Int J Appl Earth Obs Geoinformation 73 (2018) 471–481

Contents lists available at ScienceDirect

Int J Appl Earth Obs Geoinformation

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

Tracking the removal of buildings in rust belt cities with open-source geospatial data

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ARTICLE INFO

Keywords:
Shrinking cities
Building removal
LIDAR
Aerial orthoimagery
GIS

ABSTRACT

Urbanization is generally understood as the process of growth in both population and developed areas. However, this perception is not reflective of the type of change that is occurring in the Rust Belt region of the United States where many urban areas reveal shrinkage instead. While much of the research surrounding these shrinking cities is in the realm of socio-economic implications, few studies have investigated how to map these shrinking areas. This research aims to contribute to the growing body of shrinkage research by examining methodology to monitor the fast removal of buildings in the Rust Belt shrinking cities with easily available open source data such as Light Detection and Ranging, aerial orthoimages, and GIS datasets. Our ultimate goal is to develop methodology for improved, generalizable mapping of shrinking cities. We applied our methods to Detroit, Michigan and Youngstown, Ohio which both show significant urban shrinkage and both have a variety of survey datasets available for validation. We map a 5-year change in Detroit as well as a 10-year and 19-year change in Youngstown to provide, in high detail, the process of building removal. For Detroit we found that 12.9% of all land parcels that contained a building in 2009 had lost this building by 2014. New builds were drastically overshadowed by the demolished structures, accounting for < 1% of the total number of parcels in the city. We found similar results in Youngstown, were 13.1% of all parcels studied revealed that a structure was removed between 1994 and 2013, with similarly low rebuild percentages (< 1%).

1. Introduction

Exploring changes in urban land cover is important for understanding how human-environmental interactions impact the natural processes and biodiversity of a region. In addition to removing native plant and animal species, the introduction of built environment can alter air quality and have damaging downstream effects on water quality and quantity (Foley et al., 2005; Grimm et al., 2008; Kowarik, 2011; McKinney, 2008). Because the global urban population is projected to increase to nearly 5 billion people by 2030, undoubtedly placing significant stress on already strained resources (Seto et al., 2012), many urban land cover change studies tend to focus on rapidly urbanizing regions (Bhatta et al., 2010; Hegazy and Kaloop, 2015; Jat et al., 2008; Xu and Min, 2013). However, while many urban areas have revealed substantial growth over the course of the last half-century, multiple regions of the world, including the United States, reveal significant declines in the population of some cities (Haase et al., 2014). For example, several former economic and industrial centers such as those found in the Rust Belt have steadily been losing their populations.

A city experiencing significant population decline in addition to decline in economic prosperity earns the moniker of a “shrinking city” (Beauregard, 2009; Pallagst et al., 2009). The research surrounding the causes of shrinkage is vast, with many studies noting that the decentralization and decline of industry (Rieniets, 2009) are the main drivers for shrinkage in the USA and falling birth rates are the main drivers in other industrialized countries like Germany (Wiechmann and Pallagst, 2012). While shrinking cities can be found around the world, the majority of the most significantly shrinking cities in the U.S. are isolated to the Rust Belt region. This colloquial region spans roughly 500 miles across the heart of the U.S. and represents the spatial extent of the early twentieth century’s economic backbone. Much of the shrinkage research focusing on the U.S. examines cities such as Pittsburgh, Pennsylvania; Cleveland, Ohio; Detroit, Michigan; and Buffalo, New York which are all located within the Rust Belt (Rosenthal, 2008; Schilling and Logan, 2008; Weaver et al., 2017; Zingale and Riemann, 2013).

Almost exclusively, the body of U.S. shrinkage research discusses the aforementioned contributors to population decline, but there has been a push toward examining the shifts in land use as a result of

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https://doi.org/10.1016/j.jag.2018.07.007
Received 24 October 2017; Received in revised form 4 July 2018; Accepted 4 July 2018

population loss (Hollander et al., 2009; Pallagst, 2010). Thomas and Bekkering (2015) used historical maps to visualize the progression of urbanization in Detroit. However, these city-wide historical maps do not provide information on the actual presence of buildings. They did examine the presence of buildings on parcels of land in some portions of the city, but this was limited due to the datasets being used. Hollander (2010) conducted a case study of three neighborhoods in Flint, MI in which in-situ photographs were compared to population dynamics to examine reflections of population shifts on housing density. While this study was effective for this small study region, this time intensive approach would not be ideal for an entire city and in-situ photographs are not necessarily available for other cities or at multiple time steps. Hillier et al. (2003) used a large information system to monitor risk of housing abandonment in Philadelphia, PA. This study is notable in that it not only makes use of a large database, but it also identifies indicators of physical abandonment of a property such as overgrown vegetation. Most cities have property information systems available through tax assessors, but they do not often contain property characteristics other than basic ownership, lot size, and address information. Replication of this study in a region with limited resources would require a significant amount of ancillary data.

While ground surveys and high resolution historical maps can be effective to map urban shrinkage, these activities are also very time intensive, and hard to standardize over multiple cities in different states. In addition, cities typically design their own surveying methods at different time intervals, with some cities not surveying at all, making comparisons even more difficult. For example, while Detroit has performed extensive surveys of residential properties over multiple time steps, such surveys are rarely available for smaller cities, like Youngstown.

Remotely sensed data allows landscapes to be displayed in relatively high detail and satellite images are often used to study urban areas (Xiao et al., 2006; Yang et al., 2003; Yuan et al., 2005). Many studies use remotely sensed products such as Landsat data with a moderate resolution of 30-meters to examine urban land cover for multiple years (Fu and Weng, 2016; Sexton et al., 2013; Song et al., 2016; Stefanov et al., 2001). While this publicly available product has been proven to be effective at analyzing large scale changes across urbanizing areas, the moderate resolution proves to be too coarse to use in shrinking cities due to the overgeneralization of the landscape which misses small details on the surface (e.g. the removal of a small singular structure such as a residential home). As a result, few studies analyze urban shrinkage with moderate resolution data and those that do use a proxy for urban abandonment. For example, Ryznar and Wagner (2001) used Landsat data to map urban greenness in Detroit, Michigan as a proxy for shifts in demography. This study found increased greenness in areas of suspected abandonment in addition to moderate to higher income areas. Although this study provides a snapshot of how the removal of the human influence from a property can change its land cover and biodiversity, it provides no information about the impacts of abandonment on the built environment.

Technological advances over the years have allowed for high and very high resolution products such as WorldView, Quickbird, and Ikonos to be used to analyze change in great detail, however, these products are often not freely available and can become quite costly when the aim of a study is to explore the landscape of an entire city or compare multiple cities (Herold et al., 2005; Myint et al., 2011; Novack et al., 2011; Pu et al., 2011; Zhou et al., 2009). Ortho imagery are a viable alternative (Taylor and Lovell, 2012) and cities often make these photos publicly available. Orthophotos are used by many large cities for general mapping purposes.

Another alternative is to use Light Detection and Ranging (LiDAR) data which is also publicly available and has the ability to showcase small details on the landscape at a very high resolution. LiDAR data can be used to characterize complex landscapes while avoiding mixed spectral signatures. Mixed spectral signatures are typically found when coarser resolution pixels, as retrieved by orthophotographs or satellite imagery, overlap multiple land covers. Much of the literature surrounding the use of LiDAR data to map urban environments focuses on building detection (O'Neil-Dunne et al., 2013; Verma et al., 2006). Features can be extracted from the LiDAR point cloud (Tarsha-Kurdi et al., 2007), from a digital surface model derived from the point cloud (Priestnall et al., 2000), or by using a combination of LiDAR data and other products such as aerial imagery, high resolution satellite imagery, and GIS databases (Cheng et al., 2011; Singh et al., 2012; Sohn and Dowman, 2007; Wu et al., 2016). Building detection has been shown to be an effective means of analyzing the landscape, but we have not found other papers that explore the use of building detection from LiDAR data to analyze shrinking cities.

This study aims to combine publicly available LiDAR data, orthophotos, and GIS databases to classify administrative land parcels in order to examine the removal of structures in two U.S. shrinking cities and explore the rates at which shrinking cities are removing structures. In our first case study, we will use extracted building footprints from LiDAR in combination with GIS survey data to classify changes in parcels. In our second case study, we will use aerial imagery and demolition records to identify changes in parcels. As mentioned previously, while there are examples of studies that have examined land use change in shrinking cities (D. Haase et al., 2008; Hollander, 2010; Hollander et al., 2009; Ryznar and Wagner, 2001; Thomas and Bekkering, 2015), these studies do not address how the presence of structures is shifting over time. We demonstrate how multiple freely available spatial data sources, such as LiDAR data, orthophotos, and GIS databases can be combined to map urban changes at various time steps, providing a snapshot of the contemporary urban landscape in the Rust Belt region of the United States.

2. Detroit and Youngstown

The Rust Belt of the United States stretches from western New York state to far east Illinois and includes areas of western Pennsylvania as well as the states of Ohio, Michigan, and Indiana. The cities within this region were once primarily populated by the workers of the automobile and steel manufacturing industries, but many of them have seen drastic population declines since the height of the twentieth century. Fig. 1 shows the span of the Rust Belt for reference in this study. Because this region does not have a formal administrative boundary we created this figure by selecting cities that were identified as being typical Rust Belt manufacturing locations in Hobor (2013). A 20 mile (32.2 km) buffer was created around each city to represent the mean U.S. commuter distance to work which was identified in Rapino and Fields (2013). We then used the outermost portions of the buffers to create a boundary which encompasses all of the cities selected. Notably contained within the region are the cities of Detroit, Michigan and Youngstown, Ohio which have been selected for analysis in this study.

The city of Detroit is nestled along the Detroit River, which flows into Lake St. Clair to the Northeast and Lake Erie to the Southeast. Its municipal boundary spans 370 km^2 (Fig. 1.) and is contained within Wayne County in Southeast Michigan. Detroit is often highlighted as a prime example of a shrinking city (Wiechmann and Pallagst, 2012) because of its early rise to prominence in the automobile industry followed by its decades long spiral into socio-economic hardship. Detroit reached its peak population of 1.85 million in 1960 and suffered a 62% decline to 711,000 by 2010 (United States Census Bureau) and currently has a population of less than 690,000. The significant shrinkage came as a result of the decentralization and dispersion of the automobile industry, increased crime rates, political corruption, and economic downturn (Martinez-Fernandez et al., 2012; Siljanoska et al., 2012). Although Detroit continues to lose population, it has made significant strides to monitor the impacts of population decline on the landscape. We specifically selected Detroit as one of our areas of studies since the city has extensive datasets available on urban abandonment