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Is remote sensing useful for finding and monitoring urban farms?

M.E. Brown [a,*], J.L. McCarty [b]

[a] Department of Geographical Sciences, University of Maryland, College Park, MD, United States
[b] Michigan Tech Research Institute, Ann Arbor, MI, United States

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ABSTRACT

As the world becomes increasingly urbanized, the need for fresh fruits and vegetables in urban areas grows while the difficulty of bringing these perishable products to these areas also increases. Small-scale agriculture located in urban areas is a highly effective and profitable way to provide these products to communities that are far from extensive commercial agricultural areas. Here we describe how remote sensing can be used with data mining approaches to monitor urban and peri-urban farms within cities in both developed and developing countries. Using very high resolution satellite imagery together with moderate and coarse resolution imagery and information from social media and the web, we analyze the usefulness of different methods to identify farms within urban boundaries in four countries. The analysis shows how a mixed-method approach is necessary in order to identify where urban farming is occurring and to monitor its change through time. Although remote sensing-based vegetation and water indices were useful, without ancillary data they are not effective at remotely mapping the locations of urban farms. However, remote sensing is a good way to monitor vegetation condition in locations where actively managed urban farms are known to exist.

1. Introduction

Urban and peri-urban agriculture (UPA) are gardens, plots and other small fields near or within urban boundaries whose objective is to produce food for sale or local consumption, including the growing of plants and the raising of animals, along with activities related to distribution and marketing of food (Smit, Ratta, & Asr, 1996). The scale of urban agriculture is typically small, and is usually highly intensive with the use of more technology than is typical in surrounding rural areas, but less than is typical of large-scale, capital-intensive farms (Brown & Mata, 2016; Dubbeling, Zeeuw , & Veenhuizen , 2011). Given the rapid urbanization of populations in southern low income nations (United_Nations, 2014), the food system is being transformed to deliver food to these urban populations, including the expansion of food being grown within the urban center. In the high income north, urban agriculture competes with other, higher value land uses and although it can have an important role in food provision, the environmental and health risks associated with intensive production, including soil contamination and high cost of electricity, are challenging (Mok et al., 2014).

Remote sensing has been used for decades to monitor agricultural productivity (Frere & Popov, 1979; Kennedy & Payongayong, 1992; Unganai & Kogan, 1998; Zengchao Hao Navid Nakhjiri and Alireza Farahmand 2014). A range of approaches has been used to measure crop yields and food shortages for national governments, humanitarian agencies, and decision makers (Higgins, Hintermann, & Brown, 2014; 2015). These analyses have focused on the productivity of row crops or small fields in rural areas to understand the amount of food produced through agriculture. Here we use remote sensing of vegetation to identify UPA and to monitor its productivity (Usman, Liedl, Shahid, & Abbas, 2015). By exploiting estimates of productivity, we seek to identify UPA in diverse climates and cultures that have very different urban ecologies, histories, and densities (Dorélien, Balk, & Todd, 2013; McIntyre, Knowles-Yánez, & Hope, 2008).

UPA involves a complex mix of activities and actors, including fisheries and forestry, market gardening, neighborhood garden plots and is present in cities in both developed and developing countries (FAO, 2010; Lado, 1990; Taylor & Lovell, 2012). It contributes to food availability, provides employment and income, and is an important part of food security and nutrition of urban dwellers, particularly in low income countries (FAO, 2012). Both

* Corresponding author.
E-mail addresses: mbrown52@umd.edu (M.E. Brown), jmccarty@mtu.edu (J.L. McCarty).

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urban and peri-urban agriculture contribute to food security for urban residents by affecting four levels of the food system, namely food production, processing, distribution and consumption (Opitz, Berges, Piorr, & Krikser, 2016). Research on UPA has shown that it is an enduring and integral part of the urban socio-economic and ecological system, using whatever land and water resources that are available and serving the ever-changing needs of the region in which it is located (Mougeot, 2005). Given this complexity, identifying urban agriculture using satellite remote sensing has all the challenges of smallholder agriculture with small fields combined with the difficulty of identifying market gardens from other types of irrigated vegetation (Addo, 2010). Most approaches require significant secondary information on the location and type of agricultural activities being conducted, such as on-the-ground surveys or interviews (PSRC, 2013).

Urban agriculture can be profitable, even on very small scales (FAO, 2007). Using survey results from Zezza and Tasciotti (2010) with probability distribution models, Hamilton, Burry, Mok, and et al (2014) calculate the total number of urban farmers in developing countries to range from 207 million to 329 million households with a media of 266 million urban farming households. Orsini, Kahane, Nono-Womdim, and Gianquinto (2013) estimate the number of urban farmers globally to range from 100 to 200 million based on a survey of international development and scientific literature. In developing regions, the urban poor spend as much as 60–80% of their income on food (Benin & Randriamamonjy, 2008; Ruel, Garrett, Hawkes, & Cohen, 2010). To offset this expense, approximately 40% of the population in African cities and up to 50% in Latin America are involved in urban agriculture, although these numbers vary by city (Mougeot, 2000). The urban agricultural system exists within the context of the national and international food system that supports each city, providing products that cannot be easily or inexpensively provided, such as perishable products, or those that require rapid delivery upon harvest (FAO, 2007). UPA is a critical source of income and food for low-income urban residents. Armar-Klemesu (2000) show that 11% of all irrigated croplands are in urban or peri-urban locations. A case study in Nairobi, for example, showed that when compared to their non-farming neighbors in low income neighborhoods, farming households consume more calories and protein and are significantly less dependent on gifts and remittances (Armar-Klemesu, 2000). Given this importance, we focus on identifying ways that UPA can be identified remotely through a mixed methods approach.

1.1. Challenges of mapping UPA

A critical part of identifying UPA is to identify the extent of urban areas. Remote sensing data has been used for decades to identify and map urban areas, starting with aerial photography and moving to satellite remote sensing. Despite the ongoing technical use of remote sensing information, there is still no standard definition of an urban area, nor are there agreed-upon spatial boundaries of urban areas around the world (Dorélien et al., 2013). This lack of a common framework makes it difficult to map urban extent because of the heterogeneous land cover types within urban areas, and the different ways ‘urban’ is defined across cultures and regions (Potere, Schneider, Angel, & Civco, 2009).

Using coarse resolution imagery combined with observations of anthropogenic lights, Schneider, Friedl, and Potere (2009)was able to identify urban areas using 500m MODIS data with a supervised decision tree classification algorithm. Part of this study was to identify what urban meant. In their study, all impervious surfaces, including roads, buildings, runways, parking lots, and other human-constructed elements that constituted more than 50% of the landscape unit was considered urban. Although this provided a clear framework for the analysis, this definition has not been widely accepted in the literature. For example, we visually assessed the urban core and metro areas of each city using the VHR data in Google Earth Pro. While initially we attempted to rely on the official boundaries of each city, that proved to be problematic given that both Harare (Commercial Farmers Union of Zimbabwe (CFUZ) 2010) and Ho Chi Minh City (Gubry & Le Thi, 2002) have extended their boundaries in the past to include fairly far-flung rural areas for food production and space for future residential development. With that in mind, an outline of each city was made within Google Earth Pro using the VHR data to determine areas of dense to fairly dense residential structures and road networks, taking care to exclude the transition to rural areas at the edges of the cities. In the case of Detroit, with such a sprawling metropolitan area, only officially registered urban farms within Wayne County (home of Detroit, Michigan, USA) discovered via data mining were also included.

Once we have identified urban areas, then distinguishing parks, undeveloped land and back yards from gardens is the second challenge. Thebo, Drechsel, and Lambin (2014) presents a global assessment of UPA that estimates that there are about 24 million hectares of UPA irrigated area. Further, they show that 60 percent of all irrigated croplands are within 20 km of an urban area. Thus determining if an irrigated field qualifies as UPA or not depends on the boundary of the nearby urban area. This analysis documented urban farms that fell into two categories: raised beds and open fields. Here, we exclude rooftop gardens due to the resolution of the satellite imagery and difficulties with geometry, although rooftop gardens are growing rapidly and contribute significantly to UPA in developed countries (Specht et al., 2014).

Many communities and institutions seek to register UPA activity through self-reporting and community engagement via the internet. The widespread availability of smartphones and computers with internet access has led to an expansion of online communities who grow their membership through networking and providing services such as extension, education and connection to employment and grants. An excellent example of such an online forum is the Urban Farming network (http://www.inuag.org/) that seeks to both network existing UPA and to foster the development of new farming activities. Formal institutions such as the Food and Agriculture Organization (FAO) of the United Nations and the U.S. Department of Agriculture (USDA) are using online, self-registration techniques to gather information about UPA across different urban areas. Although these efforts are new, they are likely to be effective ways of inexpensively fostering and growing the UPA activity across diverse urban areas.

Another key way our knowledge of ongoing UPA activities can be improved is by using data mining techniques. Web scraping of social networking sites such as Facebook, Twitter and Instagram, and intersecting economic, community development and agricultural data with geospatial information will enable a substantial improvement in our knowledge of the location and growth of UPA. There is no one source for identifying and mapping of UPA across countries, and thus our knowledge of its contribution to global food production is still quite uncertain.

The mixed methods approach we used made it possible to overcome the issues of classifying and monitoring urban farming across four disparate and different cities. Very high resolution (VHR) and moderate resolution imagery could be used together with non-imaging information discovered via data science methods about where farms are located to determine the possibility of identifying UPA remotely. Fig. 1 shows our overall methodology. Our objective here is to test methods that could identify UPA remotely to improve identification and change of food