Spatial analysis of influence of urban agriculture on food insecurity and stunting in Yogyakarta, Indonesia

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Abstract

Since 2000s there has been a renewed interest in the role urban farming plays on food security. Here we contribute to two branches of this literature: one promoting the use of geographic information systems to map urban systems and the other examining how urban farming contributes to malnutrition and stunting mitigation. We aim to produce a spatial visualization of the Yogyakarta, Indonesia urban farming system and examine the extent with which it mitigates childhood stunting the city. We conducted a survey to a sample of urban farmers where along with production and socio-economic information we collected information on the exact location of the farms. Our findings reveal a very diverse urban farming system both in terms of crops and areas of the city. Most farmers in our sample produce for auto-consumption and the majority is managed by women. The size of the farm, the use of polybags and hydroponic production technologies increase the odds of selling, while female managers decrease them. Then we investigate how urban farming mitigates childhood stunting, finding that it decreases when women manage the farm, age of farmer, number of children in the household and levels of education.

Keywords Urban farming, food security, malnutrition, stunting

JEL code R11, Q12, Q180, H14

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1. The role of urban farming in food security

According to the United Nations Department of Economic and Social Affairs (2019) by 2050 68% of the population will live in urban areas. In the last decade there emerged a debate on how urban farming could contribute to food security in cities. The literature suggests it is unlikely urban food production will significantly contribute to food security, still can contribute to the provision of a significant proportion of high value horticultural products (Korth et al., 2014; Grafius et al., 2021). Of particular interest, is the role urban farming may play mitigating malnutrition and stunting in fast growing developing country cities (Zezza and Tasciotti, 2010; Orsini et al., 2013; Siswati et al., 2022).

In Southeast Asian cities urban farming has the potential to increase low-income households' food security (Orsini et al, 2013). A recent report from the Indonesian government and UNESCO revealed that the incidence of malnutrition and stunting among women and children in low-income urban households is still high (BAPPENAS and UNICEF, 2017). Malnutrition and stunting are related to household incomes, and a significant proportion of the Indonesian population is at risk of falling below the international poverty line of US$1.91 per person and day. This is particularly the case of the special region of Yogyakarta, where the local authorities are setting a range of policy interventions increasingly promoting urban farming as a tool to reduce food insecurity (Siswati et al 2022).

Our goal is to characterize the Yogyakarta urban farm system and assess its potential to mitigate malnutrition and stunning among vulnerable children and women. Specifically, we aim to answer the following research questions: What products are produced in urban farms? Are there any spatial patterns of production? To what extent does urban farming contribute to household food security and incomes? Can urban farming mitigate childhood stunting? To answer these questions, we draw on Edmondson et al (2020) and Grafius et al. (2021) to get a geographical characterization of the urban farming system which, along with sub-district level data on stunting incidence, we can start to identify how urban food production can reduce malnutrition. Furthermore, answering these questions and visualizing the urban farm system can help inform local food policy and what role urban farming can play.

To understand the role of urban farming in reducing food insecurity it is imperative to know what is produced and who is producing. Recent developments in digital and information technologies are enabling the cross-sectional combination of spatial and, socio-economic data and their visualization using geographical information systems (GIS). Indeed, high-resolution GIS are widely accessible and can be layered with production, infrastructure, and social-economic data to represent urban farming locations. When combined with production and socio-economic information through digital technologies and platforms, these geographical systems, provide insightful information to support private and public decision-making that might not have been easily available using traditional methods.

This paper is organized into four further sections. Next, we provide an overview of the literature relating urban farming to food security and how GIS have recently been employed to characterize urban farming systems. Then we describe our methods. Section four presents the results and then we discuss of findings and conclude.

2. Urban agriculture and food security spatial context

While there is a growing literature on the impact of urban farming on the environment, health and communities, to the best of our knowledge, the spatial analysis of urban farming systems is still scarce. This section briefly reviews the extant literature examining the contribution of urban farming to food security and how GIS methods help characterize and visualize urban farming systems identifying opportunities to contribute to food security and reduce malnutrition in cities.

2.1. **Urban farming and food security**

The early literature on urban farming focuses on gardening and community allotments. The potential contribution of urban farming to food security has been document since 1991, when Patel surveyed 178 gardeners in Newark, New Jersey to assess the socio-economic impacts of Gardening. He reported that gardening improved life quality, with 44% of respondents stating they had access to fresh fruits and vegetables, while 35% reported improving their diets. Another study by Armstrong (2000) assessed the how community gardens contributed to community development and health promotion using a survey of gardeners in urban and rural areas in upstate New York, finding that a significant number of respondents agreed that access to gardens improved both nutritional and psychological wellbeing as well as food access to low-income segments of the population.

More recently, the research from Balmer et al. (2005) and, particularly, Corrigan (2011) reported that most gardeners donate or sell about a half of their produce to the local community, thus contributing not only to household but also community food security. However, any barriers to land access or cash to buy urban farming produce in community markets limits the contribution of urban farming to food security and healthy diets (Suarez-Balcazar, 2006).

Three reviews of the literature on the contribution of urban farming or agriculture to food security were produced in the last decade. Orsini et al (2013) conducted a comprehensive, and mainly non-academic review of the social, cultural, technical, economic, environmental, and political factors affecting urban agriculture. They find that urban farming can play a significant role on food insecurity mitigation, mainly through the supply of perishable vegetables. In African, East Asian, and South American cities about 25 to 30% of the population have some sort of production, but city planning is often ignoring the need to keep land available for production. Orsini et al. also point out that misuse of pesticides and fertilizers, use of polluted water, soil contamination, and zoonotic diseases transmitted by animals may hinder the positive impact urban farming has on food security. Korth et al (2014) conduced a systematic review on the contribution of urban farming to food security, concluding there is not strong evidence supporting a positive impact of urban farming on individual or household food security in low and middle-income countries. However, they report on a range of cross-sectional studies suggesting there is potential for urban farming to increase food security in East and West Africa. They conclude calling for more rigorous and robust measures of the impact of urban farming in food security. Finally, Warren et al. (2015) found that, while there is some clear evidence of the contribution of urban farming to diet diversity, it does not necessarily boost food security. This review has also highlighted that access to land, cost of inputs, theft and lack of technical advice all hinder the potential of urban farming and its contribution to more nutritionally dense diets and food security.

An early example using robust quantitative methods to measure the impact of urban farming in food security, is Zezza and Tasciotti (2010). They make use of a household survey database from 15 developing or transitioning economies to conduct an international comparison of the contribution of urban farming to poor urban dwellers food security. Their analysis has some caveats, namely in that the definitions of what urban farming is varies across the countries and that it proved impossible to have detailed location of the urban farms. The measure used to assess the impact of urban farming on food security was the contribution to household incomes. They report that African countries had the largest proportion of urban farming contribution to incomes. Another measure was the contribution of urban farming to total agriculture production and marketing orientation. Again, African, and Central American countries (namely Madagascar and Nicaragua) where those for which the urban farming had a larger contribution to total production and household consumption. Using multivariate analysis, they show that urban farming positively explains increases in calorie consumption and a diverse diet.

In brief, urban farming has a clear role to play in mitigating food insecurity and reducing nutrition deficiencies in vulnerable segments of the city dwellers. This is particularly relevant to low- and middle-income countries where these issues largely persist. Also, there are barriers to access land, inputs and technical advice on urban farming production methods. There often is limited information on what, how much and where food surpluses from urban farms or community gardens are available to poor urban households. Moreover, the studies so far seldom use quantitative methods to evidence the contribution of urban farming to food security.

2.2. Untapping Urban Farming contribution to food security using GIS methods

As Zezza and Tasciotti (2010) report location is one of the factors to consider when assessing the potential and actual contribution of urban farming to food security. Recently British researchers combined GIS with surveys to urban farmers, gardeners, and allotment users to conduct geographical and spatial analysis of urban farming systems. Edmondson et al (2020) wrote a case study examining the relevance of allotments for vegetable provisioning in the city of Leicester. They used a novel methodology combining citizen science, field mapping and GIS to collect data on allotment plots and then use GIS to map the plots and what is produce in different parts of the city. Using these methods, they found that the allotments have the potential to contribute to 2% of the total demand for fruits and vegetables of Leicester. Moreover, by layering GIS data on allotment production with data from the UK Multiple Deprivation index, they could identify opportunities with which allotments and private gardeners could be used to mitigate food insecurity.
Another study using GIS to examine the potential of urban farming to feed cities was conducted by Diehl et al. (2020) in Singapore. The aim of this work was to track changes in agricultural land use and examine recent trends in policy. They used GIS to track trends in agricultural land changes in the Singapore's Master plan between 2008 and 2014. Thus, this study combines spatial and time data. They found that the land use policies of the past three generations significantly prioritized commerce and infrastructure development and reduced the amount of land devoted to food production. The latest City Master plan further reduce the amount of agricultural land, but local authorities are promoting high tech food production and rooftop farms to address food insecurity in Singapore. Thus, in this research, GIS is used to track policy impacts and point solutions.

Finally, Grafius et al (2021) also combined yield data with GIS information on allotments and private gardens locations to estimate the current and potential fruit production capacity in three large-sized towns in central England's (Bradford, Luton and Milton Keynes). To identify the location of greenspaces with potential for fruit trees the study combined maps from UK Ordnance Survey Open Greenspace (to identify allotments), Ordnance Survey MasterMapdataset (to identify private residential gardens) and, finally, GIS data from OpenStreetMap®, OS AddressBase® Plus and OS MasterMap® (to identify other green areas with potential to free occupation). Current yields were determined using the same citizen science method used by Edmondson et al (2020). They combined yield, area and GIS data to develop three scenarios to estimating the potential food production across the three cities. In the most conservative scenario, they found that the combined average production potential is close to eight thousand tons per year, whereas in the maximum potential scenario is over 42 thousand tons. But this latest scenario would involve a significant use of private gardens for production.

Put together these studies show the advantages of combining production and geographic data to estimate the current and potential contribution of urban farming to food security and to assess the impact of land use policy. However, none of these studies use socio-economic information which is another important element influencing the contribution of urban farming to food security.

3. Methods

To characterize the Yogyakarta Urban Farming system and address our research questions we combined of GIS, secondary data from the Yogyakarta City council and a survey to collect more detailed data on urban farm location and production system as well as on farmers' characteristics. Our approach closely aligns with Edmondson et al. (2020) who combine citizen science with GIS data to assess the potential of allotments in Leicester. In our case, GIS are mainly employed to visualize urban farms locations and to identify clusters with common production patterns as well as opportunities to mitigate food insecurity. While ideally, we would map every farm in the city, in practice that proved challenging due to our budget constraints and the fact we collect data during the pandemic. So, it was decided instead to gather a representative sample by sub-district (Kabupaten). We start with a characterization of the city, then describe how we obtained GIS information. A third part describes our survey and sample methods. Finally, we describe our approach to data analysis and geographic visualization.

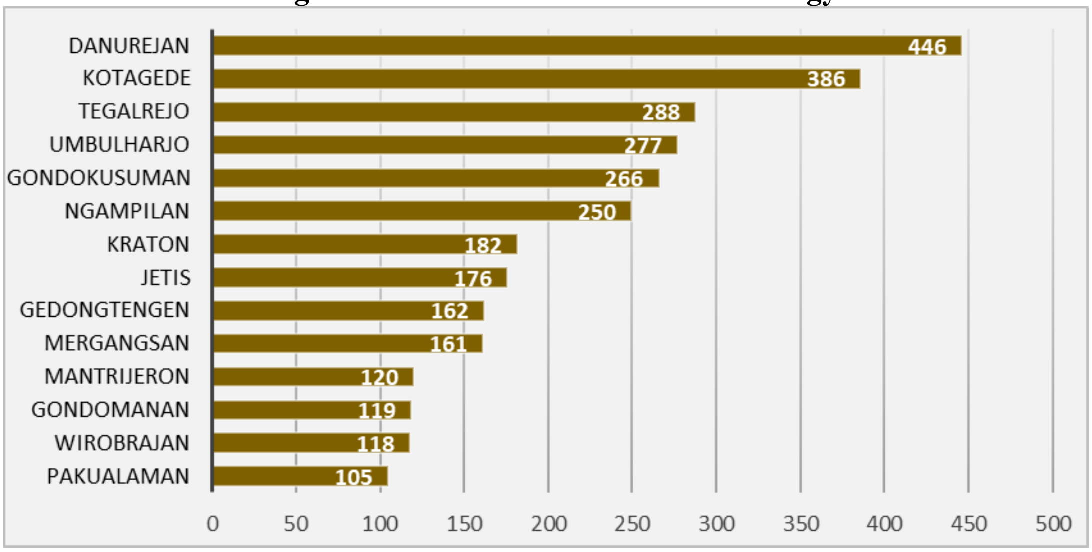
3.1. **Study area**

The city of Yogyakarta (7°48′5″S 110°21′52″E) is in the South-central part of the island of Java, Indonesia, and is the capital of a special region with the same name. It is a cultural centre of Javanese arts and culture. The city had a population of over 440,000 in 2020. The city is a hub for education and was considered the easiest city to invest in Indonesia by the World Bank in 2012. The economy had grown steadily until 2020 and recovered significantly in 2022 from the COVID 19 pandemic. The main sectors of activity are in industry, tourism and education.

A recent report from UNICEF, reporting on progress to SDG 2 (Zero Hunger) reveals that over 165,000 children in the Yogyakarta special region live below the Indonesian poverty line. More worrying about 27% of these suffer from stunting while 10% are overweight (BAPPENAS and UNICEF, 2017). The Yogyakarta Province economy is based on both agricultural, industrial, and services related sectors. The contribution of agriculture towards the Provincial Gross Domestic Regional Product was 9,97 percent in 2022. The largest sector, Industry, contributes 11,43 percent and the second largest (information and communication sector). The total rice field surface has around 110,000 ha and is spread-out along four (4) regencies (Sleman, Bantul, Kulon Progo, and Gunung Kidul). Still around the city there are 100 ha rice field. The main horticulture crops produced are pepper, chillies, and red onion. In addition, farmers also grow kale, spinach, and Chinese cabbage. On average farms are below 0,5 ha and are farmed in traditionally farming systems.

In 2019, the number of urban farmers in the city if Yogyakarta was 3,056. Most of them belong to informal farmers groups supported by extension support offices from the city's Agriculture and Food Service. The distribution of the urban farms across the Yogyakarta sub-districts is displayed in Figure 1.

Figure 1. Number of urban farms in Yogyakarta



Source: Yogyakarta City Agriculture and Food Service, 2021

3.2. Visualizing the Yogyakarta urban farms

Despite several requests to the Yogyakarta City Council, we could not access an official digital map of the city. Thus, we had to resort to alternative GIS maps of the city of Yogyakarta on which we could base our project. A solution was to make use of widely available platforms (namely OpenStreetMap but also GoogleMaps, Mapquest, etc) and use them to visualize the farms and its characteristics. An issue faced was that the resolution and detail of the maps did not necessarily feature the city but rather the whole region of Yogyakarta. So, a limitation is that we do not have detailed information on the districts (Kecamatan-Kapanewonan), the wards, population demographics, socio-economics, and land use information.

We had to find a compromise between keeping the region of investigation sufficiently small to not exceed free tiers or download limits, while ensuring we gather relevant data required to answer our questions. As this stage of our work, the choice of the most adequate platform on which to base the urban farming system was not the limiting factor, but future extensions of the work may need to reconsider this issue.

Once we identified a platform to map the urban system, the next step was to get the precise location of the farms so we could visualize them in the digital platform using the what3words geocode system. This is a proprietary platform designed to identify any location on the surface of the earth with a resolution of about 3 metres. Thus, when our numeraires visited the farms or when our respondents accessed our survey online, we requested them to go to the what3words website and write the 3 words of their location. This information then enabled us to map the farms in our digital maps of the city and region.

While we had precise locations of the farms, to comply with General Data Protection Regulation (GDPR) and protected the participant confidentiality, it was decided that in our maps we would aggregate information of farmers and farm characteristics by sub-district. While this limits our ability to have a more detailed and nuanced perspective of the urban farming system, it still enables an insightful visualization on relevant information of production system, economics and social characteristics of farms.

3.3. **Survey and sampling**

The Yogyakarta City Council provided a dataset with the locations of the urban farms in the city and other types of information, including broad categories of production types. We also identified groups of farmers connected via WhatsApp that became instrumental in data collection. Since data collection was compromised by COVID19, we had to adjust and adopt a citizen science approach which was enabled and facilitated by access to the farmers' WhatsApp groups. The Agriculture and Environment Departments in the City Council also had a group of extension officers supporting the farmers and they became an important source of information. We were also able to get data on prevalence and incidence of stunting in children from the Yogyakarta City Council Health department. While this secondary information was valuable, it was nevertheless incomplete, both in terms of the actual location of the farms but also on what and how much was produced. Also, there was not any specific information on production systems, motivations, and socio-economic characteristics.

Consequently, we decided to develop a survey to fill the information gaps we had. While ideally, we would interrogate all the farmers in the city time and budgetary constraints prohibited it. Instead, we decided to develop a questionnaire and administer it to a representative sample of the urban farmers' population. The survey instrument was developed along with research team members and urban farmers groups in the city. We requested and obtained ethical approval from Newcastle University Research, Policy, Intelligence and Ethics Team (Ref **12894/2020**). As previously mentioned, we used what3words in the survey to get precise location of each farm. The questionnaire included questions on production information (such as products types, productivity, inputs and technology used); economic information (namely whether farmers participate in markets or produce for self-consumption and product prices) and social-demographic information (gender, education, and household participation in farming). Once the instrument was tested and edited, it was uploaded onto Qualtrics (a proprietary survey software).

The survey was administered to a convenience sample of 450 urban farms segmented and distributed proportionally by sub-district between May and June 2021. Data were collected by students from the Faculty of Economics and Business at UGM with the support of extension officers from the Yogyakarta City Council and the urban farm groups in the city. Of the 450 farmers in our sample, after cleaning up the data we end up with 375 usable responses.

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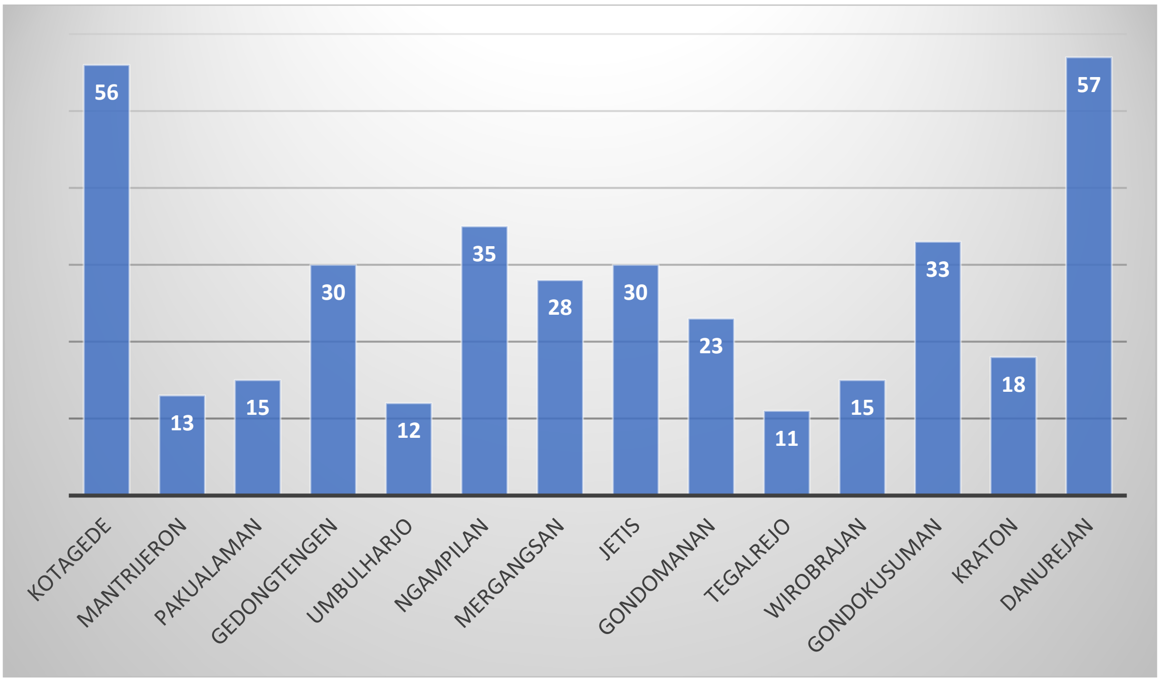
Figure 2. Distribution of the sample by sub-district location



Source: Survey results, data processed (2021)

3.4. Analysis and visualization

Once we concluded the data collection, cleaned the data we were able to start the analysis, we employed standard statistical and econometric methods to characterize our sample but and draw inferences on the importance and potential contribution of urban farms to mitigate food insecurity in Yogyakarta. Specifically, we used descriptive statistics and multivariate methods to characterize the farms and farmer's profiles. Then we employed logistical and multi-logit regression methods to make inferences on the determinants of using the farm for household self-sustenance and selling to markets or donating food to other households. The published data will be stored in the data repository at Newcastle University.

While our statistical and econometric analysis provided a good insight on the type of urban farms and production process, as well on socio-economic and demographic profiles of the farmers, our goal is put these in a geographical context. Thus, making use of our knowledge on specific locations of the farms and the information from the survey, we produced maps enabling us to visualize differences across sub-districts of the city and identify clusters with similar characteristics.

Ultimately, these visuals provide an overview of the urban farm system of the city which can be shared with stakeholders (City Council managers and urban farmers) to make decisions on city food policy and plans to support urban farming developments.

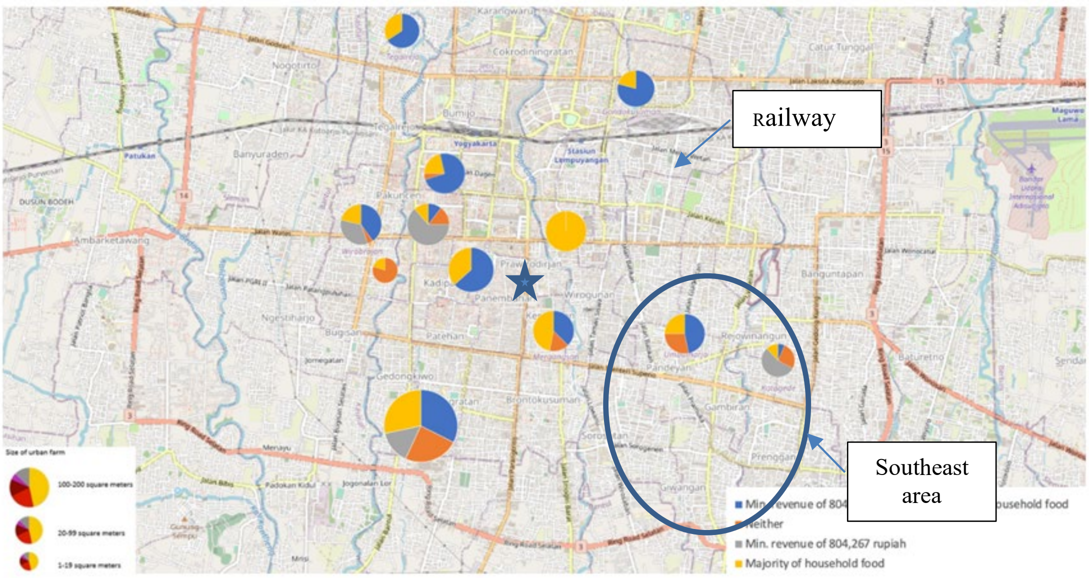
4. Results

Here we start by providing an overview of the Yogyakarta urban farming system, using maps to show how farms contribute to self-sufficiency and what the main productions are by sub-district. We also use descriptive statistics to characterize our sample and show what are the most popular crops and their productions. Then we present our results on the determinants household consumption and selling of urban farmers. Finally, we present the results of our analysis on how urban farming contributes to stunning mitigation.

4.1. Mapping Yogyakarta urban farming systems

As reported in the previous section the metropolitan area of Yogyakarta has 13 sub-districts, and we can distinguish between three areas: the vicinity of the city centre (indicated with a star in the map in Figure 3), the sub-districts north of the railway and those southeast of the city. The latter is a peri-urban area with more green spaces and with larger urban farms. Figure 3 below shows how farms differ in size and contribution to household food income measured by a variable capturing whether farms generate sales or contribute to auto-consumption. The size of each circle represents the average sub-district urban farm size and the yellow the segments in the pie charts represent the share of farms whose production contribute exclusively to household income.

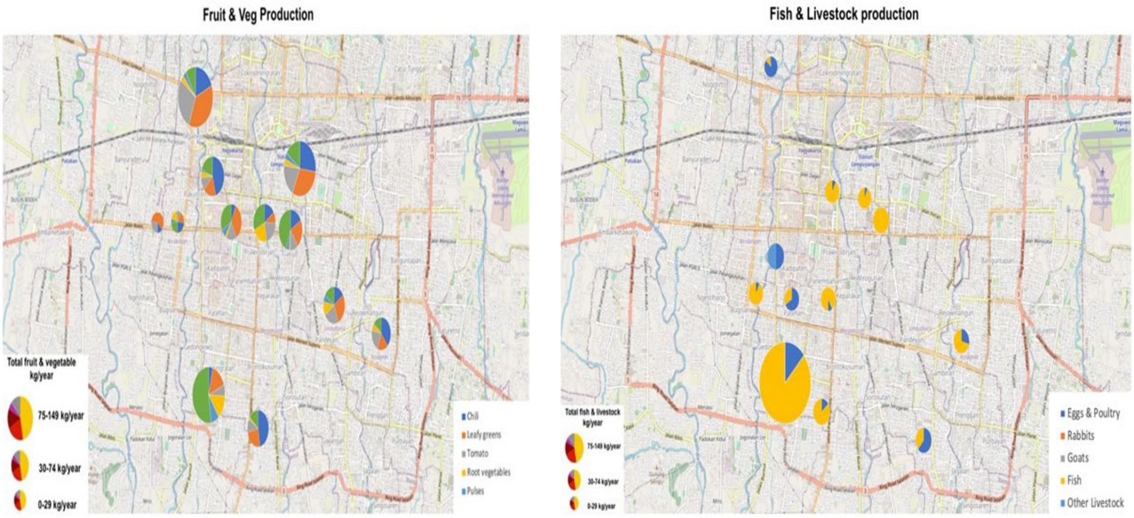
Figure 3. Mapping the sub-district urban farms average size and urban farm's income



What the map reveals is a heterogeneity of the contribution of urban farms to household incomes, with the farms located north of city centre contributing the least whereas those in sub-districts closer to the city centre contributing the most. Furthermore, there are noticeable differences of urban farms sizes across sub-districts, with the most frequent size being 20 to 99 square meters.

Turning to the types of products produced, Figure 4 shows the production of fruits and vegetables (left panel) and animal production (right panel).

Figure 4. Mapping types of products in Yogyakarta urban farm system



What the map shows are again a difference across sub-districts in types of production. Focusing first on animal production and noting that the bigger the circle the more production (in kg) per farm, per year, most animals produced are fish and poultry, as it might be expected. The sub-district immediately south of the city centre has the largest productivity with an average of 75 to 100 kg annually. Turning to fruits and vegetables note that the main products produced are chilies, leafy greens, root vegetables and pulses. Clearly there is more diversity of fruits and vegetables produced than of animals and also considerable variability across sub-districts. It is worth noting how urban farms in city centre sub-districts produce between 30 and 74 kg of produce a year and leafy greens seem to be an important crop.

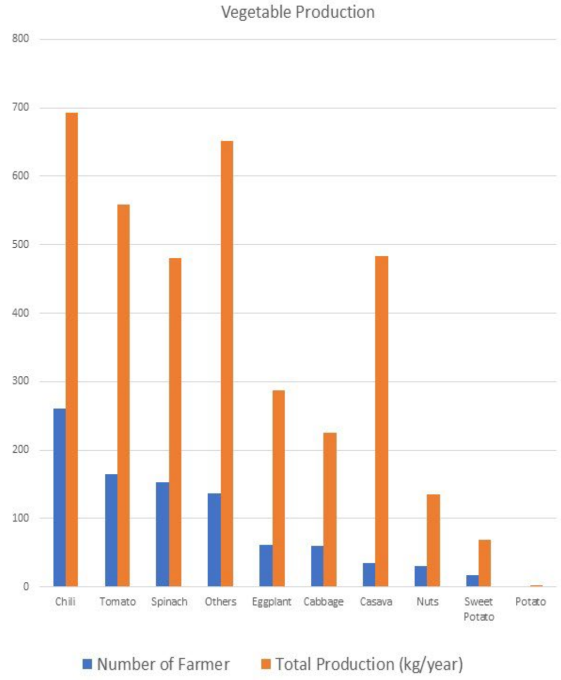
Put together, Figures 3 and 4 suggest that Yogyakarta has a diverse urban farming system, where families use farms not only for self-consumption but also sell to complement household incomes. As reported in the literature, for example Orsini et al. (2013) and Edmondson et al. (2020), the Yogyakarta urban farm system is unlikely to be able to do a very significant contribution to the city food security and fruits and vegetables are the most common products produced in urban farming systems. Still given its current diversity it can certainly help mitigate malnutrition by improving access to fresh produce.

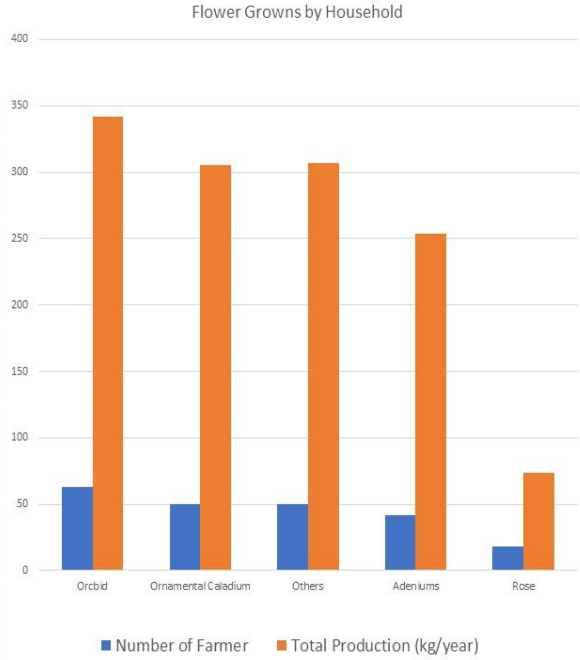
4.2. Main products and motivations for urban farm products auto-consumption and sales

Turning now to a closer analysis of our survey to urban farmers, we present the most popular fruits and vegetables as well as flowers produced in Yogyakarta in Figure 5.

The first thing to note in this figure is that cut flowers are produced in over 50 farms and as later explored, these are mainly for sale. The most popular flowers produced are orchids followed by caladiums. Regarding the fruits and vegetables, we can see that chilies are by far the most popular crops produced (in over 250 farms), followed by tomatoes and spinach. The latter with cabbages are the most popular leafy greens produced. Interestingly, despite being produced in few farms casava has a high level of production.

Figure 5. Most popular and productive fruits, vegetables and flowers.





Turning now to the popularity and productivity of animals in urban farms, Table 1 below shows that the catfish is the most popular animal production followed by chicken. Urban farmers in our sample produce just over 6 tons of catfish, which is possibly a good source of protein for households.

Table 1. Animal production in Yogyakarta urban farms

Livestock	Total Production (kg/year)	Number of Farms
Catfish	6068	58
Tilapia	2198	24
Pomfret/Butterfish	1332	4
Eggs	1229	15
Chicken	1053	39
Other Fish	619	14
Gourami	234	6
Rabbits	13	1
Other Livestock	11	2
Goats	8	1
Ducks	0	0
Quails	0	0
Geese	0	0

We now turn to an analysis of sales drivers of the purpose of urban farms. In other words, what determines the market or auto-consumption orientation of urban farmers. Before we show the results of our econometric analysis, we characterize variables and the sample. This is shown in Table 2 below.

Table 2. Urban farm sample characteristics

Variables	Descriptive	N	Mean (St. Dev)
Consumption	Dummy = 1 if farmer consuming the output of UF	375	0.821 (.383)
Selling	Dummy 1 if farmer selling the product of UF	375	0.366 (.476)
Female decision	Dummy 1 if woman is UF decision maker	375	.776 (.417)
Education	Level education (dummy multinomial 1 to 5 represents elementary school-1 to tertiary education-5)	375	3.36 (1.03)
Children	Number of children	374	1.50 (1.18)
Age	In years	375	53.2 (10.03)
Food expenditure	Log food expenditure in 1 year	368	16.6 (.590)
Income UF	Log of total yearly income from sales	127	16.1 (1.85)
Production	Total UF production (kg) in 1 year	375	732.8 (2019)
Flower	Total production flowers (kg) in 1 year	375	13.8 (121)
Vegetable	Total production of vegetable (kg) in 1 year	375	229 (780.3)
Livestock	Total production of livestock and fish (kg) in 1 year	375	34.0 (172)
Hydroponic	Dummy 1 if using hydroponic	374	0.139 (.346)
Polybag	Dummy 1 if using polybag	375	.909 (.287)
Pot and wall	Dummy 1 if using pot and wall plantation	375	.725 (.446)
Other Technology	Dummy 1 if use others technology in urban farming	375	.176 (.497)
Land	Urban Farming land size (m2)	374	34.9 (53.5)
Region	Dummy 1 = central, 2 = northern, 3 = Southern Yogyakarta	375	1.776 (.906)
Urban	Dummy 1 if located in Urban, otherwise rural	375	0.715 (452)

The results in this table reveal that over 80% of farmers consume the produce of their farm whereas just over 37% sell their produce. The large standard variations on the production variables reflect what we observed above in terms of diversity of size of farms. It is interesting to note that while most farms use standard horticulture and gardening technologies, about 14% use hydroponics which are more advanced technologies. Another important factor to notice the respondents are well educated. Finally, we note that most farms are either in the central or northern part of Yogyakarta but about a third of our sample is on rural areas close to the city.

Table 3. Drivers of consumption and sales

Variables	Consumption (Odds ratio)	Sales (Odds ratio)
Female decision	2.35*** (0.748)	0.457*** (0.127)
Age	1.028** (0.015)	0.990 (0.011)
Education	0.877 (0.122)	1.072 (0.002)
Children	1.300** (0.166)	
Food expenditure	1 (0.00)	
Income UF	1 (0.00)	
Region 2	0.273** (0.106)	
Region 3	0.452 (0.322)	
Urban	0.869 (0.623)	
Land		1.01*** (0.002)
Production		1.000 (0.000)
Hydroponic		1.853* (0.61)
Polybag		3.777** (1.985)
Pot and wall		0.989 (0.260)
Other technology		0.798 (0.201)
Cons	1.104 (1.403)	0.270 (0.253)
N	375	374
LR Chi^2 (10)	31.75	37.93
Prob>Chi^2	0.0002	0.000
Pseudo R^2	0.09	0.0785

NB: *** Denotes significant at the 1% level, ** at the 5% level and * at the 10% level.

Table 3 above shows the results of logistic regressions on drivers of auto-consumption and sales by Yogyakarta urban farmers. Focusing first on the auto-consumption model, the odds of this occurrence significantly increase when women make decision and there are children in the household, as well as with age and being in central city sub-districts. Then, in our second model we report the results on the determinants of selling urban farm products. The results show that female farmer reduce the odds of sale, whereas the larger is the farm and the use of hydroponic and polybag production technologies increase the odds of selling. Interestingly, the production volume does not affect the odds of selling.

Another way of investigating the impact of sales is examining the income from urban farming. We asked farmers how much farmers earned from sales of each product from the farm and then aggregated these and take the log to construct the Income UF variable. We then estimate a standard OLS model to examine what determines these incomes, the results are reported on Table 4, below.

Table 4. Determinants of urban farmer income

Variables	**Income UF (log)**
Female decision	-9251224** (4356554)
Age	-343049.9* (177750.1)
Education	-2359058 (1734452)
Flower	33596.81** (14857.08)
Vegetable	27469.33*** (2302.55)
Livestock	6401.673** (2683.4)
Hydroponic	-4031436 (5274844)
Polybag	8232666 (6220638)
Pot and wall	4679875 (3983722)
Other technology	2171988 (3656706)
Land	96804.08*** (34670.97)
Cons	$2.35e^7$ ($1.37e^7$)
N	374
F(11,362)	19.48
Prob>F	0.0000
R^2	0.3727
Adjusted R^2	0.3527

NB: *** Denotes significant at the 1% level, ** at the 5% level and * at the 10% level.

First note that our independent variables significantly explain the variance on urban farming incomes and the model explained a reasonable amount of the variance as seen in the value of the adjusted R^2. What we infer from these results is that consistent with our previous results, when women are decision makers that income from urban farming significantly decreases, as it does with age and, surprisingly, with use of hydroponic technology not significantly. As we would expect the larger the farm the higher is the income and sales of livestock, flowers and vegetable significantly increase urban farmers income. There is however a caveat in this analysis, which is that farmers self-reported their incomes from sales, which may not reflect the true income from urban farming.

4.3. Does urban farming mitigate stunting in Yogyakarta?

Our final analysis examines the potential contribution of urban farming to children malnutrition and stunting mitigation. To examine this, we make use of a data set from the

Health office of the City of Yogyakarta, reporting the distribution of stunting in Yogyakarta. This data reports the number of children stunting cases at the village level, which we then aggregated at the sub-district level and link to each of observations in our sample. Specifically, since we have the sub-district location of each farm, we insert a variable with the stunting data for that sub-district and associate it to each observation on our urban farm sample. Using this construct, we can then investigate how urban farming relates to stunting incidence. It is important to note that we don't have information on children with stunting in our sample, which is a limitation of our approach. Still, we think it is informative to assess how urban farming correlates to stunting data. Table 5 below shows the descriptive statistics of the stunting data.

Table 5. Descriptive statistics of stunting variables

Variable	Description	N	Mean (St. Dev)
Stunting child	Number of stunting children in 1 village	375	17.01 (19.8)
Stunting prevalence	Stunting prevalence in 1 village (%)	375	5.81 (6.967)
Stunting rank	Ranking of stunting (1 to 4) indicates the level of severity the higher the worse	375	1.2 (0.433)

It is worth noticing that the rank stunting variable is based on the prevalence of stunting in a village. Further, the total number of stunting cases and the prevalence is low in the sub-districts we sampled. In this paper we focus on the number of cases in children as we do have data on the number of children in households with urban farms. Given the nature of the nature of our dependent variable (number of children with stunting on the sub-district of the urban farm in our sample), we employ simple OLS regression and show our results in Table 6 below.

Table 6. Determinants of Urban farm income

Variables	Stunting Child
Female decision	-7,452*** (0.848)
Age	-0.197* (0.101)
Education	-1.105 (0.69)
Children	-1.705** (0.848)
Income UF	$5.57e^{-8}$* ($3.04e^{-8}$)
Production	-0.0000656 (0.00059)
Auto-consumption	-3.35 (2.625)
Food expenditure	$-4.90e^{-8}$ ($6.90e^{-8}$)
Other job	6.151*** (2.045)
Constant	39.230 (7.559)
N	375
F(9,365)	5.10
Prob>F	0.0000
R^2	0.1116
Adjusted R^2	0.0897

NB: *** Denotes significant at the 1% level, ** at the 5% level and * at the 10% level.

The first thing to note is that our independent variables significantly explain the variance on children stunting cases, however the model has limited explanatory power as can be observed in the value of the adjusted R^2. Then, the number of stunted children decreases when women manage the farm, with age, (perhaps surprisingly) with the number of children in the household but increases when the manager of the farm had another job. While auto-consumption and production both contribute to children's stunting mitigation they are not significant.

What these results suggest is that urban farming can play a role on child stunting mitigation, but our results need to be confirmed with further and more detailed research.

5. Discussion and final remarks

This researcher had two main goals: 1) investigate the extent with which combining geographical information systems and survey methods allows us to not only characterize urban farming systems and 2) to understand the extent with which urban farming can contribute to food security, particularly reducing children malnutrition and stunting.

Regarding our first aim, we find that adding a geographical dimension to the analysis enabled us to get a much richer picture of the Yogyakarta urban farming system. In line with the studies by Edmondson et al. (2020) and Grafius et al. (2021) in British cities, we find that most farms produce fruits and vegetables, namely chilies, tomatoes and leafy greens. Interestingly, perhaps reflecting the geography and climate of Indonesia, we find a quite diverse system, not only in terms of crops produced but also across sub-districts.

When we focus on what drives auto-consumption and sales of urban farms output, we can see that when women lead the farm there are lower odd of sale. This is somewhat consistent with the literature, as Orsini et al. (2013) argues that most urban farms are operated by women, but the most entrepreneurial are led by men. However, both Orsini et al. and Poulsen et al. (2015) in their reviews find that in Africa women using urban farming as source of income and are quite entrepreneurial. So, there may be cultural factors contributing to what we find. We also find that older farmers and households with children tend to have more auto-consumption.

Regarding market orientation, in our sample only about a third of farmers sold their produce. This is not consistent with findings in the literature, but it may reflect some bias in our sample. What seems to drive sales is the size of the farm and the production technology. This is consistent with O'Sullivan et al. (2019) recommendations that the potential of urban farming to become a significant contributor to food security requires investments in technological and production innovations.

Turning to our second goal, on the role urban farming can play mitigating food security, our results are consistent with the literature in that level of production is quite small and there is no clear evidence more production reduce childhood stunting. In this we align with what Warren et al. (2015) found in their review of the literature. Still, the fact that we find such a diverse urban system may open opportunities for reducing carbon food print of fresh produce supplies at least for some groups of urban dwellers. However more research and then more clear incentives and policy will be required to realize such opportunities. Even though our results on the impact of urban farming production on childhood stunning need to be taken with a pinch of salt, it is nevertheless encouraging to note women farm management correlates with lower numbers of stunted children. We aim to explore this further in future work.

To conclude, this research has shown that employing and combining geographical information systems to visualize farms with data on both production and socio-economics characteristics of urban farmers allows us to have a much better picture of the system and its potential. In line with the literature, our results show that urban farm has a limited but important role to play in contributing to urban food security and malnutrition mitigation.

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