LiDAR data were supplied as classified LAS files, with points classified into three classes: ground, non-ground, water.

2.2.2. Analysis of remote sensing data

2.2.2.1. Data pre-processing. The raw LiDAR data were used to produce two layers for subsequent use. First, the LiDAR data were imported and processed to yield a Digital Elevation Model (DEM) from the ground returns, a Digital Surface Model (DSM) from the first returns, and finally a normalized digital surface model (nDSM) by subtracting the DEM from the DSM. Processing was carried out using the ArcGIS 10.1 software package (ESRI, 2012). The surface models were created using natural neighbours interpolation with a cell size of 10 cm to match the resolution of available RGB aerial photography. To minimize the existence of spurious cells in the nDSM, the dataset was smoothed with a 3 × 3 moving window focal analysis. Next, a slope dataset (degrees) was derived from the smoothed nDSM dataset.

2.2.2.2. Tree cover mapping. Mapping of individual trees prior to building demolitions at each studied property was undertaken via a combination of object-based image analysis (OBIA) (see review in Blaschke, 2010) and manual crown delineation. OBIA on RGB photography has successfully been used for classifying vegetation (Li & Shao, 2012; Walker & Briggs, 2007) and classification accuracy of vegetation in urban areas is improved with OBIA compared to pixel-based image analysis (Cleve, Kelly, Kearns, & Moritz, 2008).

An OBIA routine, built using eCognition Developer 8.7 (Trimble Navigation, Ltd., Sunnyvale, CA), was used to segment then classify landscape features into ‘woody vegetation’, ‘buildings’, and ‘other’ based on spectral, structural, textural, and neighbourhood characteristics. For segmentation, a multiresolution segmentation (scale = 15, shape = 0.1, compactness = 0.5) algorithm was applied to group objects based on the red, green, and blue bands, as well as the median nDSM and slope.

Objects were classified based on feature values: a) spectral; b) structural; c) textural; and d) neighbourhood characteristics. The feature values of sample image objects were used to build a user-