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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

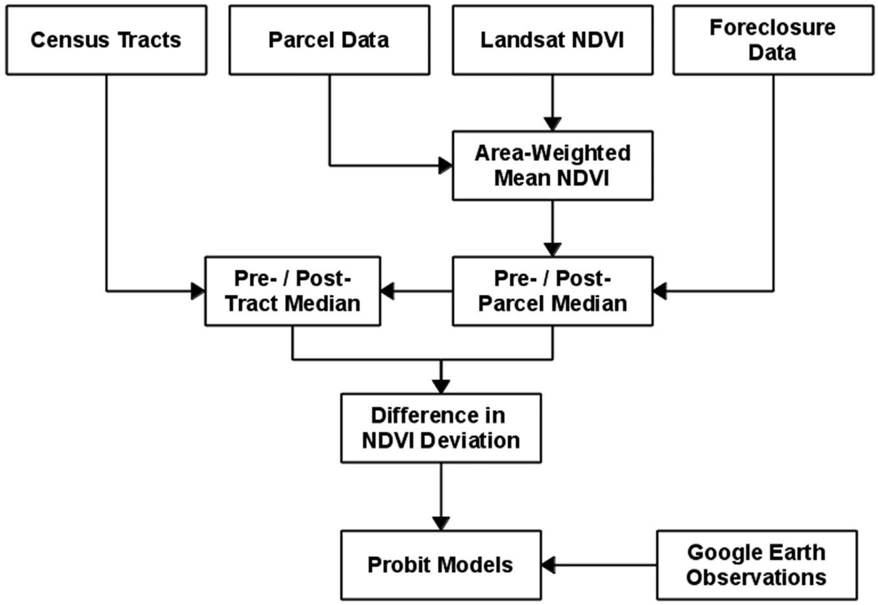

Fig. 1. Data flow chart.

reduce the vegetated area that can be affected by foreclosure and any associated landscape management changes.

The foreclosures analyzed were those that passed through non-judicial foreclosure, or Trustee's Sale, as outlined in the introduction. During the study period, 28% of all residential parcels passed through at least one foreclosure (The Information Market, 2013). The county was a significant beneficiary of the housing bubble in the early 2000s and victim of the bubble implosion, with foreclosures skyrocketing after 2007 (The Information Market, 2013). The analysis period of 2002–2012 was chosen to cover the start of the housing bubble and the reduction in foreclosure rates following the crash. As of January 2015, the foreclosure rate in Maricopa County had dropped to a level of around one foreclosure per 797 homes per month (RealtyTrac, 2015), although it was still above the levels seen during the bubble, as shown in Fig. 2.

Phoenix has built a reputation as an "oasis in the desert" (Larsen & Swanbrow, 2006) and has never faced mandatory water restrictions (Gober & Trapido-Lurie, 2006; Redman & Kinzig, 2008). As such, per capita residential water use of around 409 L per day is close to the national average despite the arid climate (Kenny & Juracek, 2012; Santos, 2013). Climate and its effect on evapotranspiration drive high levels of outdoor water use (Wentz & Gober, 2007), and much of domestic water use goes to support vegetation that would not be able to survive if reliant only on the 182 mm of rain that typically fall in a single year, given the average high temperature in July is 41.2 C (National Weather Service, 2015).

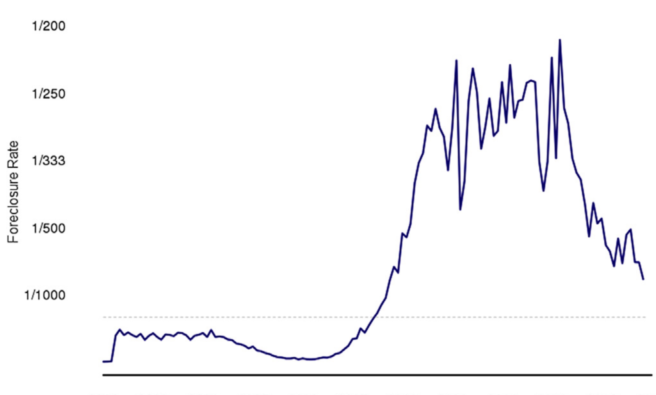

Fig. 2. Maricopa county monthly foreclosure rate: 2002–2012.
The Information Market, 2013.

Review of key data sets

Landsat NDVI

For this analysis we used Landsat path 37, row 37, which covered 95% of the county's residential parcels. The Landsat series of sensors captures biweekly imagery (approximately 26 images per year) at 30 m^2 resolution, and have a historical archive dating back to approximately 1984 from which NDVI can be calculated. We used Landsat Five Thematic Mapper (TM) data for the period 4 January 2002 through 4 November 2011 and Landsat Seven Enhanced Thematic Mapper Plus (ETM+) data for the period 12 January 2002 through 31 January 2012 that was downloaded from the USGS EarthExplorer website.

The data set consisted of 438 radiometrically-corrected images. Landsat path 37, row 37 covered Maricopa county with the exception of the sparsely populated southwest corner. The fmask raster (Zhu & Woodcock, 2012) provided with the Landsat multispectral data permitted masking of cloud-covered areas. Some data was also missing from the Landsat Seven scenes due to the scan-line-corrector (SLC) problem, which results in a loss of around 22% of the pixels within any given scene (USGS, 2013). Because the two satellite systems provided interleaved 16-day passes, no attempt was made to interpolate missing data within individual scenes. For each scene, we calculated NDVI.

Census data

2013 TIGER/Line shapefiles for census tract boundaries in Maricopa were downloaded from the United States Census Bureau website.

Parcel data

We used the Maricopa County Assessor's Office 2013 parcel database shapefile representing all 1,545,616 residential and non-residential parcels, joined with the entries in their 2013 ST 42030

Residential Master Data Table to create a spatial database of 1,214,578 residential parcels in the county.

Foreclosure data

We acquired a residential foreclosure database from a commercial vendor (The Information Market, 2013) covering NOS for the period 2002–2012. The database contained 462,380 records, representing 341,983 distinct parcels or approximately 28% of the 1,214,578 residential parcels documented by the Maricopa County Assessor's Office (2013). Of the foreclosure records, 242,638 (52% of total records) indicated a completed foreclosure (Trustee's Deed or TD), representing 232,266 distinct parcels or 19% of total number of residential parcels as of 2013.

Data cleaning and processing

Of the 232,266 distinct parcels in the foreclosure records, 226,706 had entries in the Assessor's residential data file and associated parcel shapefile. The 809 parcels foreclosed within the first year of a home's existence (based on the construction year in the county data set) were excluded under the assumption that the one-year pre-foreclosure period would not reflect owner-initiated landscape management practices and would overlap with prior parcel land use (often high-NDVI agriculture) that was not considered relevant to this analysis. An additional 71,896 parcels were excluded because the one-year pre-/post-foreclosure window extended into the period before or after the 2002–2012 analysis period. An additional 13 parcels were excluded because of inadequate NDVI data due to location on the margins of the Landsat scenes or because of the aforementioned masking. This left 153,988 parcels for analysis.

Area-weighted mean NDVI

Landsat data has a moderate temporal and spatial resolution that makes it possible to compare vegetation before and after a parcel is foreclosed. However, the small size of many residential parcels (under the 30 m^2 Landsat pixel size) and differences in initial vegetation complicates the direct use of Landsat data and NDVI to assess vegetation. Pixels are not aligned on parcel boundaries, multiple pixels can be affected by a single parcel and multiple parcels can be covered by a single pixel, diluting the measured NDVI change associated with sub-pixel sized additions or removal of vegetation. The LEDAPS orthorectification of the Landsat data reduces the average geolocation error to ±1 pixel (±30 m) (Thomas et al., 2011), leaving the possibility that the pixels associated with some small parcels can actually be covering adjacent small parcels in some time-series scenes. In addition, small parcels are commonly covered by large houses, leaving only fringes of potential lawn area (Robbins & Birkenholtz, 2003) around the edges of these parcels, limiting the amount of area where vegetation can be added or removed, and constraining the practical range of NDVI change.

To account for some of these challenges, parcel NDVI was calculated by taking an area-weighted mean of the values of pixels that covered each parcel. This parcel-centric algorithmic approach addressed the weaknesses of using conventional statistical sub-pixel classification techniques (such as those used by Yang, Xian, Klaver, & Deal, 2003) with foreclosure events that were sparsely distributed across time and space. Pixels that did not have a centroid within a residential parcel were masked in order to mitigate distortions from potential pixel overlaps with public green spaces and agricultural land.

Pre-post parcel median

For each individual parcel, the median NDVI was taken of all available scenes in the period both one year prior to the foreclosure auction and one year following. This interval was chosen in order to encompass the typical 240 days needed to complete a foreclosure (O'Donnell, 2013) and a comparable post-foreclosure period, and to control for the annual phenological cycle. NDVI medians were used rather than means to mitigate distortion from transients caused by brief climate events, or errors in individual Landsat scenes caused by misregistration or cloud cover.

Pre-post tract median

Normative NDVI was defined as the median NDVI for all parcels in the census tract containing the queried parcel, excluding any parcels that ever went into foreclosure. Norms were calculated during the pre-foreclosure and post-foreclosure periods defined above, which yielded pre/post norms specific to each foreclosure incident. Use of tract median as a norm controlled for confounding social or weather conditions.

Difference in deviations calculation

The before and after medians were compared with before and after medians for the normative NDVI to obtain pre-foreclosure deviation and a post-foreclosure deviations as shown in Fig. 1. The differences between the pre-foreclosure deviations and post-foreclosure NDVI deviations were then used to determine the direction and magnitude of foreclosure-coincident lawn status change (Fig. 3). A negative difference indicated a potential decrease in lawn status, while a positive difference indicated a potential increase in lawn status. The magnitude of the NDVI differences represented the magnitude of change in vegetation, which was hypothesized to correlate with the potential that a lawn status change occurred.

Fully understanding the social and ecological factors that might lead to the diversity of landscaping changes to foreclosure is beyond the scope of this paper. The methodology developed in the paper is specific to semi-arid environments, and would not be directly applicable in more-temperate climates. While unmanaged turf grass can be expected to wither in the Arizona Summer sun (lower NDVI), it could be expected to grow tall in areas with plentiful rainfall (slightly higher NDVI).

We illustrate the technique by highlighting results for two foreclosed parcels. Fig. 3 shows an example visualization of analysis for a single parcel in Tempe. The tract norm for this 2-acre parcel is stable over the displayed period, whereas the median parcel NDVI showed an obvious change after the foreclosure auction on May of

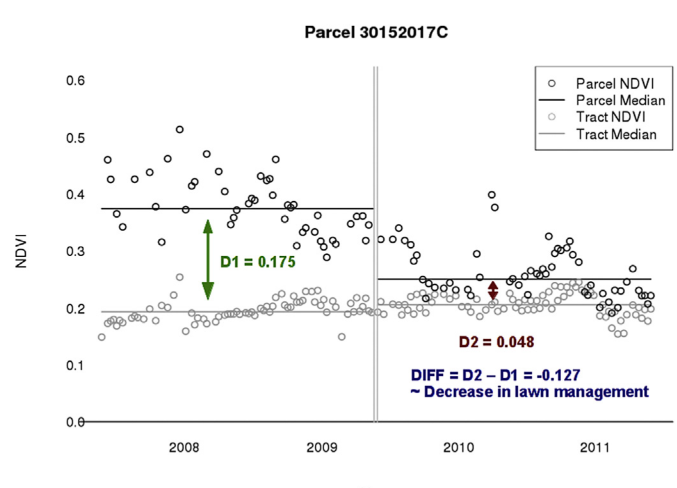

Fig. 3. Example parcel with NDVI change.

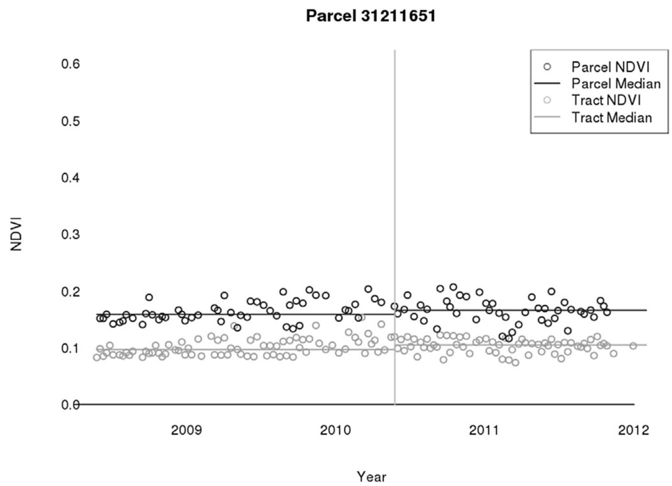

Fig. 4. Example parcel with no change.

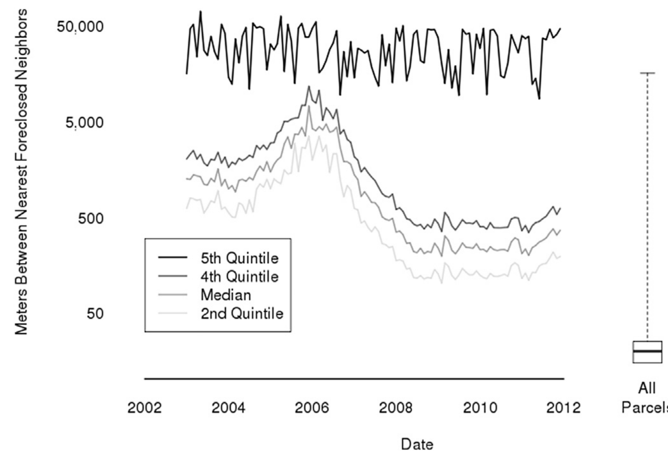

Fig. 5. Nearest-neighbor analysis of foreclosed parcels by month 2002–2012.

2009. By contrast, Fig. 4 shows a parcel in Mesa where NDVI was quite low and there was little obvious change before and after the foreclosure in May of 2010.

Validation

To identify parcels where lawn status change appeared to coincide with foreclosure, we analyzed historical high-resolution imagery available through Google Earth to compare pre- and post-foreclosure vegetation. A random sample of 100 parcels was weighted based on the magnitude of the z-score of the difference in NDVI deviation. This strategy allowed us to sample the parcels in the long tails of the normal distribution of the differences in deviation adequately. We anticipated the tails would correspond with the most significant change in vegetation. This method of sampling provided an inverse normal sampling distribution that captured more of the parcels with potential change than an unweighted random sample (Griffin & Hauser, 1993; Long, 1997).

Historical imagery for each sampled parcel was observed in Google Earth by three independent research assistants and coded as positive change, negative change, or no change. Observations were also coded as high, medium and low certainty based on the spatial resolution, color contrast, and temporal availability of imagery. Conflicting interpretations were resolved by majority. Changes in vegetation were coded positive or negative based on observed additions or removal of managed vegetation, regardless of size. Mixed changes (such as removal of turfgrass and addition of desert plants in xeric landscaping) were coded as positive or negative based on which area of change was estimated to be greater. Transient changes in vegetation that appeared to be related solely to climate events (based on similar changes on surrounding parcels), or appeared to be caused by maturation of vegetation unrelated to observable management change (like the growth of trees in yards that exhibited no other changes) were coded as no change.

A second random sample of 100 non-foreclosed parcels with randomly-selected event dates was processed as a control group using the same procedure.

Probit regression model

We used probit models to calculate the probability that parcel difference in NDVI deviation values underwent foreclosure-coincident changes in lawn status based on visual inspection of Google Earth images. Separate models estimated the probability of observing "positive change" (as opposed to no change or negative change) and "negative change" (as opposed to no change or positive change). The probability curves were then multiplied by the difference in deviation z-scores to provide estimates of the number of parcels that underwent foreclosure-coincident change in lawn status.

Results

Foreclosure events were spatially and temporally diffuse. Even at the height of the foreclosure crisis in 2009, the median nearest-neighbor distance between parcels undergoing foreclosure within the same month was around 250 m, in contrast to the median nearest-neighbor distance between all parcels of 20 m (Fig. 5). This spatio-temporal dispersion made it difficult to analyze foreclosure-coincident lawn status change in terms of aggregated clusters (Greenberg et al., 2014), necessitating analysis at the parcel scale.

Most parcels had little change in NDVI coincident with foreclosure, indicating that foreclosure did not usually result in large declines in vegetation. The overall distribution of differences for the analyzed foreclosure events shown in Fig. 6 was a normal curve with a mean that was slightly negative (−0.002), indicating a slight NDVI decrease associated with foreclosure. However, the standard

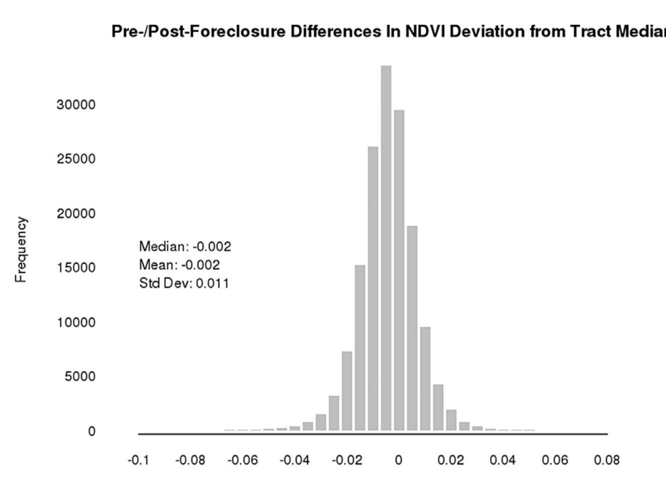

Fig. 6. Aggregate distribution of foreclosure-coincidental deviations from tract norms.

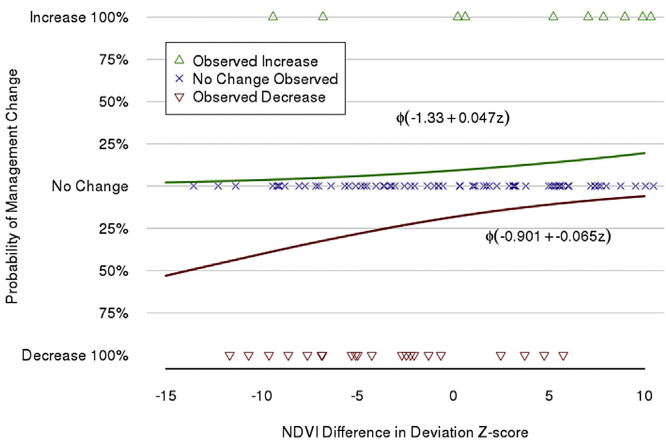

Fig. 7. Probability modeling of landscape management change on foreclosed parcels from sampled Google Earth observations.

deviation of 0.01 indicated that 99.7% of all events were within a ±0.03 NDVI deviation, which is only 3% of the practical NDVI range of zero to one, or 8% of the aforementioned typical NDVI range of 0.4 between vegetated and non-vegetated surfaces. Therefore, from a macro viewpoint, lawn status changes coincident with foreclosure had a minimal effect on overall vegetation or resource usage in Maricopa County.

However, visual coding of sampled foreclosed parcels using Google Earth historical imagery before and after foreclosure indicated that observable changes in lawn status sometimes occurred. The fitted probit models (Fig. 7) indicated that increases in NDVI difference in deviation resulted in decreases in the probability of decreased lawn status and increases in the probability of increased lawn status. Multiplication of the probit models by the parcel differences in NDVI deviation resulted in an estimate that 28,000 foreclosed parcels underwent observable declines in lawn status from 2002 to 2012. A slightly smaller 14,000 foreclosed parcels were estimated to have increases in lawn status that coincided with foreclosure.

Similar coding for the non-foreclosed random control group (Fig. 8) revealed far fewer observations of negative lawn status change, which indicates an increased probability of decreased lawn status associated with foreclosure.

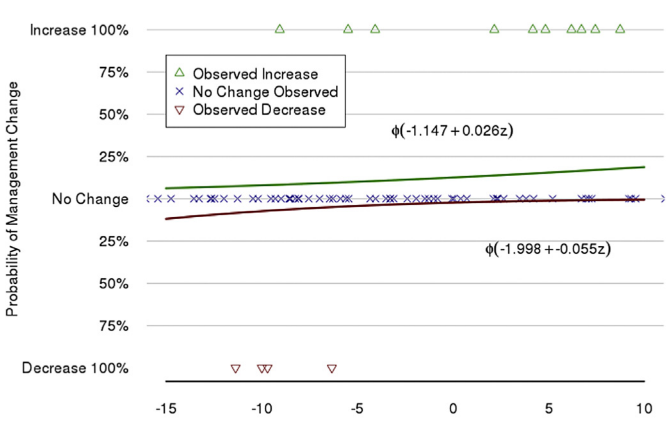

Fig. 8. Probability modeling of landscape management change on all parcels from sampled Google Earth observations.

Discussion

The difference in deviation analysis developed in this paper assesses parcel changes in NDVI after controlling for the influence of (a) urban form, (b) landscape esthetic, and (c) spillover due to other changes in the neighborhood and (d) weather and climate conditions. Based on validation using Google Earth images and probit regression models, we conclude that most individual foreclosures in Maricopa County did not lead to observable changes in lawn status. However, the difference in deviation method is a successful way to identify changes in lawn status. The presence of thousands of parcels that did experience post-foreclosure vegetation change suggests the need for investigation into the factors that define those specific places and times, and whether analysis of those characteristics can be generalized to answer broader questions about foreclosure and/or urban ecology.

Although the method may be useful to work in other cities, researchers should consider the context of foreclosure and climate when they interpret results. The deviation of differences methodology is based on the specific dynamics of foreclosure in Maricopa County, which did not result in widespread demolition of homes (Schuetz, Spader, & Cortes, 2015) and where water inputs are required to maintain lawns due to the arid environment. In cities like Detroit, Michigan or Cleveland, Ohio, foreclosure is frequently a prelude to abandonment and demolition (Griswold, Calnin, Schramm, Anselin, & Boehnlein, 2014) and rainfall is more abundant. Additionally, the City of Cleveland, OH has instituted a policy to mow vacant lots and properties (City of Cleveland, 2015). Both of these activities could change the direction of NDVI change expected to follow if regular maintenance stops.

The methodology we present identifies coincident vegetation change and therefore the structure of causation will require grounded theoretical work to address ontological questions. For instance, understanding how landscape changes should be related to the social disruptions and transitions that sometimes accompany foreclosure. Current theory cannot guide decisions about whether management changes associated with preferences of new owners should be attributed to foreclosure, and whether transient changes associated brief periods of foreclosure-related vacancy should be considered significant.

A broader objective of this research was to address the challenge of using urban remote sensing to analyze small-scale ecological phenomena that have broad temporal and spatial dispersion. Uncertainties associated with data quality and availability were addressed by generating probabilistic rather than categorical outputs. We believe this simple but novel application of remote sensing represents a meaningful contribution that may prove valuable for analysis of other sparse, temporally-distributed urban ecological phenomena. While applied to foreclosure, it may also be a useful tool for examining other phenomenon that create tensions between drivers of residential landscape management. The recent water restrictions in California, for example, have highlighted the potential for nuisance property ordinances and water use restrictions to be inconflict (e.g. Horseman, 2015).

The results of this study raise the question of what forces kept existing management practices in place on most parcels, and whether this indicates a resilient system where behavioral and institutional factors are critical. From the perspective of urban ecology theory, this raises the question of whether persistence in mesic lots indicates a maladaptive but path dependent system, much in line with field studies of lawn management and residential landscape preferences (e.g. Polsky et al., 2014). The failure of foreclosure to modify vegetation in a universal and detectable way suggests that many of the institutions that work beyond the household may play a strong and disparate role in modulating the degree to which foreclosure results in ecological change. This suggests that foreclosure, a temporally and spatially explicit opportunity for management change, may provide a useful experiment for the emerging ecological homogenization hypothesis, that surmises that cities are becoming more ecological similar to one another over time (Polsky et al., 2014). For instance, homeowner's associations are very common in Maricopa County (Turner & Ibes, 2011), may suppress the impact of foreclosure on yard vegetation when foreclosure are low and the income base for property management provided by other residents allows it. As foreclosure increases and revenues decline, there may be fewer opportunities for management. Understanding the space-time nature of foreclosure filing information is likely to be an important component of analysis building from the dependent variable we have constructed.

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