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Detection of foreclosure-related landscape management changes using Landsat

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ABSTRACT

The volume of properties affected by foreclosure over the past decade suggests the potential for dramatic change in vegetation cover due to changes in management. Yet, the specific pathology of each foreclosure, the temporal asynchrony among foreclosures, and differences in the area available for vegetation growth across properties presents challenges to observing and measuring change. This paper develops and tests a difference in deviations approach that compares the parcel NDVI to a neighborhood norm before and after foreclosure. The difference in deviations approach addresses the challenges of separating parcel-level change corresponding to foreclosure and identifies changes on both small and large parcels. The method relies on a time series of Landsat Normalized Difference Vegetation Index (NDVI) data, individual home foreclosure records and property tax assessment data for Maricopa County, Arizona from 2002 to 2012. To establish the level of difference associated with observable landscape change, we use a probit regression model, coding Google Earth images for properties across the range of observed deviations of difference. The basic assumption underlying the approach is that if foreclosure coincides with a change in management, it will lead to changes in vegetation structure and thus, NDVI values. We estimate that 13% of home foreclosures in Maricopa County over the period from 2002 to 2012 resulted in declines in vegetation whereas 6.5% resulted in vegetation increases. Future uses of this method for understanding landscape management in residential landscapes are discussed.

Introduction

Over 10 million U.S. homeowners submitted foreclosure filings during the foreclosure crisis between 2007 and 2012, mostly in urban areas (RealtyTrac, 2014). Many neighborhoods achieved peak foreclosure rates in 2009, with as many as one in every five homes foreclosed upon in some neighborhoods (RealtyTrac, 2012). Numerous studies have investigated the geography of foreclosure in different locales and at different scales (e.g. Perkins, 2008; Schafran, 2013; Yanmei, 2011). This work contributes to that tradition by examining the relationship between foreclosure and land cover change in Maricopa County, Arizona. Understanding the drivers of land use and land cover change is a fundamental goal in geography and it is especially important to do this in urban systems, which are dynamic and affected by social, economic and ecological drivers.

The volume of properties affected by foreclosure over the past decade suggests the potential for dramatic change in vegetation cover driven by changes in lawn management. There is anecdotal evidence of vegetation change in light of high foreclosure rates and images of overgrown or barren property are common (Schilling, 2009). However, it does not appear that prior studies have attempted to quantify the effect of foreclosure on vegetation and determine the extent to which vegetation changes on individual foreclosed properties are ubiquitous and inevitable or dependent on neighborhood, and city-level intervention dynamics.

Identifying whether parcel-level lawn management changes are coincident with foreclosure relies on the ability to isolate foreclosure from other drivers of neighborhood vegetation patterns. These drivers include (a) urban form, (b) landscape esthetic, and (c) spillover due to other changes in the neighborhood and (d) weather

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and climate conditions. First, the cover and greenness of lawns and other residential vegetation (hereafter *lawn status*) is dependent on urban form and development style, which varies across time period and has resulted in changes in the density of houses and the amount of outdoor space in each lot (Atkinson-Palombo, 2010). In this definition, high lawn status is not necessarily the same as a high-status lawn. Rather, it is an area with a high NDVI value in relation to other nearby yard spaces. Second, lawn status depends on landscaping aesthetics. Vegetation growth depends on initial landscaping practices. Grasses are more sensitive to management changes than trees and larger shrubs (Pouyat, Yesilonis, & Golubiewski, 2009). Additionally, the prevalence of grass as a proportion of yard space varies depending on the landscaping esthetic developed on the property. Other covers, such as trees, bare ground, or pavement contribute to both differences in initial lawn status and the degree to which the lawn can change. In Maricopa County, yard vegetation ranges from xeric landscaping – which requires less water and does not include grass – to mesic landscaping – which often includes summer and winter grasses as well as many leafy tree species (Martin, Peterson, & Stabler, 2003). Third, land cover outcomes may change due to the social dimensions of the economic crisis itself, through which spillover effects have changed the prices of nearby homes (Ihlanfeldt & Mayock, 2014; Leonard & Murdoch, 2009; Lin, Rosenblatt, & Yao, 2009) and willingness to pay for environmental amenities (Cho, Kim, & Roberts, 2011). Many homeowners associations (HOA) lost significant revenue during the foreclosure crises (especially those that weren't yet at 100% build out) and many responded by cutting back on services and landscaping requirements (Perkins, 2009). Last, the timing of climate events such as rain and extreme heat may influence lawn status, although the level of compensation to these events with increased irrigation varies across census tracts in accordance neighborhood norms like lot size, the prevalence of mesic landscaping and the income levels of the residents (Balling, Gober, & Jones, 2008). Disentangling these complexities suggests the need to examine changes in lawn status using a dataset that can capture the spatio-temporal heterogeneity of the urban landscape at the scale of a parcel.

Non-judicial foreclosures are the most common type of foreclosure in Arizona and are well documented in the public record, making them amenable to study (Fidelity National Title Agency, 2014; Thompson, 2010). When a homeowner stops making payments on their mortgage and goes into default, the lender can file a notice of sale (NOS) with the county to auction the house to a new owner. An auction would be scheduled no earlier than 91 days after the NOS, and three things could happen: (1) the borrower repays the debt amassed through missed payments and penalties and the auction is canceled; (2) the property receives no acceptable bids and becomes a Real Estate Owned (REO) until the lender sells it on the open market; (3) the auction results in a sale followed by a title transfer when paid in full and the original occupant is evicted (if they had not already moved out).

While foreclosure is a clearly documented process, existing documentation does not indicate what physically happened on properties in the periods before or after foreclosure that may have resulted in a change in level of property maintenance. There is a need to develop a technique to quantify vegetation change associated with foreclosures, as they are broadly dispersed through time and space, occur at the scale of a parcel, and are subject to complex contextual differences. Remote sensing data, particularly imagery from long-term continuity missions such as the Landsat program, can provide insight into parcel-level lawn changes over multi-decadal time periods, with an approximately 16 day sample frequency. Remotely-sensed data has been used extensively in urban areas for photogrammetry, landscape classification and macro-level statistical analysis (e.g. Blaschke, 2010; Jensen & Cowen, 1999; Wilson & Brown, 2015). Previous work on land cover classification (Wentz et al., 2014) is especially relevant to the research in this paper, although attempts to identify temporally and spatially dispersed sub-pixel changes in land cover appear to be rare. The Normalized Difference Vegetation Index (NDVI) has been used with macro-level analysis of urban vegetation (for examples see Buyantuyev & Wu, 2009; Guhathakurta & Gober, 2007; Turner & Ibes, 2011) although Mesev (2011, 156–157) notes that micro-level urban classification with remote sensing yields tenuous results and temporal lags between structure and function reduce the validity of static classifications. Therefore, there is a need to develop methods that are more temporally sensitive.

Here, we examine changes in the Normalized Difference Vegetation Index (NDVI) derived from a time series of Landsat imagery collected over the period of 2002–2012 (Fig. 1). NDVI is a normalized ratio of reflected near infrared (NIR) light, which is related to the height and total area of vegetation, and red light, which is related to health (or "greenness") of the vegetation, and is calculated as:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{Red})/(\mathrm{NIR} + \mathrm{Red})$$

Decreasing lawn management in arid systems such as Maricopa County is hypothesized to lead first to the red reflectance increasing as the photosynthetic pathways break down (the plant is unable to absorb red light for photosynthesis), and subsequently in a decreasing NIR reflectance as the internal leaf structure breaks down through decomposition. Thus, as plants begin to dry up and decompose, NDVI is expected to decrease. Vegetative cover/NDVI patterns are particularly pronounced in desert landscapes when turf grass is introduced and must be maintained in the arid climate.

To address these challenges, we developed a technique to quantify small-scale ecological phenomena, like vegetation change associated with foreclosure, that are broadly dispersed through time and space and subject to complex contextual differences. Our study aims to do this in a way that bridges applied studies of the geography of foreclosure (e.g. Ihlanfeldt & Mayock, 2014; Kaplan & Sommers, 2009; Zhang & Leonard, 2014) with studies of human–environment interactions that focus on the ecological consequences of yard care choices (e.g. Fraser, Bazuin, Band, & Grove, 2013; Nassauer et al., 2014; Polsky et al., 2014).

Methods

Study area description

Our analysis focused on Maricopa County, Arizona from 2002 to 2012. Maricopa County is located in south central Arizona and was home to around four million residents in 2012, 90% of whom lived in the urban area surrounding Phoenix, which itself had a population of approximately 1.5 million residents (USCB, 2014). The population of the county has quadrupled over the past 50 years and doubled in the past 25 years (ADOA-EPS, 2014; USCB, 2014). In 2013 there were approximately 1.2 million residential parcels in the county, defined as single-family detached homes and condominiums (MCAO, 2013). This number excludes commercial multi-tenant rental properties (MCAO, 2013).

The character of parcels in the county varies widely. Most residential parcels are under 30 m^2. Houses on average occupy 28% of the area on each parcel, although the standard deviation of 23% demonstrates the wide range of potential lawn area (The Information Market, 2013). Many homeowners and communities have adapted to the climate with low-management practices which