A Pilot Study to Quantify Urban Agriculture

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Abstract

Community gardens, urban farms, and locally grown food are becoming increasingly popular in urban areas in the United States. The U.S. Department of Agriculture's (USDA's) National Agricultural Statistics Service (NASS) conducts many surveys; however, most do not adequately sample urban areas to obtain valid information regarding operations in these areas. In 2015, NASS collaborated with the Multi-Agency Collaborative Environment (MACE) to conduct a list building exercise for urban agricultural operations. An algorithm combining satellite imagery, web scraping results, and other publically available data were used to identify possible agricultural operations within the city limits of Baltimore, MD. A sample of the resulting list was selected, and an interview was conducted with each sampled operation's owner or resident. Information for this survey is compared to the NASS list frame to address issues, such as validation and under coverage. In this study, the methods used by MACE and NASS to identify and obtain information on urban operations are presented. The results from this pilot study are discussed, and some of the statistical challenges in calculating valid estimates addressed.

Key Words: Community gardens, Remote sensing, Urban Agriculture, Urban farms, Web scraping.

1. Introduction

In recent decades, agriculture of various types has become much more prominent in cities and other more developed areas in the U.S (Tjeerd and Girardet, 2000). The popularity of selling and serving locally sourced foods is continuing to grow and has become a priority in many areas. This has caused a need for food production to occur closer to where it is served or sold, often within cities, suburbs, and other urban areas (Tjeerd and Girardet, 2000). Some residents in these locations are producing their own food supply to reduce the food budgets of their families, provide healthier dietary options, or as a hobby (Feenstra, 1997). Many of these residents produce food in small personal gardens or farms in their own yards. However, operations, such as community gardens, have provided other alternatives for people who wish to produce their own food but do not have the space to do so. Organizations, such as churches and schools, have begun operating small farms, gardens and even small livestock operations in an effort to produce their own food, to raise money for their organization, or to educate students, members or other operators. Due to the increase in popularity of agriculture in urban areas of the United States, the USDA's National Agricultural Statistics Service (NASS) has been asked to explore methods that would increase the precision of the estimates of the number and production of these operations.

NASS collects vast amounts of data on farms and other agricultural businesses based on sampling from both area and list frames, as well as other methods. However, the primary focus of NASS is large production agriculture, which is predominately in rural areas. Urban agriculture differs from large production agricultural operations in rural areas and it is more difficult to identify urban operations. This leads to fewer of these operations being identified and added to the list frame of farms and potential farms maintained by NASS. Urban areas have a lower probability of being sampled during NASS's annual June Area Survey, than rural areas because the vast majority of the nation's agricultural production occurs in rural areas. Urban agricultural operations tend to be much smaller in physical space, production, and total sales than agriculture in rural areas (Tjeerd and Girardet, 2000). The size of the operation is often limited as operations may have to occupy small spaces including backyards and patios, vacant lots, rooftops, or warehouses. These restrictions in physical space tend to limit production and sales of businesses (Redwood, 2012). Operations that produce livestock typically raise far fewer animals than livestock farms in rural areas (Redwood, 2012). As a result of smaller scaled production, agricultural businesses in urban areas go in and out of business more frequently than large-scale farms (Redwood, 2012). Limited space also results in operations being more dispersed than operations in rural areas (Redwood, 2012). Production from agricultural operations is often more diverse in urban areas than in rural areas where production typically consists of only major commodities (Redwood, 2012). Urban agricultural operations often produce small amounts of numerous agricultural products. Finally, many operators may produce agriculture for their own uses and do not intend to sell their products making it difficult to classify and locate urban farms. Because of these factors, the estimates of agricultural activity in the urban areas have not been very precise.

Urban agriculture accounts for a small portion of US agriculture. However, interest in urban agriculture has been increasing. Cities have adopted policies favorable to urban agriculture in an effort to increase food security and to put vacant lots and buildings to productive use. To assess the efficacy of these programs, estimates related to urban agriculture must be improved. In an effort to meet these needs, NASS has begun exploring ways to better quantify urban agriculture. NASS partnered with the Multi-Agency Collaboration Environment (MACE) to conduct a pilot study. MACE is a collection of government agencies and contractors that develop and apply state-of-the-art technologies and methods to solve complex problems. The goal of this pilot study is to identify agricultural operations in an urban area using non-traditional data sources, and to assess the feasibility of the approach. MACE was tasked with developing repeatable and cost efficient methodology to locate potential urban agriculture in a manner that could be scaled to include all urban areas in the United States. Once a list of potential operations was developed using MACE's methodology, a sample was taken by NASS and USDA employees visited the sampled locations to determine whether agriculture was present. Information regarding any production, sales, and demographics of the operation was also recorded.

This paper describes the methods used to identify potential agriculture in an urban area and the initial findings from the pilot study. Section 2 describes the area of focus and the difference between a farm and a potential agricultural area. Section 3 describes the methods used to identify potential farms and the sample taken to verify agricultural use. Section 4 provides the findings from the sample of potential agricultural sites. In Section 5, conclusions are drawn and the lessons learned from this pilot study are discussed.

2. Scope of Study

One of the challenges to identifying agricultural operations in urban areas of the United States is to develop a clear definition of the operations that are in-scope. In order for MACE to create a list of potential operations, specification of the target areas and type of operations was required. A clear definition of "urban" needed to be established to provide geographical boundaries for urban agriculture.

For the purposes of this pilot study, NASS has chosen to use the definition of urban area defined by the U.S. Census Bureau. An area is classified as an "Urbanized Area" by the U.S. Census Bureau if it has a contiguous grouping of census blocks, each with a population density of at least 500 people/mi^2, with a total population that is at least 50,000 people (U.S. Census Bureau, 2016). This definition includes suburbs and other developed areas within the metropolitan areas associated with cities, but excludes the rural land that may be included if the entire county containing particular cities was used as the target area.

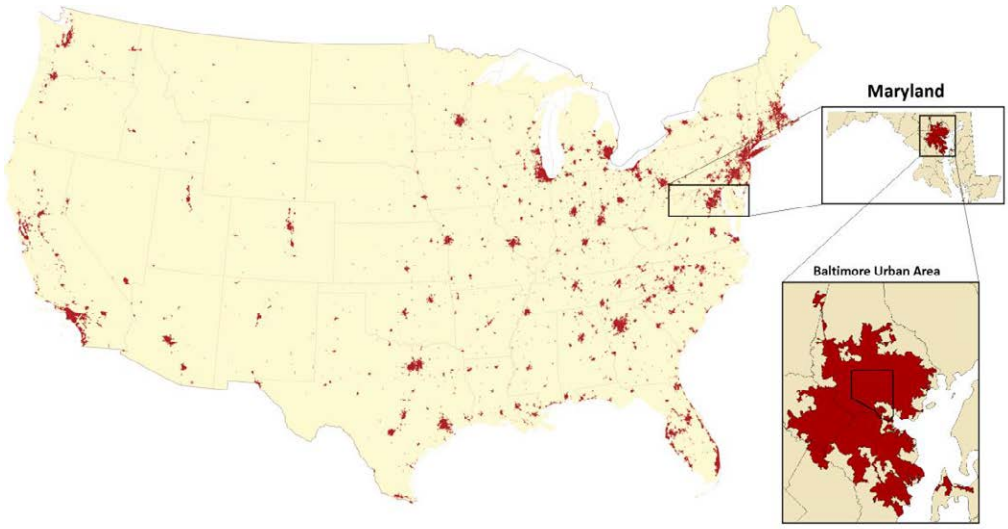

Figure 1: Map of the contiguous U.S. with urban areas shown in red. The urban area associated with Baltimore, MD is shown on the right. The city limits of Baltimore are outlined in black within this urban area.

This pilot study focuses on the urban agriculture in the City of Baltimore, Maryland. A map of all urban areas in the contiguous United States is shown in Figure 1. The inlay on the right of this map shows the urbanized area associated with Baltimore, as well as the city limits of Baltimore outlined in black. The urban area associated with the city is much larger than the city itself. Funding was not sufficient to include all of Baltimore's urbanized area. Thus, the pilot study was restricted to the City of Baltimore. MACE generated a list of potential agricultural operations that are within the city limits of Baltimore.

The USDA has defined a farm as an operation that produces and sells or has the potential to sell $1,000 worth of agricultural products within a year. Operations can be classified as

point farms if they do not sell $1,000 of agricultural products but have the potential to sell this much. In these cases, points are assigned to the operation based on its holdings. For example, an operation that owns horses may not sell anything within a year but points are assigned based on the number of horses owned. Other examples of point farms include other types of livestock and land used as permanent pasture. Point farms are included in the count of US farms.

Much of the agriculture in urban areas does not qualify as farms to the USDA. However, the interest of this study is not USDA defined farms, but all agricultural activity within an area. The combination of all agricultural activity in these areas contributes to the overall food security within the associated urban area and the entire country. Also, it cannot be determined whether an operation is classified as a farm based on the available data used in this study. Finally, agriculture in urban areas presents new challenges and the USDA definition of a farm may not be suitable to operations that exist in these areas.

During the development of a list of potential agricultural activity, information on the production or sales of an operation may not be available. Thus, the definition of agriculture needs to be broadened to identify possible agriculture that has the potential to be a farm. For the purposes of this pilot study, NASS and MACE agreed on the following description for agriculture of interest:

1) The agricultural area must have a minimum area of 36 ft^2.
2) The operation must exist within the city-government-defined city limits
3) The operation must be classified as one of the following types:
    a. Farms
    b. Garden
    c. Greenhouse/Hoophouse
    d. Livestock
    e. Beekeeping
    f. Hydroponics/Aquaponics

This definition excludes locations that have single vegetable plants, potted plants, window boxes, and various types of urban greenspaces with no agricultural value (e.g., parks or forests). In addition, mobile gardens, such as in the bed of a pickup truck, were excluded.

3. Methods

In order to create a list of potential farms in Baltimore, MACE, in collaboration with the U.S. Air Force Research Laboratory, used a combination of text and image analytics on a variety of different data sources. Text analytics were performed using a variety of different information available on the internet. Yahoo API searches were used to obtain search results from keywords specific to urban agriculture, such as “community garden”, and to extract location information about operations identified from the search results. In addition to the API searches of keywords, webcrawlers were used to automatically navigate through a much larger base of webpages. These webcrawlers used focused keywords to locate websites related to urban agriculture in Baltimore and extracted millions of webpages from the relevant pages. These websites were then filtered to obtain a list containing information regarding potential urban agriculture in

Baltimore. The Yahoo API searches and webcrawler results were used as an input in an automated procedure used to find the locations with agriculture. This automated urban agriculture finder used an algorithm that attempted to identify names and addresses from the input webpages and to return a list of potential agricultural sites along with a score indicating the likelihood that a site contained agriculture.

In addition to the automated urban agriculture finder, other publically available data was used to build a list of potential agricultural sites in Baltimore. Adopt-A-Lot, a Baltimore based non-profit program, was used to identify vacant lots in Baltimore that had been commissioned as gardens or for other agricultural use. This source produced the largest number of potential agricultural sites (Adopt-A-Lot sources identified 32% of the validated locations). Raising many types of livestock requires a permit from the city of Baltimore, including bees, chickens, and goats (Baltimore Office of Sustainability, 2016). These permits were obtained from the city or from the internet and the locations were identified as possible livestock operations. Some agricultural operations were also identified using open sourced research.

MACE attempted to enhance the lists of potential agricultural sites using high-resolution satellite imagery and imagery analytics. Three satellites were used (GeoEye, Pleiades, and Worldview 2), each with a resolution of 0.5 m^2. Images were obtained over 5 different dates between 2012 and 2014 in order to obtain imagery from different seasons and to evaluate changes in potential agricultural growth. Classification of agricultural sites was attempted using spectral classification and pattern recognition algorithms. Spectral classification attempted to identify agriculture based on the spectral signature of the pixels. Using pattern recognition procedures, characteristics specific to agriculture, such as crop rows or irrigation systems were identified.

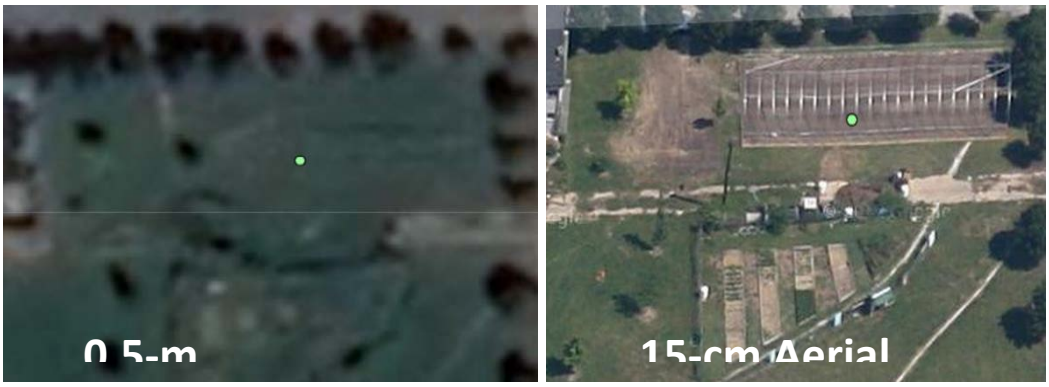

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Figure 2: *Comparison of an agricultural site using 0.5-m^2 satellite imagery (left) and 15-cm^2 aerial imagery (right). The green dots represent the same location in space.*

Imagery analytics using 0.5 m^2 satellite imagery was not particularly useful in identifying agriculture in this study. Spectral readings from agricultural sites could not be distinguished from non-agricultural greenspaces, such as parks or lawns. The resolution of the satellite images was also not fine enough for pattern recognition algorithms to identify agricultural features. Figure 2 shows an example of an agricultural operation captured with 0.5 m^2 resolution satellite imagery and with 15 cm^2 resolution aerial photography. The green dot in the image indicates the same location in space. It is

difficult to identify specific features in the satellite imagery that are easily recognized in the aerial photography. Thus, imagery analytics were not utilized to produce the final list of potential agricultural operations.

The result of MACE's list building effort was a list of 505 areas of potential agriculture. These records contained the operation name, location, contact information for a person of contact, and the operation type. Community gardens comprised the majority of operations based on the MACE classification, with 332 (66% of total records) sites. Open source imagery (Google Earth and Digital Globe) were used to validate these locations and to confirm the existence of agriculture. Of the 505 potential agricultural sites, agriculture could be confirmed at 159 of them with this imagery. The remaining 346 locations were identified as unique sites and had evidence of agriculture based on at least one web-based data source. Although agriculture could be confirmed at 31% of sites, imagery may be out of date and thus validation did not indicate that agriculture currently exists at a location. Figure 3 shows the locations of these sites overlaid on a satellite image of Baltimore city, as well as two zoomed in aerial views of specific sites. In the upper image, a community garden can clearly be identified (outlined in yellow). The lower image in Figure 3 shows several backyard or vacant lot gardens where evidence of agriculture is difficult to discern.

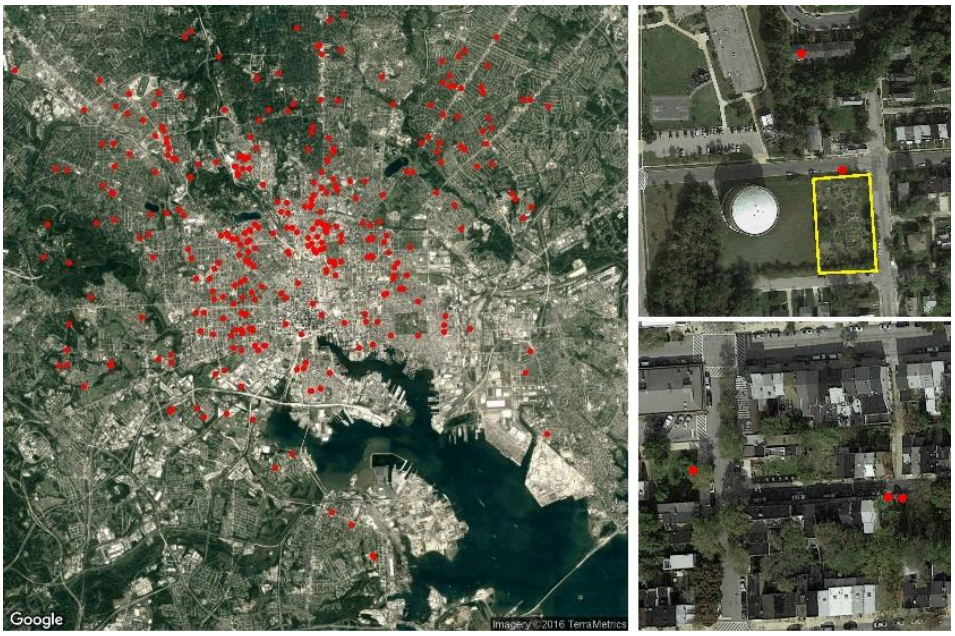

Figure 3: The 505 operations identified by MACE in the city of Baltimore, MD. The images on the right show zoomed in aerial views of some of these sites. The yellow outline shows a community garden visible in the aerial photography.

To evaluate the accuracy of the list MACE produced, a sample of the potential operations was taken and an in-person interview was conducted with the operator/resident at the sampled sites. A survey specific to urban agriculture was developed by NASS to record information about each operation including the types, quantity, and value of products that were produced, and information about the operators, such as demographics. The sample consisted of 266 randomly selected operations from the list of 505 potential agricultural

areas. For community gardens, the operation manager was interviewed but additional information was sought from the individual plot operators. However, identifying plot owners/operators was difficult and only 12 additional surveys were conducted from six of the community gardens. If the site operator/resident could not be found or interviewed, the enumerators attempted to record any information about the site that could be identified or obtained through observation, neighbors, or other sources. In some cases, gardens, livestock or other evidence of agriculture was recorded by the enumerators even though the operator could not be found.

4. Results

Of the 188 completed surveys, 108 of the sites reported agricultural activity (Table 1). These sites contained some evidence of agriculture but are not necessarily classified as a farm based on the USDA definition. The remaining 80 sites that had completed surveys reported no agricultural activity or agriculture that did not meet the target description (e.g., an abandoned community garden or a vacant lot with no agricultural activity). Table 2 shows the types of operations that were identified and how many were classified in each category. The large majority of these operations consisted of gardens of various types; either personal gardens or gardens managed by an organization. Figure 4 shows the general categories of commodities that each of the 108 sites reporting agricultural activity produced. As expected, the majority of operations produced fruits and vegetables (47% and 77%, respectively). Thirty-seven (34%) of operations raised livestock of some kind. Most of the sites reporting livestock raised bees or chickens; however, locations were also found that raised rabbits, goats, and pigs.

If an operator could not be found or the interview could not be completed for other reasons, enumerators were asked to observe whether the site contained any evident agricultural activity. In some cases, enumerators could observe a garden or livestock at the site or were able to talk to a neighbor to estimate agricultural presence. Of the 78 sampled sites for which a survey could not be completed, the enumerator reported evidence of agricultural at 31 locations (Table 1). The enumerator either reported no agricultural activity or could not determine whether the site had agriculture at the remaining 47 locations.

Table 1: Contingency table of the number of sites that had agricultural activity based on whether the enumerator could conduct an interview with the operator.

	Agriculture Present	*No Agriculture Present*	*Enumerator Could Not Report*	*Total*
Interview Completed	**108**	**80**	**0**	**188**
No Interview Completed	**31**	**34**	**13**	**78**
Total	**139**	**114**	**13**	**266**

The number of people employed or involved in the sampled agricultural operations was also examined. For those operations that responded to the survey and reported

agricultural activity, a total of 221 people were recorded as being involved. Thirteen (13) operations did not report a value for the total number of people involved in agriculture at the site. Forty-nine (18.4%) of the 108 sites reporting agricultural activity reported only one person being involved in the operation. The maximum number of people involved in a single operation was 25. Figure 5 shows percentage of operations having a specific number of people involved.

Table 2: The types of operations identified based on completed interviews. Some operations may be classified as two or more types..

Type of Operation	*Number of Operations Found*
Backyard/Personal Garden	34
School Garden	29
Community Garden	20
Urban Farm	8
Demonstration Garden	9
Rooftop Garden	4
Vacant Lot Garden	5
Aquaponics	1
Hydroponics	1
Other	7

Twenty of the sampled sites were classified as community gardens. Typically, community gardens offer plots for rent or to be used by different individuals. Thus, the number of people involved in these operations may differ from the number involved in other types of operations. Figure 6 shows a boxplot of the number of people involved in community garden operations and all other operations. It is clear that the mean and median number of people involved in sites classified as community gardens is greater than the number involved in all other operations. The median number of people involved in sites labeled as community gardens was 2.5 versus a median of 1 operator for all other operation types. It should be noted that responses to this question may not be consistent across all operations. Some operations may include the individuals who use each plot while others may only include management or employees of the operations.

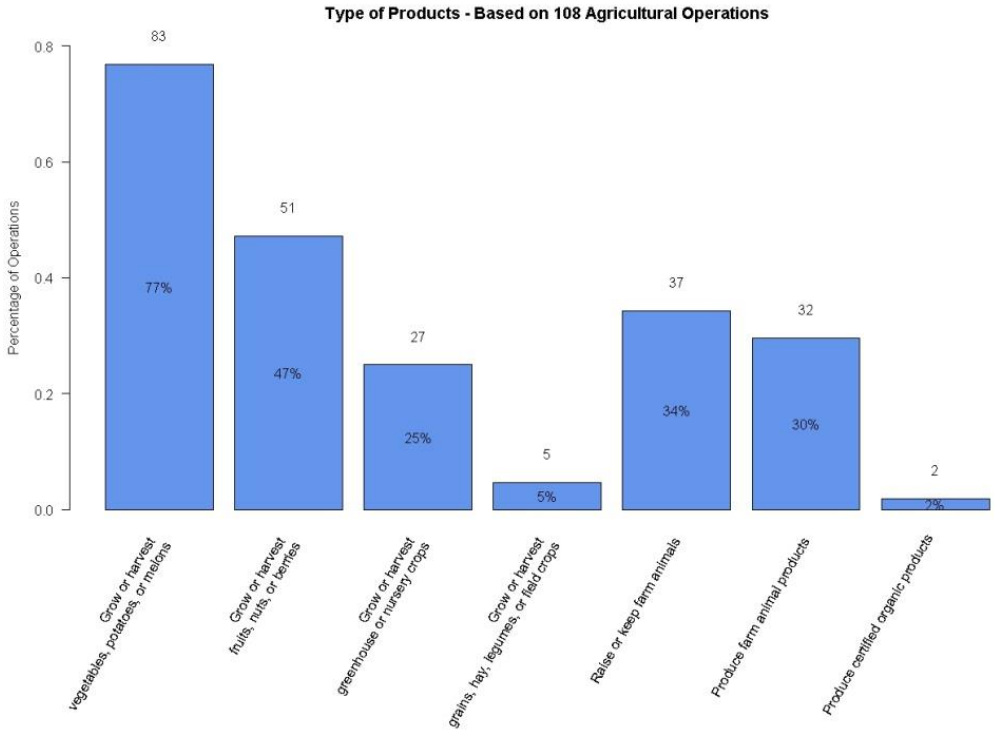

Figure 4: Number of operations that produce each category of commodity. Percentages indicate the percentage of operations out of the 108 respondents reporting agriculture. Operations may fall into multiple categories.

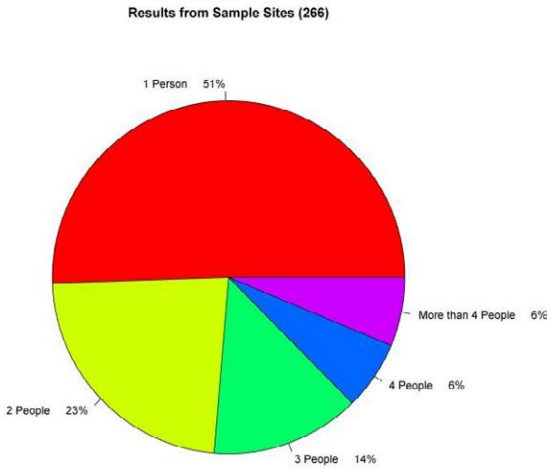

Figure 5: The number of people who are involved in each sampled site reporting agricultural activity. Thirteen operations did not respond to this question.

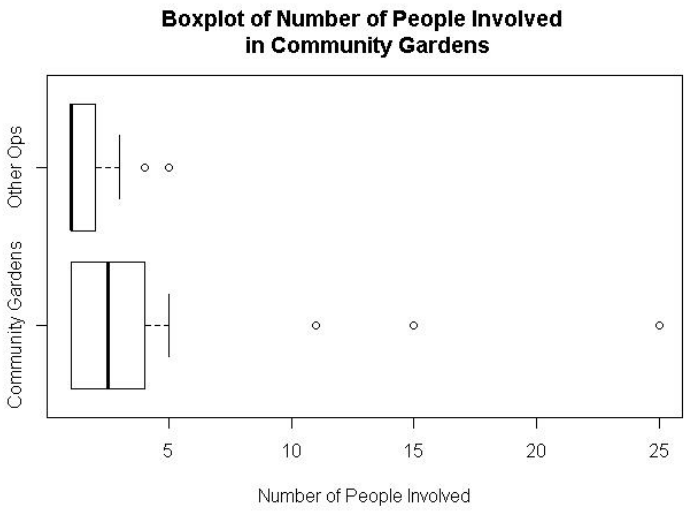

Figure 6: Boxplots of the number of people who are involved in each sampled site reporting agricultural activity. Community gardens had a greater number of people involved in decision making.

5. Conclusions

From this pilot study, NASS learned many things about its capabilities of classifying urban agriculture using these methods. One of the most surprising findings is that satellite imagery with 0.5 m^2 resolutions was not particularly useful at classifying agriculture. Spectrally, most agriculture used for production could not be distinguished from other types of community greenspaces. The resolution was also not high enough for pattern recognition algorithms to identify features that are characteristic of farms. In fact, agriculture could not be identified by eye using aerial imagery at a majority of sites. Thus the minimum area requirement of 36 sq. ft^2 will not be used for future projects as operation size cannot be determined by web based data in most cases.

Text analysis using multiple sources of publicly available data scraped from the web was useful in identifying agricultural areas. Much was learned about which data sources were useful for detecting potential farms, the types of operations found based on these methods, and the limitations of list building using web scraping. Many community gardens and other operations with web presence could easily be found; however, identification of personal gardens is difficult without the capabilities of satellite data. It is possible that this methodology could vastly increase the number of urban farms on NASS's list frames, allowing for estimation of these operations with greater precision. However, funding is not available to apply this approach to urban agriculture in the 2017 Census of Agriculture. MACE's methods are currently being used to obtain a list of Local Foods operations so that a capture-recapture methodology can be implemented to estimate these businesses. This approach is also being used for a pilot study in the state of Washington to improve NASS's ability to detect small, difficult-to-find farms.

Challenges were also presented with operators' abilities to provide specific information in the survey created specifically for urban agriculture. NASS defines farms based on agricultural production with intent to sell. However, much of the urban agricultural activity was identified as produced for home use. Many people had difficulty answering

questions specific to the quantity, value, or space used for individual commodities. Operators that did not produce food to be sold were often unable to report the weight or value of their production. This type of production is most challenging to estimate and may be excluded from future studies related to agriculture in urban areas. If these types of agricultural activity are to be included, the survey will require revision in the future in order to provide more useful data.

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