GEOSPATIAL VALUATION OF URBAN FARMING IN IMPROVING CITIES RESILIENCE: A CASE OF MALANG CITY, INDONESIA

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ABSTRACT:

Urban farming is recently acknowledged as a strategy with various services in improving cities resilience but facing cons such as land competition and rapid urbanization. The study attempts to inventory available areas for urban farming implementation and estimate the total values with case study in Malang city, Indonesia. The study divided urban farming into five forms i.e. nursery, allotment, residential, institutional and rooftop farming based on its characteristics. Land inventory has been done by estimating existing and potential areas. Existing area was manually delineated by Field Area Measure App through field visit and visualized by ArcGIS. Potential area was identified through geospatial assessment considering land use and land cover map provided by the Government of Indonesia and parcel zoning based on Guideline of Urban Farming development and literatures. The study employed Contingent Valuation Method (CVM) and Market Price Method to estimate total values of urban farming. Currently there is 1.38 ha of urban farming which is equal to 0.01 % of city's area distributed in 21 plots and 211.46 ha potential area or equal to 1.92 % of city's area. Urban farming has services for amount of US$ 28.68 m^{-2} yr^{-1}, specifically 22.86, 3.60, 0.80, 1.10 and 0.34 US$ m^{-2} yr^{-1} in terms of provisioning food; income generation; recreation and community building; education and learning; and maintenance urban comfort, respectively. If existing and potential area used for urban farming, then it could contribute to US$ 395,095.68 annually for existing and potentially up to US$ 60,646,800.35 annually for entire city.

1. INTRODUCTION

1.1 Background

The current city's vulnerabilities are exposed by rapid urbanization which goes along with urban poverty (Burger et al., 2012; UN, 2018). These phenomena most happen in developing countries like Indonesia and implicate to urban food insecurity, land conversion and degradation of environmental quality. Resulted by urbanization, in 2020 almost 57% Indonesian's inhabitants is predicted to live in cities exceeding the average share of urban population in the world (UN, 2018) which lead to increase land conversion and degradation (Subadyo et al., 2019). In the other hand, there are accounted 9.64% people living under poverty line in 2019. These situations go along with food insecurity especially for the poor people including malnutrition where 30.8% children under five was stunted in 2018 (Bappenas, 2018; Orsini et al., 2013).
Study on impact assessment of climate change in Malang city, as case study, stated that Malang had highest vulnerability especially for urban heat island effects. The urbanization coupled by climate change will increase coverage area of urban heat island effect up to 19% (IR3S, 2018). In addition, urbanization coupled by urban activities become a key contributor of more than 70% global GHG emissions including food transportation and other energy consumption that implicate to pollution (UN-Habitat, 2016). The tendency of built-up area of Malang city to increase faster in conjunction with development expansion. These challenges require Malang to improve their resilience.

Recently, urban farming which also known as urban agriculture was acknowledged as strategy to improve cities resilience associated by social and economic co-benefit (Elmqvist et al., 2019; Gonçalves, 2013; Lehmann, 2019; Olsson et al., 2016). Urban farming provides food and improve the food access and revitalizes local economy (Jonck et al., 2018; Pulighe and Lupia, 2019). Urban farming also performs in increasing well-being and social benefit (Wang and Pryor, 2019), contributes to the expansion of urban green spaces (Contesse et al., 2018), improves water and waste management and reducing energy use and GHG emissions for transportation (Lee et al., 2015). Urban farming will enhance flexibility and contribute to social-economic and environmental co-benefit as well as urban food security and thus, urban resilience.
One way to understanding the values of urban farming is to inventory the land availability for it, in order to understand whether it is valuable or not. Land inventory of urban farming was extensively documented (Clinton et al., 2018; Jantakat et al., 2019; Liu et al., 2018; Lupia and Pulighe, 2015; Saha, 2016). However, urban farming inventory in Indonesia is still limited (Bryant, 2018; Hasyim and Hernawan, 2017). Globally, the latest study already done by Clinton et al., (2018) estimated urban farming values through geospatial assessment where utilized Google Earth Engine and monetary valuation aggregated by country through replacement cost method and benefit transfer method. There is gap on this study especially if applied in small or meso level i.e. city or community level. The value and its framework cannot be applied directly since the study focused on global assessment. Parece et al., (2017) estimated potential area for urban farming particularly in vulnerable areas where more populated by urban poor in

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Roanoke, Virginia, USA. The study delineated desire area using GIS and manually by Google Earth with national spatial data and population data. The results shown that Roanoke includes 2,312 ha suitable for schoolyard gardens, urban farms, community gardens, orchards, and home gardens, of which 189.4 ha are found in neighbourhoods with extremely high rates of poverty. Although this study classified the urban farming type already but there was no proportion of parcel zoning of inventoried land. All inventoried land was considered as urban farming area. Thereby, the result seemed to be overestimated. Another research by Saha (2016) who assessed UF in Boston for provisioning food supply through using satellite dataset to evaluate suitability area in ground and rooftop level. This study was most complex however only food yield used as an indicator. Jantakat et al., (2019) assessed urban agriculture (UA) areas by spatial-temporal analysis and types of in city level. The study examined UA change with segmentation-based classification method in QGIS to classify Google Earth images into thematic maps. In similar with this work, Pulighe and Lupia, (2019) presented a spatiotemporal quantification of UA in the city of Milan (Italy) for assessing food self-provisioning potential. It was utilized high-resolution Google Earth images and ancillary data to create a detailed cadastre of urban UA for the years 2007 and 2014.
Interesting thing is Malang city as case study has been implemented urban farming initiative since 2013. However, there is no supporting data especially available area for expanding urban farming and what is total urban values can be obtained. Through enhancing previous researches and its finding, the study proposes to inventory existing and potential urban farming area associated by indicators of resilience in city level. The study tried to convey the research questions i.e. what potential areas for farming are and what are values of urban farming in monetary unit. Remote sensing and GIS-based analysis supported by google earth were utilized to estimate available areas for urban farming. These methods enable users in estimating areas based on classification and farmland characteristics.

1.2 Objective

This research aims to inventory existing and potential area for urban farming and its values by utilizing resilience indicators in monetary unit. It is important to identifying land availability of urban farming in order to maintain and expand as it is mandated in the laws (Indonesia regulation) and necessity for improving cities resilience. This also allows the stakeholders in estimating the total value of urban farming whether it is valuable or not by comparing with land value as a benchmark or not.

2. DATA AND METHODOLOGY

2.1 Study site and collection of samples

The study assessed urban farming in city level where taken place Malang city, East Java, Indonesia as case study shown in Figure 1. Malang city has 866,118 inhabitants and area approximately 10,988 ha and now there are 21 plots distributed in the city. The study considered all plots in the assessment especially for field survey purpose. There are approximately 210 active urban farmers involved in urban farming activities.

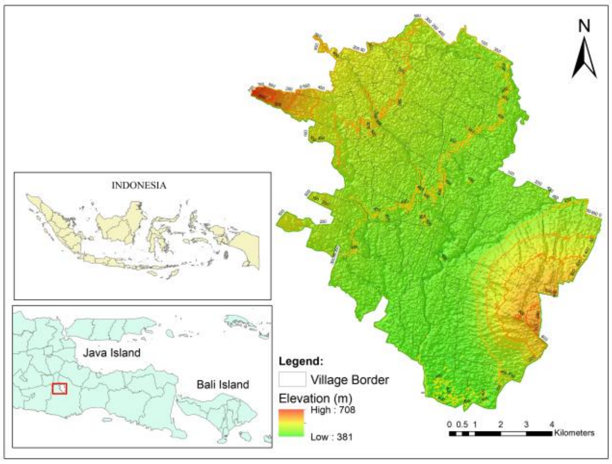

Figure 1. Malang city map

Malang city is a second biggest city in East Java, Indonesia. The city already suffers from societal associated with environmental challenges (Subadyo et al., 2019; Suroso et al., 2012), therefore city resilience should be addressed. Urban farming has chosen as one of the strategies in combating the challenges (Direct discussion with stakeholders of Food Security and Agricultural Bureau of Malang city, March 2019). The city has adopted this initiative since 2013 as part of initiative called *Kawasan Rumah Pangan Lestari* or Sustainable Food House Region and Initiative of Urban Farming Malang. The urban farming is also supported by National Law No. 26/2007 mandating to employing 30% proportion of urban area as green space and Law No. 18/2012 mandating diversification of food and nutrition. This initiative is also in line with SDGs target for Indonesia for next 10 years especially Goal 2 for zero hunger. Unique case in Malang city that developed 'community-based urban farming region' concept where they developed integrated urban farming such as nurseries, allotment farming or community farming and residential farming that connecting it each other in neighbourhood level. However, there is gap between the target implementation and current condition. In 2016, total occupation of green space in Malang city is only 15.9% of total area where less than the target, 30% (Hoff et al., 2016).

2.2 Material and Data

The study utilized primary and secondary data. Primer data were derived from field survey and interview. Secondary data such as socio-economic and urban farming-related data were earned from Statistics Indonesia and Agriculture Bureau of Malang city. Whereas spatial data consist of several type and sources. For example, administration and city planning map, the study utilized Masterplan of Malang city 2010-2030 sourced from Research and Development, Local Planning and Development Bureau of Malang city. Land Use and Land Cover data (built-up area, school distribution, cropland, plantation and dryland field) were sourced from Geographic Information Bureau of Indonesia – BIG Indonesia (https://portal.ina-sdi.or.id/downloadaoi/). To acknowledged domestic garden within residential area, the study also utilized distribution of building type map comprised residential, commercial and public as complement data that sourced from Open Street Map. This map was extracted on https://extract.bbbike.org/.

2.3 Method

Figure 2 shows the research framework.

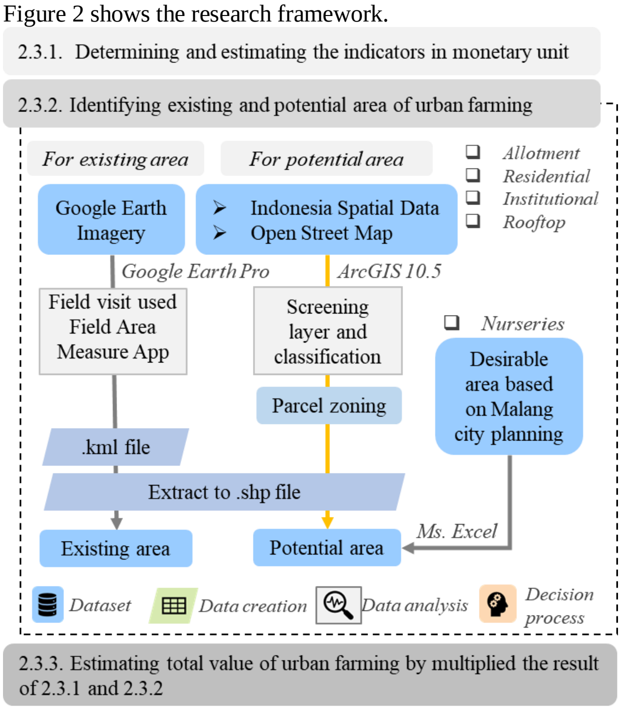

Figure 2. Procedure for the research

2.3.1 Determining and estimating the indicators: A central purpose of this work has been to narrow the long lists of possibilities to a shorter list of component and measures most relevant to Malang city's urban farming values as ecosystem services especially for improving cities resilience. Improving cities resilience means increasing ability and capacity of the city from various urban challenges. Previous studies mentioned that in addition improving resilience (Elmqvist et al., 2019; Gonçalves, 2013). Urban farming contributes to urban ecosystem which has services i.e. provisioning, regulating, supporting, and cultural services. Considering these terms, the study proposed framework of measurement indicators that consider economical (E), socio-ecological (SE), and human (H) aspect shown in Table 1. The indicator then distinguished based on its suitability with urban farming form. Urban farming has multiple type as acknowledged already by previous research (Clinton et al., 2018; Kennard & Bamford, 2020; Lupia & Pulighe, 2015; Parece et al., 2017; Toulmin, 2011b). Hence, considering existing urban farming in Malang city as well, the research categorizes urban farming form. This distinction also considered stakeholders and experts judgment. Here, checklist means that the indicator is applied on certain form.

Services	Ns	Al	If	Re	Rf
E1. Provisioning food supply		✓	✓	✓	✓
E2. local income generation	✓	✓			
SE1. Recreational and community-building	✓	✓	✓		
SE2. Education and learning	✓	✓	✓		
H. Maintenance urban comfort	✓	✓	✓	✓	✓
Total Services	V_A	V_B	V_C	V_D	V_E

Table 1. Measurement indicators for each urban farming form (Ns: Nursery; Al: Allotment; If: Institutional; Re: Residential; and Rf: Rooftop farming)

The specific methods to capture the monetary value of environmental values have been developed by economic science (Costanza et al., 2014; van der Ploeg et al., 2010). However, it is not specifically to assess urban farming values. Adopting the previous researches, the study developed monetary valuation in two ways; *direct and indirect*. *Direct way* is addressed to non-monetary indicators related i.e. indicator of SE1, SE2, and H. This method employs Contingent Valuation Method (CVM) through directly asking to urban farmers their Willingness To Pay (WTP) regarding perceive values derived from urban farming. The method enable to capture non-priced social or environmental values (Toulmin, 2011; Wang and Pryor, 2019). For this purpose, the study conducted survey to 60 urban farmers distributing in 21 plots of urban farming in Malang city. While *Indirect way* – addressed to other indicators that have market price. These indicators applied to indicator E1 and E2, were calculated in metric value first to figure out what are values of those indicators and then converted it into monetary unit by using market price or compare by another goods.

2.3.2 Identifying existing and potential area: This step contains by two parts: (1) inventory for existing area shown in Figure 3 and (2) identifying and inventory potential area of urban farming shown in Figure 4 and Table 2. To inventory existing area, first of all, we utilized Google Earth Image and mapped distribution of urban farming. Then, it was confirmed to the local authorizes and field visit. There are 21 plots distributed within city boundary. All plots were manually delineated using Field Area Measure App to get area size then saved in accordance with urban farming form (i). Utilizing smartphone in mapping areas is efficient way and cheap however it takes time, but it is more precisely. After all mapping, the result was extracted to Google Earth Map (.kml) and then was converted from .kml in Google Earth to Shapefile (.shp) using Arc Toolbox in ArcGIS 10.5 (ii-iii). Converting file into .shp aims to calculate area size and visualize spatially.

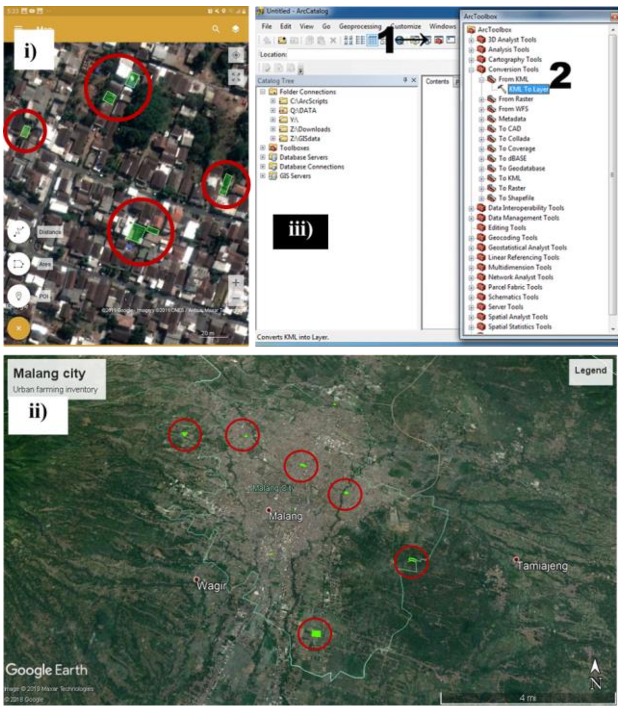

Figure 3. Identifying and mapping existing urban farming areas

In order to identify potential area of urban farming, the study was contained by two parts as shown in Figure 4. Part A means screening layer and classification which aims to considered areas need to be eliminated and used for zoning. The data utilized in this part are indicated by number in the figure. Number 1) indicates that the data sourced from Statistics Indonesia which contained by administration map, 2) Geographic Information Bureau-BIG Indonesia 2018 which contained by land cover and land use type in Indonesia and 3) Open Street Map 2018 that divided already based on building type. These data then divided by three main land cover and land use i.e. green space, build-up areas and water bodies. Since water bodies are not used for urban farming then it is omitted. It is indicated by grey colour. The green and blue colour indicated that those land use type will be considered in Parcel Zoning which is in Part B.

Part B means parcel zoning which aims to determine proportion or ratio (%) of screened layer as certain potential area. The detail zoning and proportion are shown in Table 2. For allotment farming, it is considered 100% of brownfield or vacant lots but part of them will be used as nursery. For residential farming, it is only used 4.61% areas from residential space (house and yard areas). For rooftop farming, it is considered both residential building (house) and non-residential building i.e. commercial or public. But since lack of data on rooftop house (residential) surface as well as limited cases on residential rooftop, then this part was neglected. Based on previous literature it is only 19% for maximum, the rooftop surface can be used for rooftop garden. While for institutional farming, it is considered 10% of school areas will be suitable for farming. In addition, Malang city has school garden program which in line with urban farming initiative.

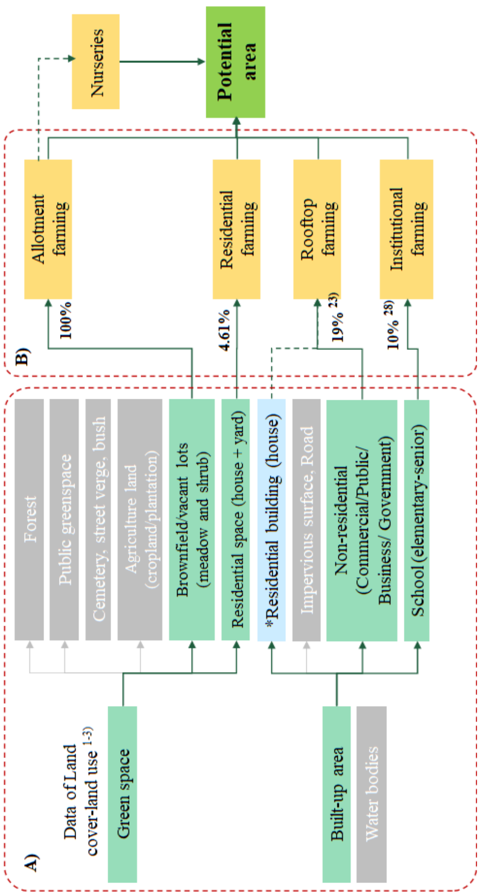

Figure 4. Identifying and mapping potential urban farming areas

Here are the detail screening layer, classification and parcel zoning for the research (Table 2). The classification was adjusted by urban farming form such as Nurseries, Allotment, Residential, Institutional, and Rooftop Farming. This table tried to show the flow in estimating potential areas by emphasize the proportion or ratio from available areas.

Urban Farming Form	**Screening layer and classification**	**Parcel zoning for potential area**
Nurseries	Minimum size of nurseries is 20 m^2 per village and 36 m^2 for average (Sustainability Food Region Guideline 2019). Thereby, it is used 36 m^2 as base of nurseries area.	Nurseries will be implemented in 36 villages (targeted to be developed as desirable areas). Since nurseries area are in the next of allotment farming (survey), then the part of allotment area will be allocated as nurseries part.
Allotment farming	The study eliminates land cover such as impervious surfaces (built-up area), forest, park and water bodies. Land use analysis then was done by eliminate all area that already sitting as agriculture land (cropland, dryland farm and plantation). *Area that not categorized in above elimination are considered in the zoning.*	Vacant lots such as meadow and shrubs are considered in the categorization for allotment farming. Entire area of vacant lots is considered as potential area. It is assumed that all area is suitable to be implemented allotment farm.
Residential farming	The study eliminate building such as commercial, business, and public or government building. *Only building categorized as residential and house type considered in parcel zoning.*	Based on spatial mapping, average area of house is 86.75 m^2. Considering household size, 4 people (average household size in Malang city based on Statistics data) and Ministry of Public Works Regulation No. 5/PRT/2008 that we need spare 1 m^2/capita for green space, then every house needs spare 4 m^2 or equal to **4.61%**. This proportion used as ratio for potential area of residential farming
Institutional Farming	School from elementary to senior high school considered as institutional farming potential	Based on analysis of School Garden on the study (Hartatik and Itaya, 2019) in collaboration with Urban Farming Initiative, this study adopts **10%** proportion of total school area as Institutional Farming.
Rooftop Farming	Only building with a minimum roof surface area (30 m^2) and surface slope (<5°). It was used data sourced	Only **19%** of total available roof that suitable to be rooftop farming. It considers green roofs and photovoltaics, in term of

	from BIG Indonesia	accessibility, well illuminated, relatively flat, capable of load bearing as necessary and water resources accessibility (Clinton et al., 2018; Saha, 2016)

Table 2. Identifying and mapping potential urban farming areas

2.3.3 Estimating total value of urban farming: total value was earned by multiplied urban farming services in unit area (US$ m^{-2} yr^{-1}) and land availability both in existing use and potential area (m^2). The result was total services of urban farming for entire city in monetary unit US$ annually. The results then were compared with land value as benchmark. Land value was average bank interest in Indonesia if land in unit area pawned in the Bank. Indonesia Bank Rule (PBI) No.9/PBI/2007 states that land and buildings (houses) can guarantee credit loans. Hence, it was used in this study as an approach. Considering land price in Malang city, US$ 247.05 per square meter (https://www.atrbpn.go.id/Peta-Bidang-Tanah) and average interest of bank in Indonesia, 12%, then the land value per unit area in Malang city is US$ 29.25 m^{-2} yr^{-1} in 2018.

3. RESULT AND DISCUSSION

3.1 Urban Farming and Potential Services

Urban farming was defined as registered practice of cultivating, growing, and distributing food and derivative products by urban farmer or community through utilizing designated yard called plot within city boundary. Each plot consists of one or several sites. There are 2 types of ownership plot such as a plot belongs to and managed by personal urban farmer and plot belongs to and managed by community. Urban farming takes multiple forms (Lin et al., 2015; Parece et al., 2017). Hence, to minimize the complexity and considering multiple forms, here, the study divided urban farming into five (5) forms based on its characteristics such as level (ground or rooftop), scale (micro or meso), actor (private or community), and intention. They are nurseries, allotment, institutional, residential and rooftop farming. Table 3 shows the detail of urban farming form. This distinction also decides each urban farming form performance known as indicator as mention earlier. Every form has certain services, thereby the valuation of urban farming services in monetary unit adjusted with particular indicator.

Form	Level	Scale	Actor	Size (m^2)	Profile (intention)
Nurseries	□	#	▲	36	A greenhouse area for cultivation purpose
Allotment	□	#	▲	40~ 50	Frequently for trade/ commercial, practice and social purposes
Residential	□	*	♦	6~ 25	For family's self-sufficient, hobby
Institution	□	#	▲	30~ 70	Intended for education, hobby
Rooftop	○	* #	♦ ▲	<10 92	Located in private or institutional building rooftop; For space utilization and hobby

Table 3. Profile and characteristics of urban farming form
Note: Ground □ and Rooftop ○; Meso # and Micro *; Private ♦ and Community ▲

Table 4 is the result of urban farming values especially in certain indicator and form. Residential farming takes highest value cause mostly urban farmers have their own farm and can access as well as obtain the benefits directly i.e. harvest and gain microclimate comfort (good air quality, humidity and temperature). For community farming, allotment takes highest value. Allotment usually uses for many purposes by inhabitants. In addition, people can access or get training or knowledge from community through utilizing partial sites in allotment farming. The total value of urban farming if it is implemented in square meter unit area is US$ 28.68 m^{-2} annually. This value has not excessed the land value yet as a benchmark for US$ 29.25 m^{-2} yr^{-1}. However, the difference between benchmark and the value is only US$ 0.57 m^{-2} yr^{-1}. It indicated that urban farming is valuable however it is still needed the support mechanism to cover the gap. The study proposed incentive mechanism scheme by local government for amount the difference between benchmark and value. Through the mechanism the government could maintain and enhance urban green private space and urban dwellers can be engaged to participate to urban farming.

Services	Ns	Al	If	Re	Rf
E1. Provisioning food		2.67	1.52	15.91	2.76
E2. local income generation	2.16	1.44			
SE1. Recreational and community-building	0.09	0.56	0.15		
SE2. Education and learning	0.12	0.77	0.20		
H. Maintenance urban comfort	0.03	0.19	0.05	0.01	0.05
Total Value	***2.40***	***5.63***	***1.92***	***15.92***	***2.81***

Table 4. Monetary valuation of the indicators in each urban farming form in USD per m^2 annually (Ns: Nursery; Al: Allotment; If: Institutional; Re: Residential; and Rf: Rooftop farming)

3.2 Land Inventory

Based on field visit and direct survey, the result shows that recently Malang has urban farming areas in the amount of 1.4 ha or equal to 0.01% of total city's area. These total areas are distributed by several urban farming form as shown in Table 5. This occupation is very small contribution in the target of green private space in Malang city of 10%. However, based on identifying potential area, there is 211 ha or 1.9% of total area could be implemented as urban farming. The highest increasement is showed by allotment form followed by residential, rooftop, institutional and nurseries farming form. Allotment occupied the highest one because there are brownfield areas in Malang city that possible to be converted into farmland. However, it is still lacking information and mechanism regarding land ownership and benefit sharing between community farmer and landowner if it is converted into farmland. Moreover, there is still gap between current condition and potential areas to the green space target. But this initial identification also indicated that there is chance to expand urban farming implementation as contribution as green private space. Here is the map of existing and potential areas (Figure 5) as well as the occupation area size (Table 5).

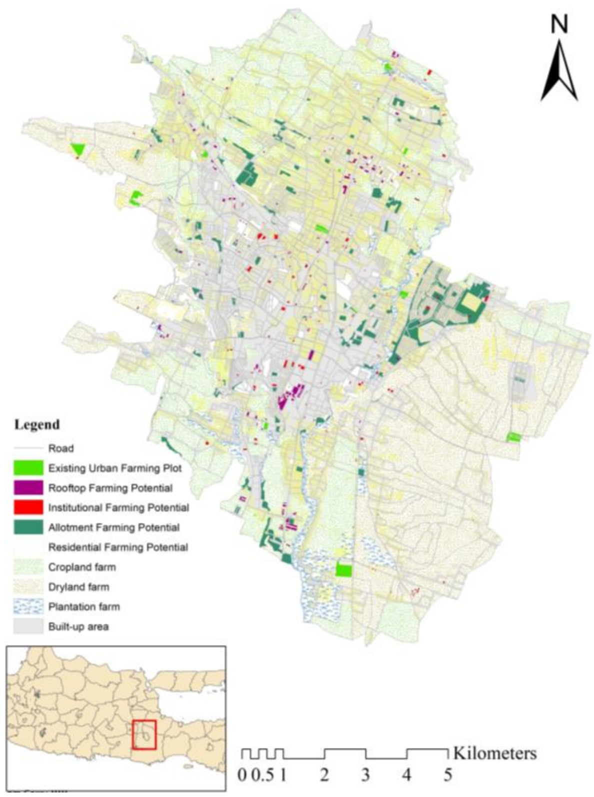

Figure 5. Existing and potential urban farming area

Urban Farming Form	Existing Area (ha)	Potential Area (ha)
Nurseries	0.0686	0.1982
Allotment	0.8580	143.4354
Residential	0.4021	58.2655
Institutional	0.0166	2.3596
Rooftop	0.0323	7.0610
Total	1.3776 (0.01%)	211.32 (1.92%)

Table 5. Number of total areas per each urban farming form

3.3 Actual and Potential Urban Farming Services

Considering total value per unit area and land availability for urban farming, then the actual and potential services of urban farming can be done. The total actual value of urban farming is US$ 395,095.68 annually while potential value is US$ 60,646,800.35 annually for entire city. This value indicates that urban farming could contribute to 2.16% of Malang city GDP and thus city's resilience.

4. CONCLUSION AND FUTURE RESEARCH

It was acknowledged that urban farming could improve cities resilience through various services such as provisioning food supply, generating local income, emerging recreational and community-building, provisioning green education and learning, and maintaining urban comfort. The total value of urban farming in Malang city was US$ 395,095.68 annually and potentially up to US$ 60,646,800.35 annually. Malang has not achieved the target of green space especially for private space. Given the potential areas, this is an opportunity to extend urban farming initiative and engage more urban dwellers in maintaining green space associated with its benefit.

The future work will be suggested as follows: (1) develop spatiotemporal analysis considering future urban development as scenario such as increasing population, land use and climate change and policies support, (2) identify suitable vegetables that appropriate with the scenario, and (3) consider undesirable effects of urban farming operation.

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