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Research Article

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Spatial distribution and socioeconomic differences between urban farms' production and distribution points in Chicago, IL

Abstract

Urban farming remains popular as a potential sustainable replacement or supplement for traditional agricultural models, but little comprehensive research has been done regarding the socioeconomic characteristics of this food production and distribution model. Using the City of Chicago as a case study, this research seeks to understand where urban commercial farms are located and whether there exists a significant disparity between the social demographics of the neighbourhoods where these farms produce crops compared to where their goods are sold. The distribution of urban farm and sale points was determined by geocoding the location of all production (farms) and distribution points (sale points) for commercial urban farming companies in Chicago, then calculating spatial statistics and calculating the mean centers, standard distance, and standard deviational ellipses (SDE) for each. These were then overlaid onto choropleth maps containing socioeconomic indicator data derived from the US 2016 census. These socioeconomic indicators — median annual household income, mean home value, and percent racialized minority population — were analysed to determine if a correlation exists between each socioeconomic indicator and the location of farm and sale points. Findings reveal statistically-significant differences in the socioeconomic indicators of census tracts of farm versus sale point locations, showing a skewness in distribution of farm locations towards areas of lower socioeconomic status versus a skewness in distribution of sale point locations towards areas of higher socioeconomic status. The results suggest that, while farms are more likely to be located in marginalized neighbourhoods in Chicago, most produce grown by these farms is sold in more privileged areas.

Introduction

Food inequality occurs at every scale of production and distribution. At international and local scales, food tends to be produced in lower-cost areas and then redistributed to higher-value areas for sale. In North America, food is largely produced in poorer rural areas, and then sold in comparatively wealthier cities, but the food distribution and access within these cities can vary wildly[3]. This variation in food access is referred to as food insecurity, which is defined as "a lack of consistent access to enough food for an active, healthy life"[4] and is a major problem in many North American cities, including Chicago, where 600,000 residents are food-insecure[5]. Food deserts, areas of high food insecurity where residents have little or no access to stores and restaurants that provide fresh, healthy, and inexpensive foods[6], are particularly prevalent in marginalized communities[7,8] within cities. In an effort to make food systems and cities more sustainable, many have looked to urban farming, believing that bringing food production closer to the people it serves may reduce disparity. Urban agriculture, the practice of cultivating, processing, and distributing food in or around urban areas, can be divided into two main categories: private gardens and farms[9]. Although they use the same intensive cultivation methods as other commercial agriculture, commercial urban farms are different in that they produce food on a local scale in a metropolitan setting for widespread distribution to retailers within the city.

Some have suggested that urban farms could serve to address food insecurity in impoverished neighbourhoods. Thus, urban farms have been a popular model of social and environmental sustainability amongst city planners. However, it remains unclear whether residents living proximally to such farms benefit from the farms' presence and outputs. Little is understood about where and how urban farmers distribute their food, and, most importantly, to whom[10]. Since food insecurity is a matter of physical as well as social and financial distance from healthy produce, there is potential for urban farms to address food deserts[11], but there are also concerns these farms may do more harm than good. Studies show that many city greening projects, such as urban agriculture, result in eco-gentrification - when property values rise surrounding urban greening projects, displacing local businesses and residents[12]. The presence of farms in urban areas may serve to take up space while transporting food to wealthier neighbourhoods or providing food that is financially inaccessible.

In order to examine the potential socioeconomic inequalities underlying distribution of commercial urban farms and sale points, Chicago, Illinois, one of the most segregated cities in the United States[13], was selected as the study area for this study. Concurrently, through advocacy, policies, and projects, Chicago has made efforts to build a local, sustainable urban food system[14]. The city has proved fertile ground for the study of urban agriculture, with over 890 farms, gardens, and other initiatives[15], including a number of commercial farms that serve as the basis for our research. Therefore, Chicago lends itself well to examining if there are social or economic differences between the location of urban commercial farms and their sale points.

When considering the social implications of urban agriculture, there is a bias in the research towards smaller-scale efforts like community gardens[10], which leaves a wide knowledge gap regarding commercial urban farms and their social impacts. Therefore, our research aimed to examine any socioeconomic differences between urban commercial farm locations and their sale points in the city of Chicago.

The purpose of our research was two-fold:

- Firstly, this research aimed to understand where urban farms and their sale points are located and if there is any pattern to their distribution throughout the city of Chicago.

- Secondly, if there is a pattern, this research investigated if any disparities exist between the socioeconomic indicators of areas where urban farms are located, versus the areas where their sale points are located.

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This research would contribute to understanding if there is a tendency for urban farms to be built in socially vulnerable areas while serving more privileged communities.

Methodology

2.1 Spatial Data

First, a spreadsheet of commercial urban agricultural production points (farms) and distribution points (sale points) was obtained. Farms were classified as places where produce is grown, and sale points as where the produce is sold. All urban agriculture projects in Chicago were located using the CUAMP database[16] and selected from locations classified as "Urban Farms". From there, each location was manually reviewed and filtered so that all selected results all met the following criteria:

• Farms that grow produce for sale;

• Farms that are not community gardens;

• Farms that have sufficient available information (location, publically accessible website, published distribution/sale points).

These criteria generated a list of 27 farms within Chicago's municipal boundaries. To determine the farms' sale points, data about sale points was collected from each farm's website to see where the produce was sold. Sale points were used as a proxy for access to produce grown by urban commercial farms. In total, there were 112 sale points. Each farm and sale points' address, name, larger parent company, and ZIP code were entered into a spreadsheet.

For spatial analysis, the production and distribution points were geocoded using GIS software via ArcGIS World Geocoding Service. Geocoding is the process of assigning an XY coordinate pair to the description of a place[17].

2.2 Spatial Statistical Methods

To measure differences between production and distribution points, three spatial statistical measures were calculated: mean center, standard distance, and standard deviational ellipse (SDE). Mean center, a widely-used measure of central tendency in point features, used all farm and sale points, respectively, to determine the mean location of each. Standard distance and SDE are measures of spatial dispersion. To determine the amplitude of spatial spread of data points, the standard distance, which is the radius of one standard deviation from the mean center, was calculated from the mean center of farm and sale points. Because standard distance does not capture directional bias, the SDE was calculated for urban commercial farm locations and sale point locations using the mean center and dispersions along a major and a minor axis in order to define the direction of maximum spread of the distribution[18]. An asymmetrical and elliptical SDE indicates skewness and bias in spatial distribution and allows for visual interpretation of the skewness of spatial points.

To visually determine the farm and sale points' respective distributions in relation to the socioeconomic make-up of different Chicago neighbourhoods, we created a choropleth map using census data published from the 2016 US Census[19]. Indicators of socioeconomic status were median annual household income, mean home value, and percent racialized minority population, a measure that represents the non-white population percentage. The standard distance and SDE for the comparison of farm and sale points' distributions to one another as well as to their census tract information. Next, statistical analyses were performed to provide further evidence in support of the visual relationships.

2.3 Statistical Analyses

A spatial join was performed in GIS to relate census tract demographic data with farm and sale point ZIP code locations. Then, "social difference" was analyzed to determine the difference between the socioeconomic indicators of farm and sale point locations. First, the aggregate mean values for each indicator were calculated for all the farms and sale points and then compared on a 1:1 basis. An identical operation was performed for median values.

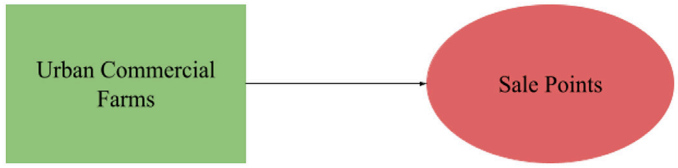

Figure 1. The green box on the left represents the aggregate mean or median data for all 27 farms, and the red oval on the right represents the aggregate mean or median data for all 54 sale points. By comparing the data on a 1:1 basis, differences between socioeconomic indicators were numerically determined.

For more granularity, social difference was analyzed in a 1:many relationship, in which each of the 27 farm locations was considered individually. Here, farm location was assumed to distribute produce equally to all associated sale points. To compare the socioeconomic indicators between individual farm locations and their associated sale points, the mean value of each indicator was calculated for all sale points (many) associated with each individual farm (one) and repeated across each of the 27 farms.

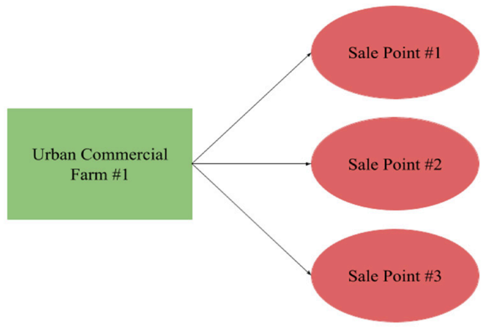

Figure 2. The green box represents a single farm location and its corresponding indicator data. The red ovals represent associated sale point locations and their corresponding indicator data. Sale point indices were averaged and compared to singular urban farm indices. Comparing data on a 1:many basis demonstrates socioeconomic indicator differences for each farm location.

The general premise of the social difference calculation is to subtract the mean or median value for each socioeconomic indicator of farm locations from the same socioeconomic indicator of sale point locations. The result demonstrates the indicator's direction of change:

$$\textit{Social Difference}_{(general)} = \textit{Sale Point Socioecon. Indicator - Farm Socioecon. Indicator}$$

To ensure the direction of change was not influenced by the calculation method, calculations were performed differently for each conceptual relationship.

For the 1:1 relationship, the mean or median value of the socioeconomic indicator for all farms was subtracted from the mean or median value of the same indicator for all sale points.

$$\textit{Social Difference}_{(1:1\ mean)} = \textit{Mean(Socioecon. Indicator for Sale Points) - Mean(Socioecon. Indicator for Farms)}$$

$$\textit{Social Difference}_{(1:1\ median)} = \textit{Median(Socioecon. Indicator for Sale Points) - Median(Socioecon. Indicator for Farms)}$$

For the 1:many relationship, farms' socioeconomic indicator value was subtracted from the associated sale point mean indicator value.

$$\textit{Social Difference}_{(1:many)} = \textit{Mean(Socioecon. Indicator for Associated Sale Points) - Farm Socioecon. Indicator}$$

A table (Table 1) was created consisting of 27 rows representing each farm, and columns representing the change in each socioeconomic indicator moving from farm to sale point. Mean and median social difference values for each socioeconomic indicator were calculated from this table.

2.4 Test for Statistical Significance

The Kruskal-Wallis H-test was used to determine the statistical significance of socioeconomic indicators' difference. The Kruskal-Wallis test is a rank-based nonparametric test used to determine if there are statistically significant differences between the medians of two or more groups[18]. Given that the data in this analysis were very skewed, we opted to conduct the Kruskal-Wallis H-test, which makes no assumptions about normality[18]. The Kruskal-Wallis H-test assumes the observations in each group come from populations with the same distribution shape, that the samples are independent, and that the dependent variable is continuous[18], assumptions with which our data aligns.

Within the 1:1 framework, the Kruskal-Wallis test was conducted to assess if the difference between medians is statistically significant. Assessing inferential statistics of the 1:many relationship is outside the scope of this research question. Rather, we seek to determine if there is a difference in aggregate between socioeconomic indicators of farms and sale points.

2.5 Calculation Method

Procedurally, the Kruskal-Wallis H-test involves pooling observations (k) from the samples into one combined sample, then ranking them in ascending order from 1 to N where $N=n_1+n_2+n_3+\ldots+n_k$[20]. When ranking, the sample from which each observation originated from is tracked[20]. Next, the test statistic, H, is calculated:

$$H = \left(\frac{12}{N(N+1)}\sum_{j=1}^{k}\frac{R_j^2}{n_j}\right) - 3(N+1)$$

Where N=the total sample size, n_j=sample size of the j^{th} group, and R_j=the sum of the ranks in the j^{th} group[20]. The Kruskal-Wallis H-test was conducted using R, at p-values of 0.10, 0.05, and 0.01, testing for different levels of statistical significance.

Results

3.1 Mean Center and Standard Distance

As can be seen in Figures 1-3, the distribution of farms and of sale points differ visually, which is shown by the different mean center locations and different standard distance radii. The sale points' standard distance from the mean center is larger than for the urban commercial farm locations, indicating that sale points are more dispersed. Conversely, urban commercial farm locations are more densely clustered.

3.2 Standard Deviational Ellipse

Additionally, Figures 1-3 depict the results of the SDEs for farm and sale points. Chicago's municipal borders and lake shoreline contribute to the city's northwest-southeast leaning shape, which affect the SDE narrowness and diagonal skewness. The differences between the SDEs can be visually judged, however, by the size of their major and minor axes and by the ellipses' location around their mean centers. The major and minor axes of the sale points' ellipse are greater in size than those of the farms' ellipse, indicating a large north-south (X) and east-west (Y) spread. Conversely, the major and minor axes of the farm points are smaller, indicating more spatial clustering in a smaller north-south (X) and east-west (Y) range. When comparing the skewness visually, it is obvious that sale point locations slant toward the north of Chicago, and census tracts with higher socioeconomic indicators. Conversely, urban commercial farm locations are located in the centre and south parts of the city, skewing toward census tracts with lower socioeconomic indicators. Statistical analysis in the following sections will numerically support this relationship.

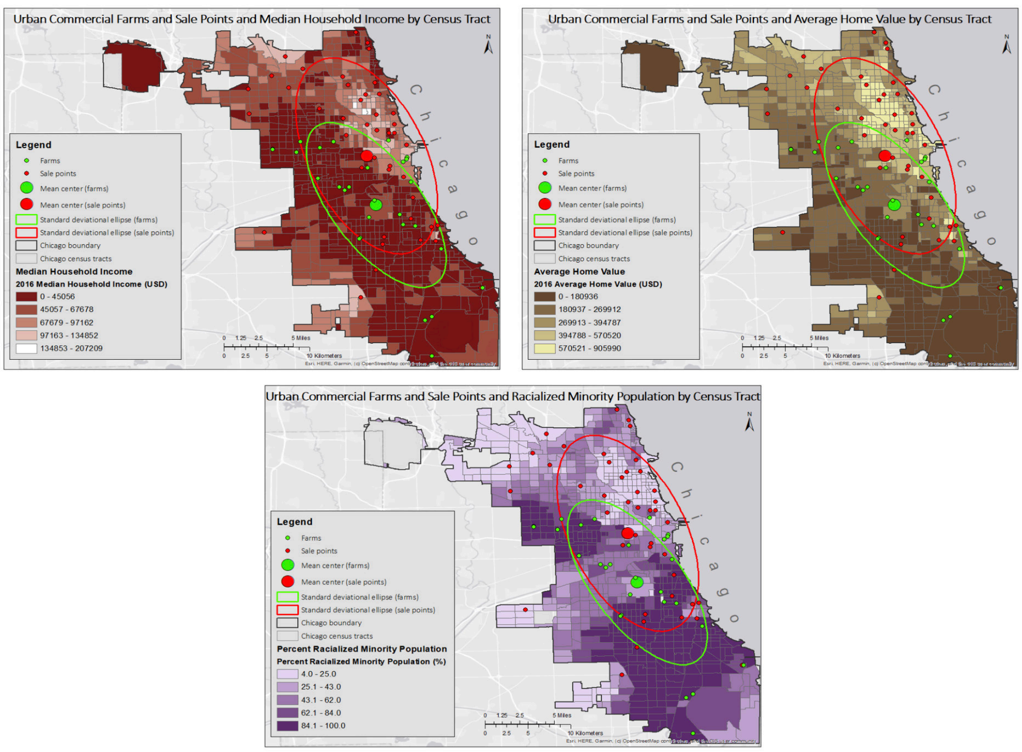

Figure 3. (Clockwise). All figures show the spatial distribution of urban commercial farms and sale point locations in Chicago overlaid on census tracts showing various socioeconomic indicators. The maps show the mean center and the standard deviational ellipse for farms and sale points respectively. A) Median Household Income by Census Tract. B) Average Home Value by Census Tract. C) Percent Racialized Minority Population by Census Tract.

3.3 Maps and Spatial Distribution of Socioeconomic Indicators

Median Annual Household Income by Census Tract

Figure 3A shows the median annual household income by census tract. Breaks in median income were determined using US Federal tax brackets[21]. The mean center of the production points (farms) is located in a lower-income neighbourhood, compared to that of the distribution points (sale points). Additionally, the SDE of sale points skews toward higher median income census tracts. Conversely, the SDE of farm points is narrower, primarily encompassing census tracts that fall within the two lowest income tax brackets.

Mean Home Value by Census Tract

Figure 3B shows the mean home value by census tract. The mean centers are in census tracts with similar home values: $269,913-$394,787 for commercial urban farms and $394,788-$570,250 for sale points. The SDE of sale points skews toward census tracts with higher mean home values, compared to the SDE of farm locations.

Percent Racialized Minority Population by Census Tract

Finally, Figure 3C shows the percent racialized minority population by census tract. The racialized minority populations are similar for the census tracts underlying each mean center. However, similar to median income and mean home value, the sale points SDE skews toward census tracts with smaller racialized minority populations, whereas farms' the SDE skews towards census tracts with higher percent racialized minority populations.

3.4 Results from Relationship Frameworks and Kruskal-Wallis H-Test

Descriptive Statistics – 1:1 Relationship

Table 1A below shows that, across mean and median values, sale points are consistently located in areas with higher median household incomes, higher mean home value, and lower percent racialized minority population. The exact opposite trend is observed for the socioeconomic indicators of farm locations.

Descriptive Statistics – 1:many Relationship

As indicated by Table 1B below, there is much variation in social difference when examining the socioeconomic indicators on a farm-by-farm basis, compared to those of its sale points. Social difference results of the 1:many relationship include negative, positive or zero values. A positive value indicates that sale points' socioeconomic indicator is higher than farms' socioeconomic indicator. Conversely, a negative value indicates that sale points' socioeconomic indicator is lower than for farms. A zero value indicates no change. More research should be conducted to understand the reasoning behind the variation. However, despite the variation, the mean and median values of the 1:many social differences support the 1:1 relationship findings above. Median household income, mean home value, and percent white population are higher on average where sale points are located, indicated by the positive values in Table 1B. Conversely, percent racialized minority population is lower in areas with sale points than it is in areas with urban commercial farms.

Table 1. (Top to bottom) A) Mean and Median Values of Socioeconomic Indicators as calculated in the 1:1 Relationship to compare farms and sale points on aggregate; B) 1:many Relationship mean and median values of socioeconomic indicators. A positive value indicates that sale points' socioeconomic indicator is higher than farms' socioeconomic indicator. Conversely, a negative value indicates that sale points' socioeconomic indicator is lower than for farms. A zero value would indicate no change.

A) 1:1 Relationship Mean and Median Socioeconomic Indicators.

		Median Household Income (USD)	*Mean Home Value (USD)*	*Percent Racialized Minority Population (%)*
Mean	**Farms**	38,331.15	228,352.15	73.52
	Sale Points	57,284.81	329,099.76	50.07
Median	**Farms**	28,531.00	179,557.00	84
	Sale Points	54,350.50	283,247.00	45

B) 1:many Relationship Mean and Median Socioeconomic Indicators. Positive values indicates that sale point value > farm value. Negative values indicate that sale point value < farm value. A value of zero indicates that sale point value = farm value.

				1:Many Social Difference		
Parent Company (Numbered)	***Farm (Numbered)***	**Number Urban Commercial Farms**	**Number Sale Points**	**Median Household Income (USD)**	**Mean Home Value (USD)**	**Percent Racialized Minority Population (%)**
1	*1*	1	1	0	0	0
2	*2*	1	2	69,264.00	259,659.50	-63
3	*3*	1	29	43,116.76	276,371.59	-57.86
3	*4*	1	29	43,116.76	276,371.59	-57.86
4	*5*	1	4	23,117.75	106,644.50	-42.25
4	*6*	1	4	23,117.75	106,644.50	-42.25
5	*7*	1	3	17,935.00	79,445.67	-29
6	*8*	1	1	0	0	0
6	*9*	1	1	-37,566.00	-41,756.00	55
7	*10*	1	9	8,146.56	40,644.78	17.11
8	*11*	1	1	-77,019.00	-527,456.00	44
8	*12*	1	1	-77,019.00	-527,456.00	44
8	*13*	1	1	10,781.00	-113,866.00	-23
8	*14*	1	1	12,948.00	22,405.00	-24
8	*15*	1	1	0	0	0
8	*16*	1	1	-29,721.00	-168,062.00	38
8	*17*	1	1	7,660.00	-96,414.00	-10
8	*18*	1	1	-2,047.00	-47,539.00	-22
9	*19*	1	4	36,337.75	127,792.25	-30.25
9	*20*	1	4	30,793.75	57,025.25	-31.25
9	*21*	1	4	-20,238.25	-112,886.75	27.75
9	*22*	1	4	-19,995.25	-107,019.75	20.75
9	*23*	1	4	13,853.75	272,858.25	22.75
9	*24*	1	4	38,580.75	116,040.25	-29.25
9	*25*	1	4	17,130.75	53,627.25	20.75
9	*26*	1	4	27,597.75	155,305.25	-28.25
9	*27*	1	4	26,979.75	146,295.25	-0.25
	Average	-	-	**6,921.20**	**13,136.12**	**-7.42**
	Median	-	-	**12,948.00**	**40,644.78**	**-10**

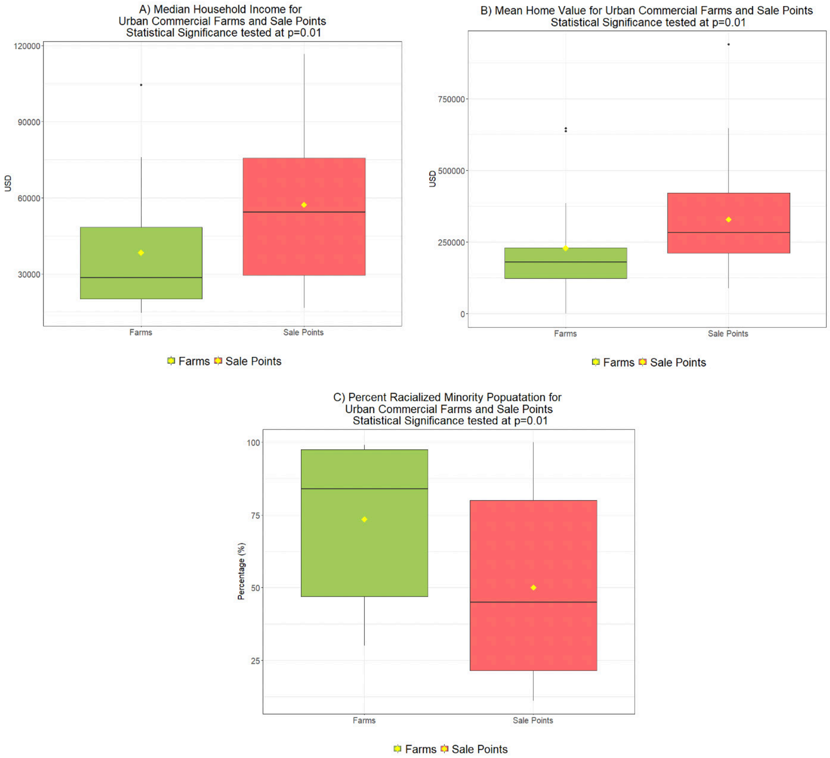

Figure 4. (Clockwise). Boxplots showing the mean and median values for each socioeconomic indicator as calculated by the 1:1 relationship. Here, all farms were compared to all sale points on aggregate and tested for statistical significance at p=0.01. A) Boxplot showing Median Household Income. B) Boxplot showing Mean Home Value. C) Boxplot showing Percent Racialized Minority.

Inferential Statistics

Additionally, to quantify the visual relationships that the maps indicate, the Kruskal-Wallis H-test was conducted for the 1:1 relationship. The boxplots in Figure 4 show the mean and median results for each socioeconomic indicator. By the Kruskal-Wallis H-test, the null hypothesis that the farm and sale point median values are equal is rejected for every socioeconomic indicator at 99% confidence. As such, sale point locations are significantly correlated (p=0.01) with census tracts of higher median household income, greater mean home value, and lower percent racialized minority population. Farm locations are significantly (p=0.01) correlated with the opposite trend.

3.5 Social Difference Results

Across different calculation methodologies, the same trend is repeated. Higher indicators of socioeconomic status are found across both mean and median 1:1 and 1:many calculations, and are found to be statistically significant. As such, our findings (Table 2) are not a result of a specific calculation methodology. Therefore, it can be concluded that sale point locations are significantly correlated with areas of higher socioeconomic status whereas farm locations are significantly correlated with areas of lower socioeconomic status, and thus, that there is a "social difference" between areas of production and of distribution.

Table 2. Mean and median social difference values for 1:1 and 1:many relationships. Meaning of positive values for socioeconomic indicators: sale point value > farm value. Meaning of negative values for socioeconomic indicators: sale point value < farm value.

Summary of Social Differences

	Median Household Income (USD)	Mean Home Value (USD)	Percent Racialized Minority Population (%)
1:1 Mean	18953.67	100747.61	-23.44
1:1 Median	25819.50	103690.00	-39.00
1:many Mean	6921.20	13136.12	-7.42
1:many Median	12948.00	40644.78	-10.00

Discussion

4.1 Interpretation and Implications

Hoping to narrow food access inequalities by bringing production into cities and increasing the supply of fresh produce in food-insecure areas, urban farms have been touted as a model of environmental and social sustainability. However, comparatively little research has examined distribution patterns of food grown in urban locales. As such, this paper examines if there are underlying socioeconomic differences between where food is grown versus where food is distributed in Chicago, Illinois.

There are two key findings, both of which have broader implications for the study of urban farming in major metropolitan cities such as Chicago. First, the majority of urban farms in the city appear to be located in areas of lower socioeconomic status. This holds true for all socioeconomic indicators, including median annual household income, mean home value, and percent racialized minority and white population. Second, while farms may grow most of their produce in lower-income areas, it is largely being sold in areas of higher socioeconomic status. The majority of sale points associated with the farms analyzed in this study were located in regions with a higher mean home value, higher median annual household income, and lower percent visible minority.

It appears that whiter, wealthier neighbourhoods might have more access to fresh produce being grown within the bounds of the City of Chicago, despite that food being grown in marginalized communities at risk of food insecurity. The benefit produced by these farms, in the form of healthy food, is being transferred out of the neighbourhoods that provide these farms with infrastructure use and space, and into more privileged areas.

It is clear that living proximally to an urban farm does not secure access to fresh, healthy food which challenges the notion that urban commercial farms help alleviate food insecurity. One of the many hopes of urban agriculture is that producing food within cities could help supplement the nutritiously poor and limited diets of residents in urban food deserts[11,22,23]. Yet, even when farms are directly located in areas associated with higher food insecurity, they do not seem to reduce the physical barriers of access that plague residents of food deserts within Chicago.

Our findings suggest that higher-income neighbourhoods may benefit the most from urban farms, thereby challenging the idealized image of urban farming, often seen in environmental and public spaces as a panacea to food insecurity and conventional farming.

However, the findings of this study suggest that urban commercial farms are not serving the communities where they are located, at least not with the food they are growing. The socioeconomic difference between farm location and sale point location means that there is an externalisation of costs to poorer neighbourhoods and a net transfer of benefits to more privileged populations. Our research shows that commercial urban agriculture, as implemented in Chicago, selects for and reinforces the same conditions found in conventional agricultural systems — production in low-cost areas and distribution to higher-income areas. We propose that this urban agricultural model in Chicago has not actually served the purpose of improving equity of food access but has instead scaled down and localized this systemic failure to the city of Chicago. If we are to endorse the current urban agriculture model as a solution to feeding future cities, then we must take a sober and critical approach to the existing systems.

This research was conducted in Chicago, Illinois, which is located in a developed country in North America, inevitably restricting any implications for questions of urban agriculture in developing nations. Also, Chicago is one of the most segregated cities in the world[13], potentially amplifying any inequalities demonstrated by this case study regarding urban farms. While our work provides a foundation for potential future research, one must be cautious in generalizing our findings to other urban areas. Additionally, this is a cross-sectional study that looks at the state of urban farming in 2016. Inferences regarding changes in possible socioeconomic indicators over time potentially due to the creation of urban commercial farms are outside the scope of this study.

This research does not account for any outputs that urban commercial farms may produce beyond the sale of produce. Many of these companies have stated social missions, including community-building, agricultural education, and employment, implying that their benefit might extend beyond physical products[25-31]. The impact these additional social programs might have on residents of neighbourhoods adjacent to these farms is outside of the scope of this study.

Finally, this study only considers physical access to produce, not financial access. As mentioned before, food deserts can be caused by a lack of healthy food within a physically accessible vicinity, or they can occur if produce is physically available but financially inaccessible[32].

There are a number of avenues for potential future research. An exploration of the financial accessibility of urban commercial farm produce will provide further insights into these companies' capacity to address food insecurity and whether urban-produced food is more expensive than traditionally produced food. Furthermore, with the understanding provided in this paper that urban farms may be more likely to reside in low-income neighbourhoods, future research could explore possible eco-gentrification as a result of massive farms purchasing real-estate in these neighbourhoods. Finally, additional research is needed to understand the full social implications of urban farms, specifically with regards to their purported social missions[10].

Conclusion

Using Chicago as a case study, this research sought to understand where urban commercial farms are located and whether there exists a significant disparity in the social demographics of neighbourhoods where urban commercial farms produce crops, compared to where their goods are sold. Our results proved the existence of this disparity, showing that the majority of Chicago urban farms appear to be located in areas with lower socioeconomic status while their produce is largely being sold in areas of higher socioeconomic status. Living proximally to an urban farm does not secure access to fresh and healthy produce, because the benefits of the commercial urban farms are being transferred to more privileged communities. Our findings challenge the mainstream perception that the urban farm model is a sustainable solution to food inequality and suggest that it simply condenses and reinforces the pre-existing inequities inherent in conventional food systems.

While acknowledging our limitations, we hope that our findings will open up future research avenues, contributing to the current understanding of the socio-economic impacts of commercial urban farms and providing a knowledge base to create a more socially-just urban agriculture model.

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