Master's Thesis of Engineering

# A study for the application of Urban Farming in low-rise neighborhoods in Seoul

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# Abstract

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The global urban population is rapidly increasing. As such, cities face the challenge of balancing resource consumption with safeguarding our environment. One such resource is food. Agricultural products travel far from the harvesting site to the final consumer. This distance is cause for several issues such as high-energy consumption, increased food prices, vulnerable distribution chains, and loss of the collective memory of farming practices.

Recently, urban farming has become an important means to tackle these issues and achieve sustainability in cities. Urban farming has environmental, economic, and social benefits. It is highly supported by the Korean Government as a strategy for urban regeneration and smart city development.

This research evaluated the potential for urban farming in low-rise neighborhoods in Seoul. Because land in Seoul is scarce and urban agriculture is a valuable tool for the resilience of residential communities, this research evaluated the possibility of implementing building-based agriculture in low-rise neighborhoods.

To measure urban farming potential, this study built a model to determine the available area for farming, the sunlight intensity, and the water collection potential of a low-rise neighborhood. This study chose the neighborhood of Samseong-dong in Gwanak-gu as the site to base the model on.

The study measured building form variables (footprint area and building perimeter) and environment variables (rainfall and sunlight intensity) to model the urban farming capacity of the neighborhood. The research also calculated the impact of urban farming in the area in terms of the reduction of CO2 emissions from transportation and crop yield to satisfy dietary requirements.

The results indicate that low-rise neighborhoods have great potential for the introduction of urban farming. They have sufficient available space on buildings (rooftops, walls, and railings) for farming. They also have sufficient rainwater harvesting capacity and sunlight intensity to grow a variety of crops. The results show that this kind of building-based urban agriculture can be useful to provide food for local residents, but has a limited impact on the reduction of CO2 emissions.

**Keywords:** urban farming, sustainability, Seoul, building-based farming, low-rise neighborhoods

**Student Number:** 2018-28901

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# Chapter 1. Introduction

## 1.1 Statement of problem

As more of the global population is moving into urban areas, we face the challenge of reconciling the often-opposing demands of growing cities with the safeguarding of our environment and natural resources. Indeed, the global urban population is expected to near seventy percent by 2050 (Ritchie and Roser, 2019). How to make cities more sustainable as the global urban population increases? There is no simple solution to this very complex issue. Cities have the biggest environmental footprint of any settlement type, but they also have less energy consumption per capita (Thomaier et al., 2014). This indicates that, while urban areas consume the most resources worldwide, they do so more efficiently. Cities will undoubtedly be even more prevalent in the future, but we must work in reducing and optimizing their consumption of natural resources.

A city relies on the resources produced outside of its boundaries to sustain its many systems. One of the crucial resources is food. Crops are grown outside the city and then brought in to satisfy the dietary requirements of urban residents. This distance between farming and the consumer is cause for a variety of issues. First, the process of transporting goods over long, sometimes international, distances is cause for a big part of the energy consumption (Quan et al., 2013). When it comes to Korea, the distance agricultural products must travel to reach the hands of city-dwelling consumers is higher than other developed countries, with 49.2% of all food being imported (Lee et al, 2015). For Korean cities to be more energy-efficient, this travel distance should be significantly shortened.

The current food provision system for cities depends on a long, complex supply chain. As the recent COVID-19 epidemic has shown, the supply system for cities is vulnerable to shocks. In light of the harsher climate that is bound to come with the increase in global temperatures, cities must face the multipronged challenge of accommodating for larger populations while being better prepared to face unpredictable shocks. It is crucial to focus on city resilience in order to prepare for these challenges. A hyper-localized farming system that supplies food to cover some of the nutritional requirements of the populations would help increase resiliency (Drechsel, 2020; Mechielsen, 2020).

In recent years, urban agriculture has gained prominence as a strategy to achieve sustainability in cities. In Korea, urban farming is favored and strongly supported by government policies, as it is considered a key pathway to urban renewal by providing a stage for economic and social activation. An example of this support is the enactment of the Urban Agriculture Ordinance and the Act on Fostering and Supporting Urban Agriculture in 2013 (Lee et al., 2015). Urban farming also falls within the smart city paradigm, of which Korea is a pioneer. Smart farming initiatives developed in Korea are useful not only for the country to achieve green growth but as sustainable technologies to export to other countries.

In Seoul, the total area allocated to urban agriculture has increased in recent years, going from 1.04 km2 in 2010 to 5.58 km2 in 2012 (Kim, 2017). Despite this growth, current levels of intra-city farming are not enough to have a significant effect on resilience. There are numerous challenges to increasing the intra-city farming area in Seoul.  It is fundamental to secure space for urban farming, but doing so poses a major challenge in such a highly dense city where land is scarce.

The words "urban farming" often conjure the idea of magnificently designed sky-scrapers with vegetation growing out of every terrace, if not highly technological vertical farms with seemingly endless racks of greens (Despommier, 2013). However, this is the extreme vision of urban agriculture. The current reality is that a majority of urban agriculture happens on vacant, undeveloped land, or in repurposed buildings that were previously abandoned (Thomaier et al., 2014). While undeveloped land is quite limited in Seoul, there is an opportunity for urban agriculture in building-adapted farming practices.

## 1.2 Research purpose

Considering all the previous arguments, the aim of this research is to see if urban farming, not dependent on land but adapted onto buildings, is a feasible way to increase the urban farming area in the city. This research aims to define a model to evaluate the urban farming potential in Seoul. The primary motivation for the introduction of urban agriculture in Seoul is to increase resilience, especially that of the most vulnerable neighborhoods. In the case of Seoul, these are old, low-rise residential areas.

The goal is to design a model that can reliably calculate the potential for urban farming in low-rise neighborhoods in Seoul. The model must be based on real building form to increase reliability and applicability in diverse neighborhoods of the city. Planners can use this model as a tool to assess urban farming potential and integrate it into regeneration proposals.

### 1.3 Scope and limitations

As Jane Jacobs (1961) said, cities are an issue of complexity. As such, this research aims to keep a wide, interdisciplinary lens of the problem, drawing from a variety of fields in order to address city complexity.

The feasibility of expanding urban agriculture in Seoul can be studied from many perspectives. It can be framed from the perspective of land acquisition, supporting policies, market viability, farming workforce, energy cost, among many others. While all these matters are important, due to time and language, constraints this study focuses on evaluating the feasibility of urban farming in terms of space available on buildings and environmental factors such as sunlight and water.

## 1.4 Research question

Based on everything discussed so far, the central research question is the following: Is building-based urban farming feasible in low-rise neighborhoods in Seoul?

The sub-questions to be answered in this research are:

- What buildings are better suited for incorporating urban farming?
- What is the area available for urban farming on buildings?
- Is urban farming feasible in terms of sun and water requirements?

## 1.5 Terms and definitions

In this study the terms urban farming, urban agriculture, and intra-city farming are used interchangeably.

# Chapter 2. Theoretical Formulation

## 2.1 Literature review

The literature was searched to establish a theoretical framework. Urban farming is an incredibly vast subject, with many theoretical postures on how it ought to be implemented in cities. This review focused on finding an urban farming approach suitable for the Seoul context.

### 2.1.1 Urban farming

Urban farming is defined as “the growing, processing, and distribution of food and other products through intensive plant cultivation and animal husbandry in and around cities” (Brown K. H et al., 2003). Urban agriculture is primarily a way to satisfy the need for food in cities, but it also provides an array of additional benefits. It generates new green spaces, helps with the control of runoff, and can provide cooling effects that reduce the urban heat island (Dimitri et al., 2015). Compared to traditional agriculture, urban farming produces higher yields as it is capable of year-round harvest. It consumes less water, is more resilient against extreme weather, is less location-dependent, and allows farmland to return to its original ecological condition (Despommier, 2013). Additionally, it leads to a decrease in greenhouse gas emissions and promotes the cultivation of social, emotional, and community well-being (Lee et al., 2015). Lastly, urban farming increases a community's resiliency by securing food supply in times of crisis.

While the definition of urban farming does not explicitly refer to sustainability, it is implicit that intra-city farming has sustainability objectives. In this sense, urban farming projects pair well with other resource-efficient technologies such as rainwater harvesting and photovoltaic panels. A study by Quan et al. (2013), using Atlanta as a case study, found that urban farming coupled with solar panels resulted in high levels of food production, energy production, and carbon emission reduction. Their results show that urban farming is a meaningful strategy not only for food production but also to achieve negative levels of CO2 emissions.

#### 2.1.1.1 Types of urban farming

Agriculture is usually associated with land consumption. However, recent technological advances (hydroponics, aquaponics, LED lighting, etc.) make it soil-less agriculture possible. Urban agriculture can be classified as soil-based farming and building-based farming or Zfarming (zero-acreage farming), the latter is called so because it does not depend on ground access for food production (Thomaier et al., 2014). ZFarming, which includes open rooftop farms, rooftop greenhouses, productive facades, and indoor farming, is the best farming alternative for highly dense cities with limited access to undeveloped land. One benefit when it comes to indoor farming is that it can be practiced year-round. Indoor farming and rooftop farming have controlled environments that are well isolated from city pollutants. As such, they are a safer alternative for human consumption than open soil-based urban farming. For these reasons, this study selected building-based farming, in particular open rooftops and productive facades, as the urban agriculture modes to consider for Seoul.

Urban agriculture has many purposes. Thomaier et al. (2014) conducted an extensive review of urban farming projects worldwide and determined it has three main goals:

1. Sustainable food production: used to create sustainable models for food supply.
2. Education and social commitment: used as a means of teaching values associated with food production and healthy nutrition.

3. Urban qualities: seen mainly as a recreational space that improves urban spaces and community.

According to their study, Asian countries tend to employ urban agriculture as a means to improve urban qualities. In Korea, the focus is mostly on community development, food sovereignty, and urban regeneration. This study shows that food production is not the only goal of urban farming. In the Asian context, it is favored for its social benefits.

#### 2.1.1.2 Urban farming technologies

Urban farming is, by definition, farming that occurs in an urban setting. As such, traditional agricultural techniques reliant on ground access and sunlight, if applied to land within a city, are still considered urban farming. This approach is the most low-tech one, as no additional technological developments are necessary. However, as previously mentioned, both the lack of undeveloped land and the risk of contamination due to air and soil pollutants make this approach less than ideal for cities.

Technological advances, such as hydroponics and LED lights have now made it possible to grow crops without soil or direct sunlight. In recent years, these technologies have become inexpensive enough to be a viable option for large-scale city farming (Taber, 2018).

Hydroponic systems are those where the soil is replaced by nutrient-rich water (Despommier, 2019) (Figure 1). A variant of hydroponics is aquaponic systems, where fish are introduced into the water medium. In these systems, the excretions from the fish function as fertilizer for the plants. Hydroponic and aquaponic systems can be stacked vertically, allowing for higher yields of crops per area. A study by Aatif et al. (2014) estimates that hydroponic systems can yield between 2 to 18 times as much food as soil-based cultures for the same area, depending on the crop.

The vertically stacked systems can be attached to walls to make outdoor productive green walls (Figure 2), or used on rooftops for open rooftop farming (Figure 3). Several companies manufacture hydroponic farming kits designed for easy use and production at the home level, such as ZipGrow in the USA and Daesan or n.thing in South Korea. For the evaluation of farming potential in Seoul, this study will consider hydroponic systems based on the previously mentioned technologies.

Figure 1. Indoor hydroponic agriculture case in Seoul. Source: Griin Agriculture Company

Figure 2. Hydroponic farming wall. Source: ZipGrow Inc.

Figure 3. Hydroponic systems for rooftop farming. Source: Daesan Precision Neulpurenchae

### 2.1.2 Urban farming and resilience

Urban farming has existed in some form for centuries but has only gained prominence in the last decade (Despommier, 2013). It can be hard to envision based on the farm-lacking nature of most cities, but historically, cities have always incorporated farming practices into their boundaries. Barthel and Isendahl (2013) explain that the modern city conception, established in the early 20th Century, zoned city uses such that farming was extricated from the urban and made entirely rural. The authors express that city and agriculture are not incompatible concepts, and that the contemporary city would highly benefit from introducing productive farming systems.

Farming has been part of cities for most of human civilization, playing a vital role in their resilience. A home-based, decentralized urban agriculture system allowed ancient cities to survive shocks such as extreme weather and anthropogenic disasters. Barthel and Isendahl (2013) describe how the Oikos (household farmstead) system in Constantinople was crucial in the city surviving an 8-year siege. Urban farming in ancient cities was not the sole form of food production, most food supplies were farmed outside city limits. Still, urban agriculture was significant in diversifying food production networks and giving low-class farmers more agency over their own livelihood.

In the current context, urban farming is considered a strategy for resilience, especially in developing countries. It is a source of food security and increased nutrition, a market stabilizer for food prices, a source of income for urban farmers, a way to improve community-based management, and a tool to mitigate the effects of harsh climate (de Zeeuw et al., 2011). The author suggests that urban agriculture should be poly-centric, micro-scale, and integrated into the most vulnerable communities.

Urban farming can also provide resiliency to cities in developed countries. These cities are less vulnerable than their developing counterparts. However, they are not exempt from a shock-induced crisis. Hervé-Gruyer (2019) says that Paris would only be able to subsist for three days from their food stock if supply is entirely cut-off. Such scenarios, while unlikely, are not impossible. The recent COVID-19 pandemic has highlighted the weakness in our supply chains. In light of the outbreak, several authors have pointed out the need to diversify and localize food production. People-centered intra-city agriculture moves cities towards sustainable, resilient food systems that are better equipped to handle future shocks (Drechsel, 2020; Mechielsen, 2020).

Urban farming for resilience must be diverse, decentralized, people-based, and embedded in the most vulnerable communities. As such, the current research will evaluate the potential for urban farming with a focus on the older, more vulnerable neighborhoods.

#### 2.1.3 Urban farming in Seoul

Urban agriculture used to be more prevalent in Seoul until the accelerated expansion of the city that started in the 80s (Kim, 2017). The development process increased competition for land use, and farming was not economically productive enough to remain in the city. This trend has not reversed. Interviews with commercial urban farmers in Seoul revealed that land is too expensive. As such, urban farming cannot compete with cheaper produce grown in rural areas. The only viable business strategies for commercial farmers in Seoul are to harvest highly-perishable, exotic crops (herbs, spices, mushrooms, micro-greens, and berries) and sell them to high-end customers, or to sell directly to consumers and remove distributions costs. As such, commercial urban farming in Seoul is unlikely to grow significantly unless production costs decrease dramatically.

In Seoul, the development of urban agriculture in recent years is mostly attributed to the baby boomer generation, who partake in it as a retirement activity (Lee et al., 2015) (Figure 4). The focus for urban farming in Seoul, as in other Asian megacities, is mostly on community strengthening, wellbeing, education, and urban regeneration. Unlike in developing countries, food self-sufficiency and job creation from intra-city farming is not a primary goal.  Citizens of Seoul and the city government both understand urban agriculture as a way to revitalize urban spaces, by building healthier communities and introducing much-needed green infrastructure. Seoul City heavily promotes urban farming through supporting research, subsidies, and educational workshops (Kim, 2017).

Figure 4. Urban farming by elder population in low-rise residential neighborhood in Seoul. Source: Korea Joongang Daily

Research conducted by Lee (2012) found that Seoul residents have a high awareness of the existence of urban farming (88.5%), even if they do not practice it themselves. It also revealed that for those who are urban farmers, the biggest challenge is the acquisition of land. The majority of farmers grow crops outdoors (54.5%). However, a significant number of farmers practice indoor agriculture on balconies and verandas (45.5%). The results reveal that for Seoul residents, there is no social aversion to growing food in buildings.

It is evident that the land market in Seoul with not promptly allow land-based agriculture to expand anytime soon. Aggressive government intervention and subsidies would be required to make this kind of urban farming feasible. As such, this research proposes that the expansion of urban farming in Seoul should be building-adapted so that prime land is not consumed. Building-based farming at the home level is suitable for Seoul by centering the practice on residents and their communities.

### 2.1.4 Durability as sustainability

What makes a building sustainable? Sustainable architecture is often framed as that which meets environmentally-friendly energy performance standards (passive housing, zero-energy building, etc.). However, this concept of sustainable buildings is too narrow as there is little consideration for a building's durability. Urban sustainability must not mean building new energy-efficient buildings at the cost of the early demolition of older ones. Ideally, buildings should be used to the maximum of their possible lifespan, as to avoid the unnecessary use of resources and energy, waste generation, pollution, and damage to the urban tissue that comes with indiscriminate demolition (Shen et al., 2013). Buildings in Korea have a very short average lifespan of 22.4 years (Seo et al., 1999), much less than the 50 to 70 years a structure could last.

Buildings are prone to early demolition or abandonment if they are unable to adapt to changing demands by the user. This condition is known as obsolescence. Rockow et al. (2019) explain that obsolescence happens when a structure is not able to satisfy the current user's demand. To overcome obsolescence, a building must be redesigned to fulfill the needs of the current context and regain relevance. Figure 5 shows the building life-cycle model they developed.

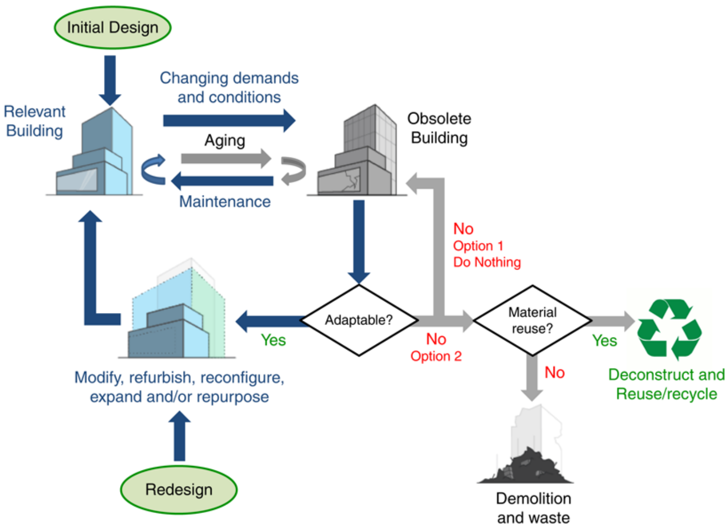



Figure 5. Building life-cycle. Source: Rockow et al., 2019

The adaptation of obsolete buildings to extend their lifespan and improve their environmental performance is gathering interest and fits well with the urban regeneration initiative currently championed by the City of Seoul. Adapting urban agriculture into old buildings is a way of gradually incorporating more urban farming into the city and substantially increasing the total area allocated to it while giving the building a new function that could expand its usable lifespan.

Which buildings are at higher risk of obsolescence in Seoul? To identify buildings that have stopped fulfilling their user's needs, we can examine the housing abandonment phenomenon. While it is a highly complex issue with social, economic, and policy-related causes, housing abandonment has links to building age and type. In Korea, abandoned houses tend to be detached, single or multi-family buildings built over 40 years ago (Jeon and Kim, 2019). Poor maintenance of the construction over the years, mainly due to the limited economic and technical capacity of the owners, has made them unsuitable for residential life.

Statistical data from The Seoul Institute (2015) shows that detached single and multi-family housing accounts for the majority (57.6%) of the housing stock built more pre-1980 (Figure 6). This building typology is at a higher risk of abandonment and early demolition. As such, it is an ideal candidate for updating by introducing farming use in addition to its residential one. As such, this study focuses on low-rise neighborhoods with detached housing as the target intervention site for the application of urban farming.

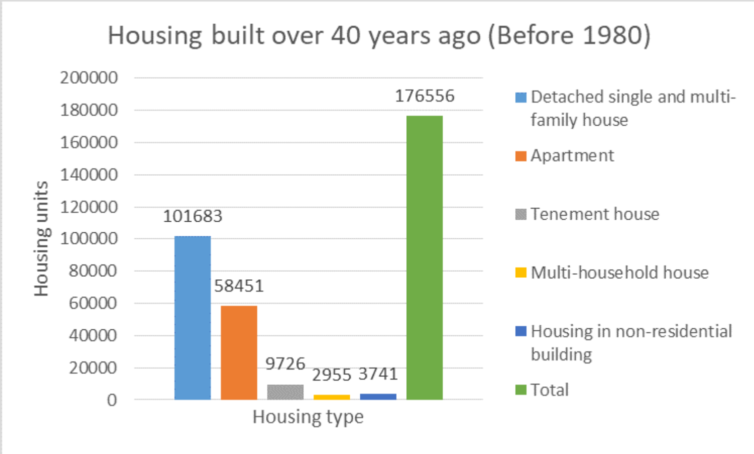



Figure 6. Housing built before 1980. Source: By Author based on

The Seoul Institute data

## 2.2 Research justification

The value of this research is in its integrated approach to the application of urban farming. Due to its theoretical formulation, while focusing on urban agriculture, this study also deals with issues of urban regeneration and resilience. Additionally, this study aims to bridge between building-scale and city-scale urban farming research. Studies to date have kept either a city-wide approach with less resolution, or a building-specific design with no expansion on how to make it scalable. The aim is that, by designing the urban farming capacity model based on building and neighborhood morphology, it can then be used to evaluate the potential for urban farming for other areas of the city with similar characteristics.

# Chapter 3. Methodology

## 3.1 Methods

This research is organized into several steps. First, a literature review and interviews are conducted to understand the urban farming context in Seoul and establish a preliminary approach to agriculture that is viable for the city.

Second, a building stock analysis is carried for old detached housing to determine the prevailing building typologies and propose better-suited farming models depending on each building type's design characteristics. The building stock analysis is conducted through GIS software, based on building data obtained from the Korean Government open data portal. A representative target site is derived from this analysis.

Third, a combination of field visits and digital resources (satellite imagery, 3D models) is used to measure a representative sample of the building population. The sample is randomly selected to ensure the reliability of the model. The field visit also informs the model in terms of existing farming practices and user-farming-house spatial interactions.

Fourth, a model to predict available farming space, sunlight incidence, and rainwater catchment capacity is established based on these measurements. Statistical tools and GIS simulations are used at this stage.

Finally, several models adapted from the literature are used to calculate the impact of urban farming in Seoul in terms of food production and the reduction in carbon emissions. Figure 7 shows the research flow.

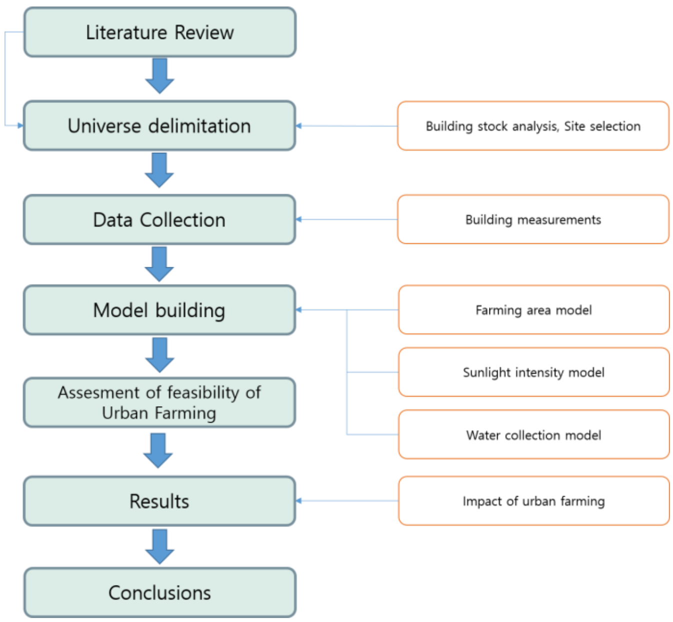



Figure 7. Research flow. Source: By Author

## 3.2 Data sources

The data for this study is a combination of direct and indirect. The direct data comes from site visits and interviews. The indirect data for this study comes from the Korean Government's open data portal, the National Geographic Information Institute, satellite imagery from Kakao Maps, and Google earth, as well as building 3D data from VWorld.

# Chapter 4. Results

## 4.1 Seoul building stock analysis

The criteria discussed in the literature review is used to identify the target buildings for adaptation. That is, detached housing built before 1990. The reason for choosing detached housing as the target building type is their high numbers, as housing stock is more prevalent in the city than any other building type. The high quantity of detached housing translates to more potential surface area for introducing building-adapted farming. Another reason to select older detached houses is their link with urban shrinkage and housing abandonment. By introducing a farming use to old detached houses, these trends could be stabilized. Lastly, a crucial step to increase the resilience of both cities and the neighborhoods that form them is diversification. Diversifying agricultural production by decentralizing it at the home-level can make communities more self-sufficient and capable of withstanding shocks. Detached housing is ideal for this, since it is already embedded in existing communities, and these can then be in charge of the farming operation.

GIS analysis was conducted on the housing data obtained from the Korean Government's open data portal. By filtering the data by building type and construction year, it was determined that 71134 houses fall within the selected criteria, with locations spread over the entire city (Figure 8). The results have detached single housing and detached multi-family housing added into the same group since the GIS data makes no distinction between these types by classifying them both as ‘단독주텍’.

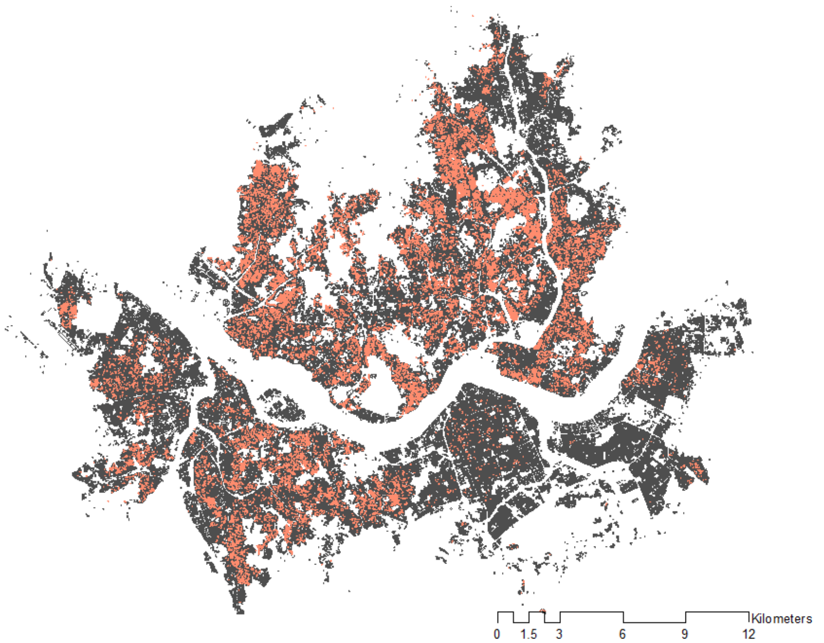



Figure 8. Footprint of detached housing built pre 1980 in Seoul. Source: By Author

Buildings were then classified by construction decade, to find the most prevalent building type and determine the most suitable urban farming strategy for each. The analysis conducted on the building stock data shows that the prevalent building type varies by decade.

Figure 9 shows how the primary construction type changed over the years from wood to brick construction.

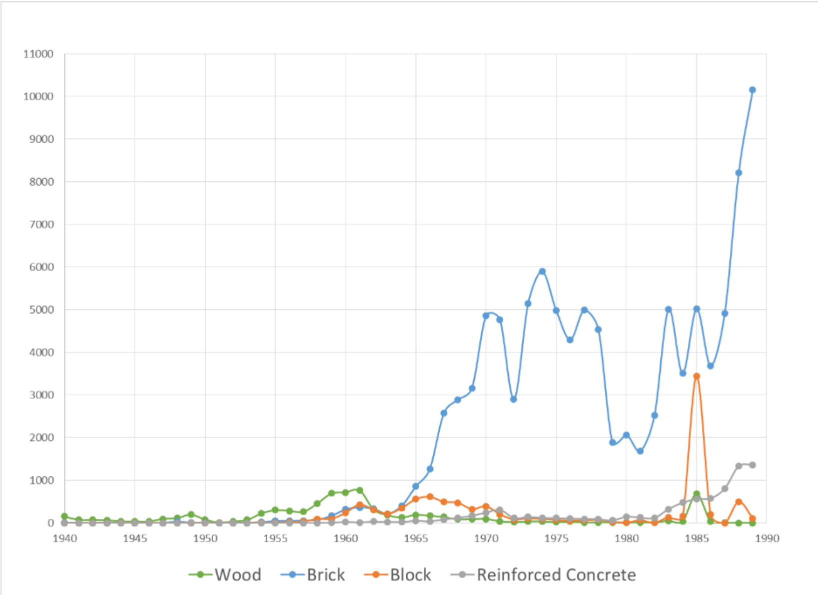



Figure 9. Number of detached houses per year per construction type. Source: By Author

The results show the prevalence of brick construction. It is encouraging, since brick structure, as well as block and reinforced concrete, is strong enough to carry the structural load of wall farming systems, according to ZipGrow, a manufacturer of wall mounted farming systems. Buildings dating from the 70s onward are suitable for rooftop farming since they have the greater structural integrity to support additional agriculture-related loads. Rooftop farming is difficult to apply to smaller, one to two-floor buildings from the 60s and early 70s, not only because of the weaker structure but also because the majority have sloped roofs that cannot be used for this purpose. Figure 10 shows the building typology difference in Seoul for houses in the 60s and 70s. Considering this, productive facades in the form of green farming walls are a better option for buildings in the second group (Figure 11). Buildings from before the 60s are discarded from the urban farming feasibility model. Their wooden structure and low numbers make them unsuitable and their influence negligible.


Figure 10. Representative building typology per decade. Source: Kwang-Joong Kim

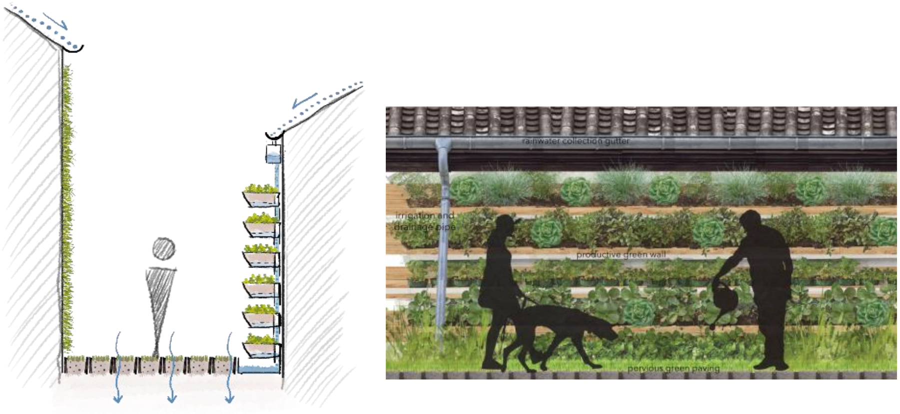



Figure 11. Productive green walls for sloped roof buildings. Source: By Author, Christine Lee and Jenny Yuen

The analysis of the Seoul building stock shows that variations in building typology must be considered when evaluating the feasibility of urban farming on buildings. Different building form characteristics such as roof type, number of floors, and construction type influence what kind of building-based agriculture can be applied. As such, these factors should be considered when calculating the total available area for farming, rainwater harvesting potential, and solar intensity.

### 4.2 Determining the site

A real site in Seoul was selected to determine how to apply urban farming at the neighborhood level. The principal condition for the selection of the site is the agglomeration of older detached housing, to calculate urban farming potential, not for a selected building but an entire sector.

In the analysis of the Seoul housing stock, detached brick houses from the 70s onward were found to be the most numerous building type. This building typology often has flat roofs with accessible rooftops, making it an excellent candidate for rooftop farming (Figure 12). The brick construction makes the building sturdy enough to hold the weight of the farming walls.

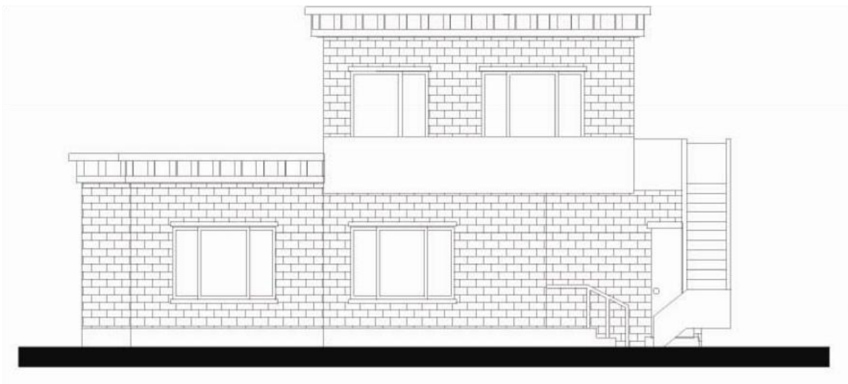


Figure 12. Typical detached housing from the 80s. Source: KIST

A GIS analysis using the same building stock data from the previous section was conducted to determine clusters of detached single and multi-family housing in Seoul, built between 1970 and 1990. Figure 13 shows the location of these clusters. The three districts with the highest number of detached housing are Gangbuk-gu, Gwanak-gu, and Geumchon-gu. Table 1 shows the districts and neighborhoods with the highest number of detached houses in Seoul. Based on this cluster analysis, Sillim-dong was selected as the target district to study as it has the highest number of the selected building type.

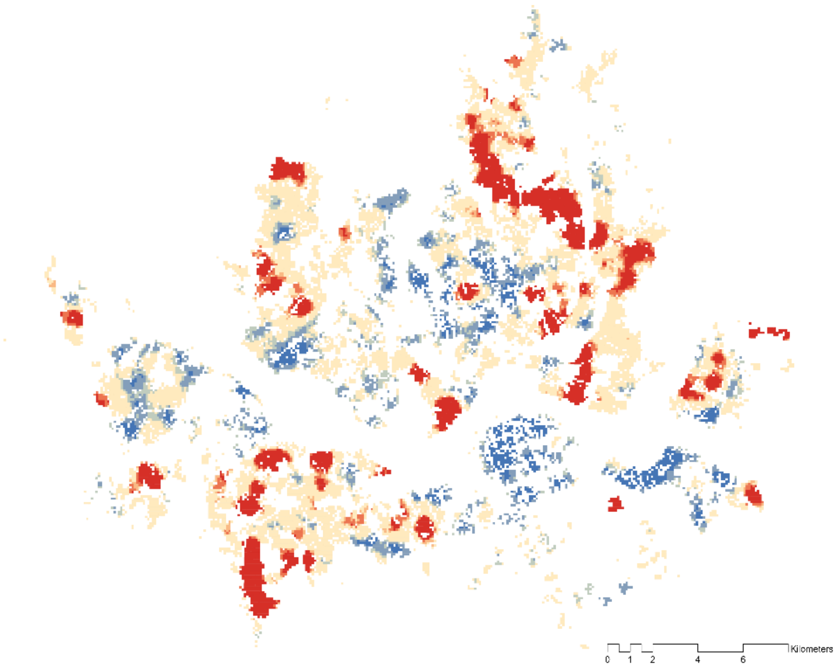



Figure 13. Clusters of detached brick housing in Seoul. Source: By Author

Table 1. Seoul neighborhoods with high numbers of detached housing.

Source: By Author

| Neighborhood | Neighborhood (in Korean) | Number of detached houses |
|---|---|---|
| **Gwanak-gu, Sillim-dong** | 관악구 신림동 | 3692 |
| **Gangbuk-gu, Mia-dong** | 강북구 미아동 | 3259 |
| **Gangbuk-gu, Suyu-dong** | 강북구 수유동 | 2914 |
| **Seongbuk-gu, Jangwi-dong** | 성북구 장위동 | 2724 |
| **Jungnang-gu, Myeonmok-dong** | 중랑구 면목동 | 2693 |
| **Gwanak-gu, Bongcheon-dong** | 관악구 봉천동 | 2456 |
| **Geumchon-gu, Doksan-dong** | 금천구 독산동 | 2140 |
| **Geumchon-gu, Siheung-dong** | 금천구 시흥동 | 2133 |

The target buildings in Sillim are spread across the entire *dong*, with some higher concentrations in the neighborhoods of Sinwon, Nangok, Samseong, and Nanhyang (Figure 14, 15).

It must be pointed out that the adaptation proposal is not exclusive to old detached housing, as other suitable buildings in the neighborhood can also be considered. The detached single and multi-family building type is an indicator of the convergence of low-rise, more vulnerable communities. It also ensures the model can be applied in other neighborhoods that have a similar composition. Because of this, the methodology used to determine the feasibility of urban farming in this section could be adapted more promptly to other clusters in Seoul.

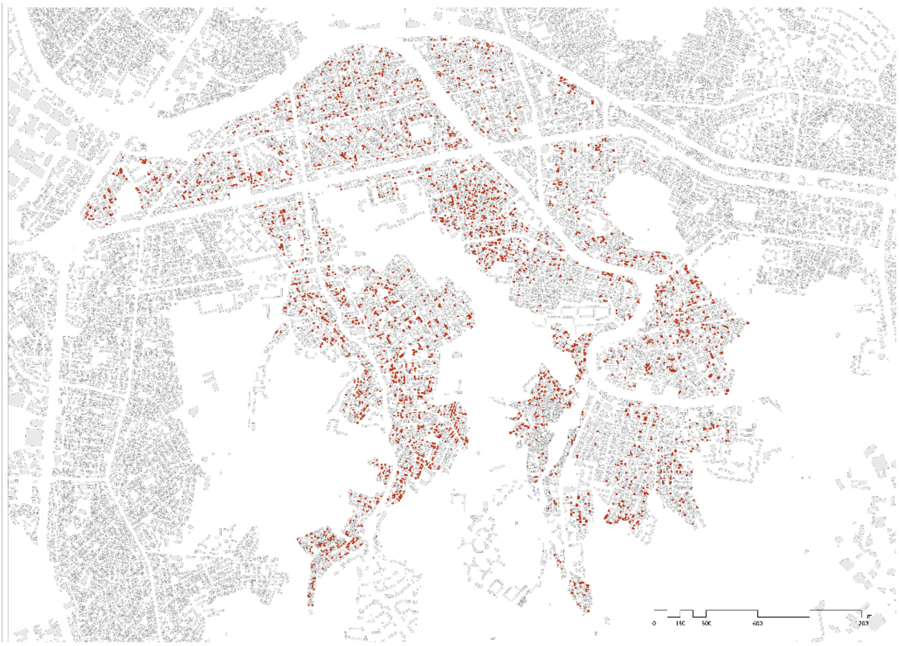


Figure 14. Detached housing from 70s and 80s in Sillim-dong. Source: By Author

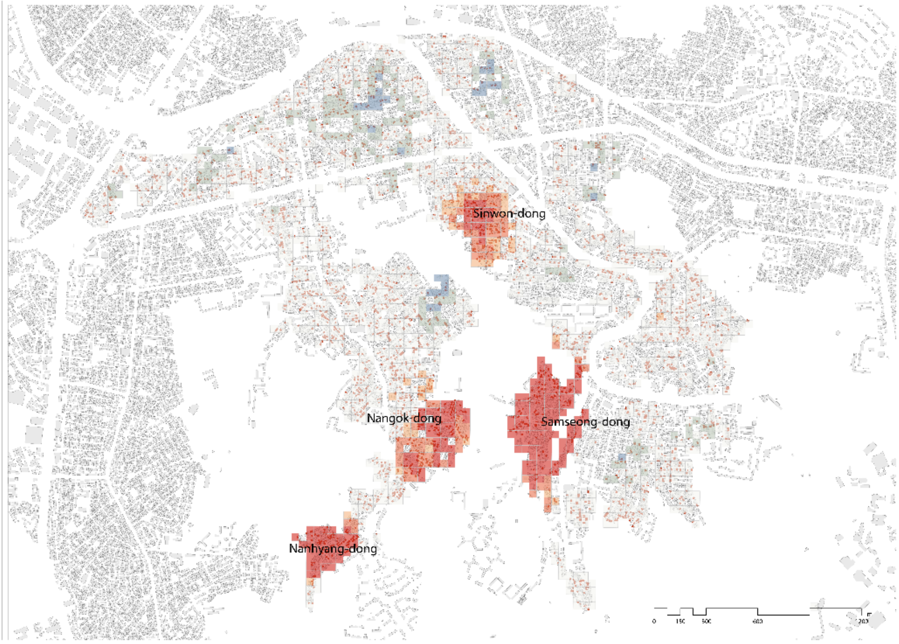



Figure 15. Cluster analysis of old detached housing in Sillim-dong. The clusters correspond to the neighborhoods of Sinwon, Nangok, Samseong and Nanhyang. Source: By Author

Samseong-dong was selected as the site (Figure 16) for the proposal of building-adapted urban farming. Its high concentration of low-rise, detached housing will enable the evaluation of urban agriculture potential for the neighborhood.


Figure 16. Site boundary in Samseong-dong. Source: By Author

### 4.2.2 Site analysis

A preliminary analysis of the site was conducted to evaluate its potential for urban farming. First, GIS analysis was used to study preliminary conditions of the site that could affect the performance of urban farming: building age, building height, street width, and terrain conditions such as elevation and slope. Then a site visit was conducted to observe existing farming practices.

#### 4.2.2.1 GIS Analysis

The construction year analysis confirms that Samseong-dong is majorly composed of buildings built before 1990 (Figure 17). Historic maps were consulted to determine the construction period for the buildings where GIS data was incomplete. The variety in construction years suggests a variety of buildings types, indicating that several urban farming technologies must be considered and adapted according to each type.

The floor number map (Figure 18) shows that most buildings are between one and four floors tall. This map, in combination with the elevation and slope map (Figure 19), suggest that solar radiation on the site will be beneficial for farming, as the buildings are not tall enough to cast significant shadow on each other and the terrain is relatively flat which also reduces possible building shade.

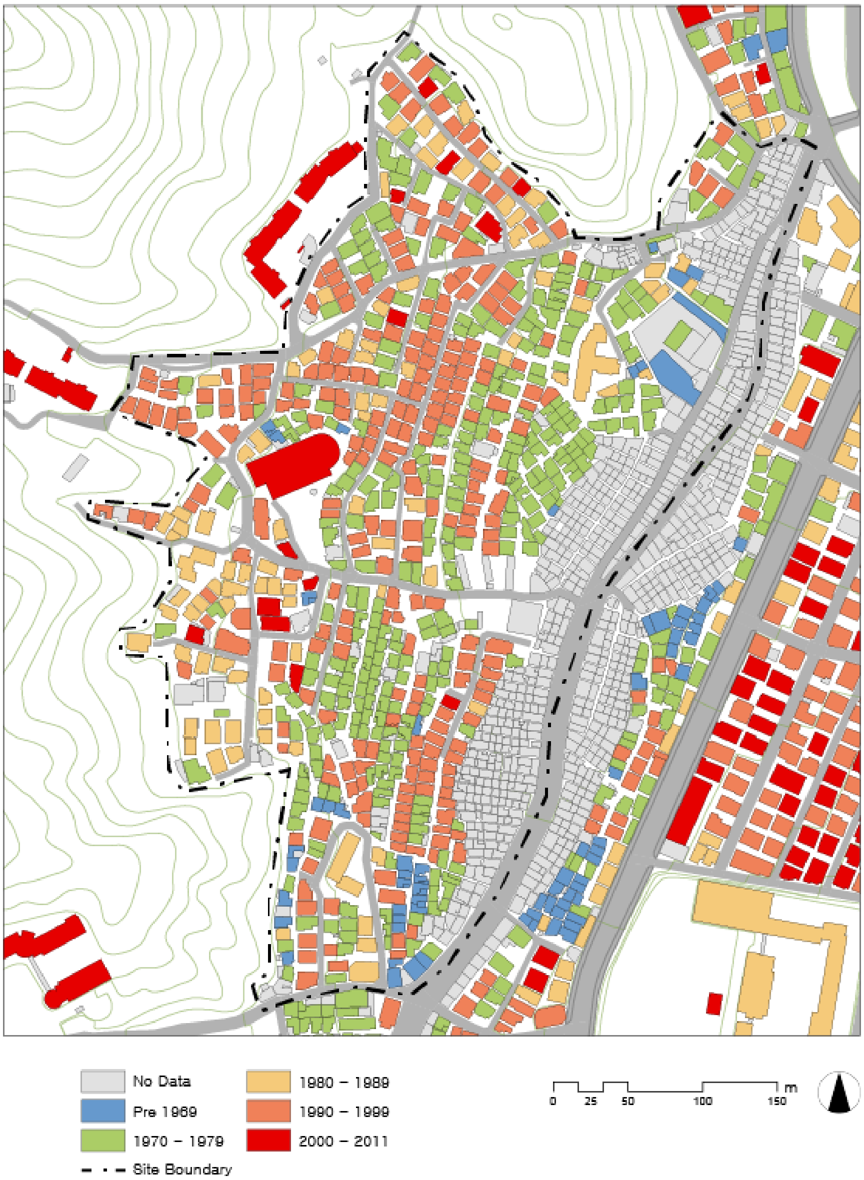



Figure 17. Construction year map. Source: By Author

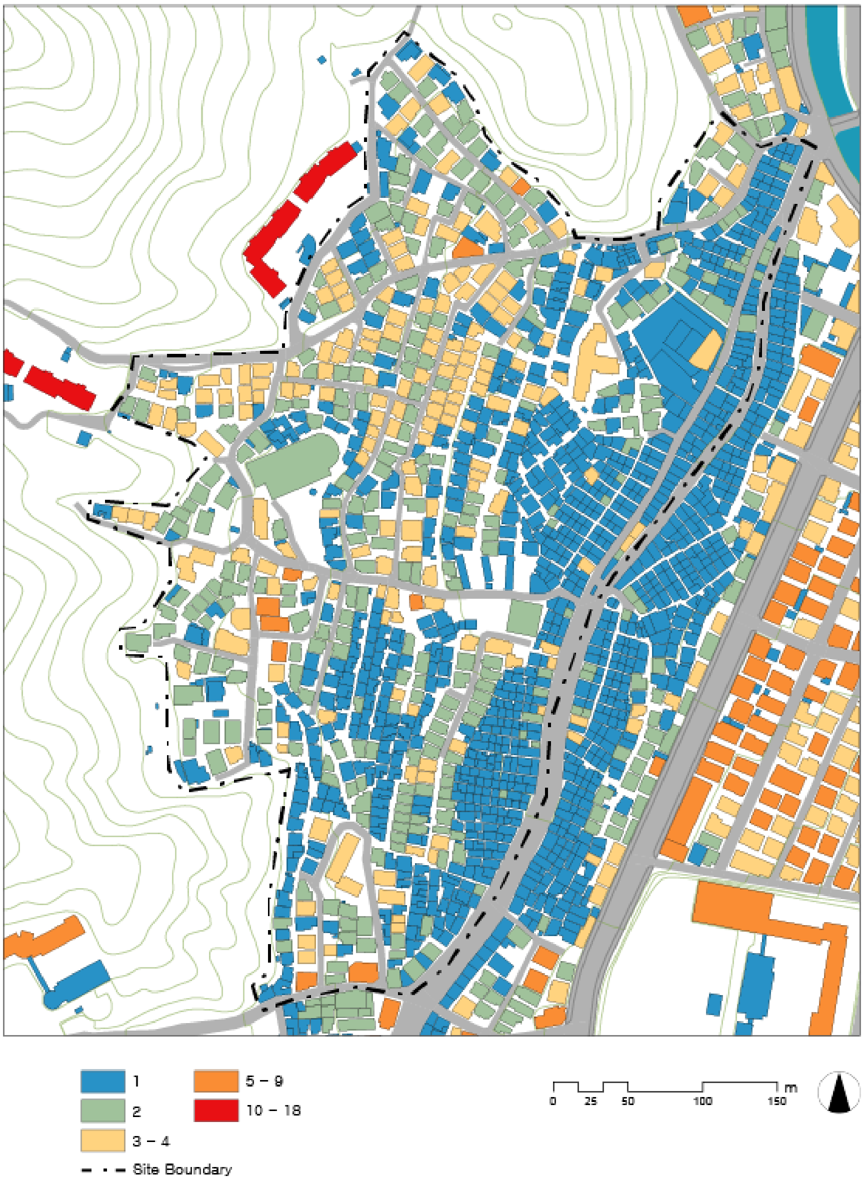



Figure 18. Floor number map. Source: By Author

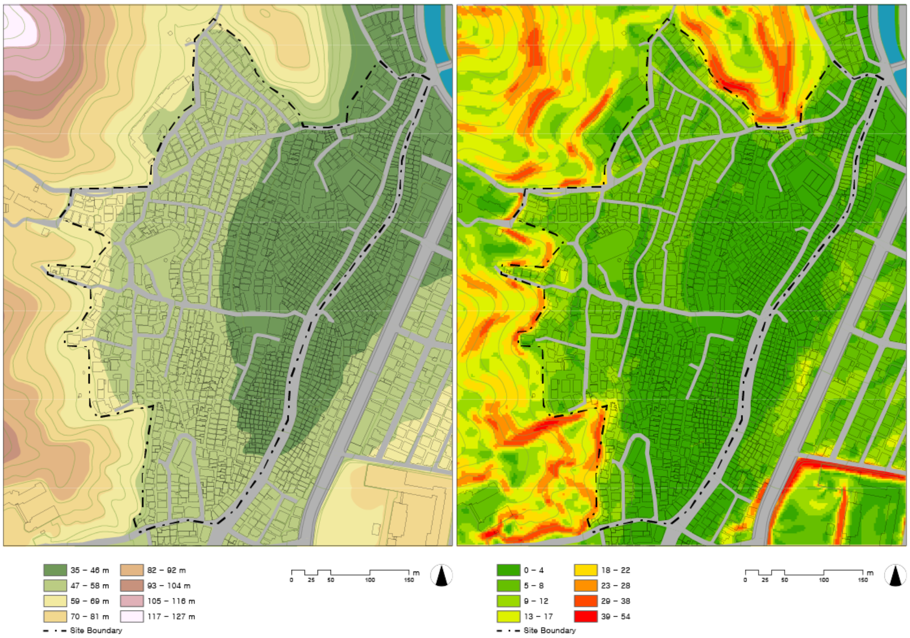



Figure 19. Elevation and Slope map. Source: By Author

Lastly, a street width analysis was conducted on the site (Figure 20). It revealed that most streets in the area are less than 4 m wide. Such narrow streets heavily restrict car traffic. Narrow streets are beneficial in the case of urban farming since reduced traffic results in less contamination risk for plants grown at ground level. Houses that face these streets are ideal for the implementation of productive farming walls accessible from the ground-level.

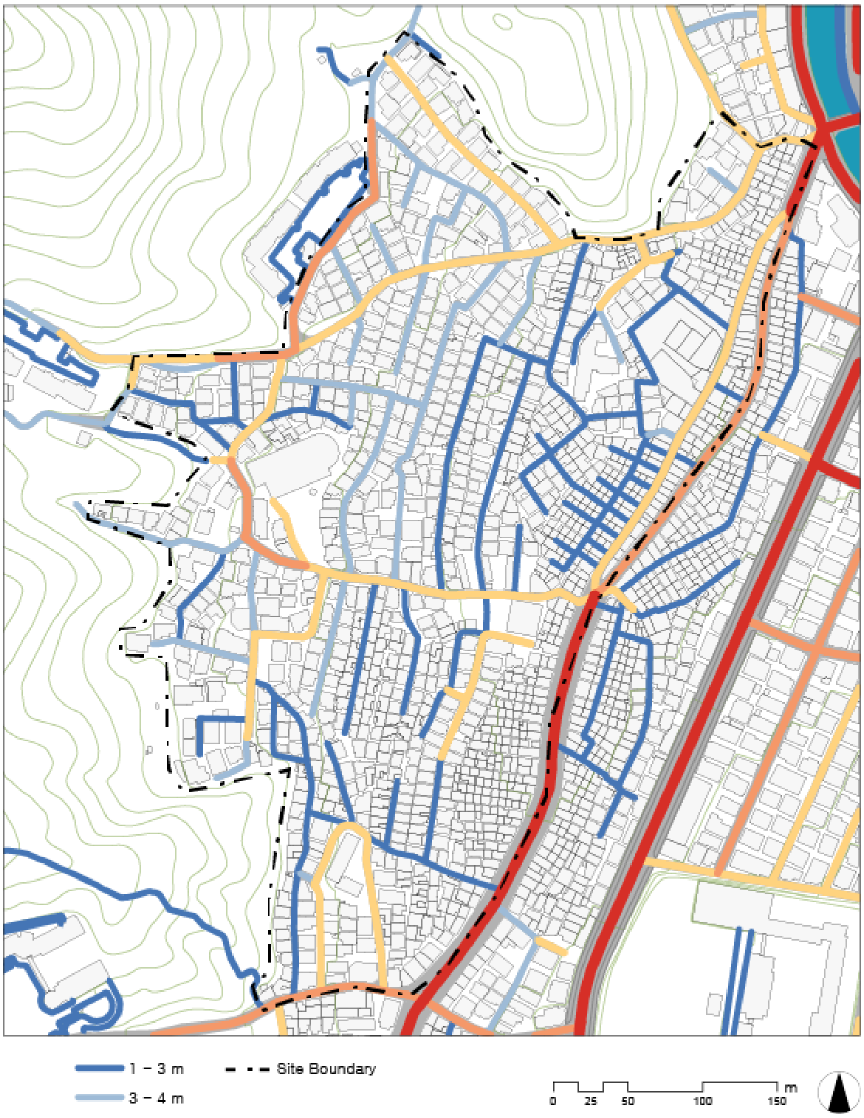



Figure 20. Street width map. Source: By Author

4.2.2.2 Existing farming practices in the site

A visit to the site was conducted on May 22nd to document existing farming practices. It showed that the horticulture of both edible and non-edible plants is common practice in the neighborhood (Figure 21). It is a positive finding, not only because it proves that locals have an active memory of how to grow crops, but also because it tells us how residents use farming to interact with space in and around their homes.

Figure 21. Lettuce farming in the site. Source: By Author

It was instructive to see the different configurations of house and farming interaction. One particularly interesting case was the use of staircase railings to hang planters (Figure 22). It is an ingenious solution to introduce farming area when the available space on the building is minimal.

Figure 22. Planters hanging from railing. Source: By Author

The most common location for growing plants in the site was in planters aligned to the outside wall (Figure 23). This seems to indicate that using a building's idle portions of a wall (these sections do not have windows, piping or cables on the wall) is a valid option to increase the area allocated to urban farming.

Plants are used on the site as a way to define street activity. Several instances of plants employed to reduce street width and prevent parking were documented (Figure 24). It suggests that if wall farming is implemented and the available street space inevitably decreases, the inhabitants of the site would not be against it, as it would help control vehicle traffic.

Figure 23. Planters next to building wall. Source: By Author

Figure 24. Planters as means to control streets pace. Source: By Author

The site visit revealed that locals are very ingenious when it comes to horticulture. They will grow plants on any given space available, sometimes even unexpected places such as the top of walls (Figure 25). This ingenuity and persistence on growing plants despite the limited space reveal the importance of this practice for locals.


Figure 25. Plants on building walls. Source: By Author

It was not possible to document rooftop farming during the visit. Instead, satellite imagery was used to confirm its presence. Rooftop farming, mainly in individual planters, is also commonplace.

This visit was insightful. It allowed deriving appropriate farming technologies suited for the site based on the existing farming practices. Most agriculture in the site is conducted in a low-technology manner, with soil as a growing medium and manual irrigation. If we keep the placement of the farming on buildings but update the technology to a more efficient one, production can grow significantly. In addition to the methods mentioned in chapter 2 (rooftop and wall hydroponic farming), a third technology (Figure 26) was selected to be placed on railings. It is a more productive version of the cases documented during the visit.

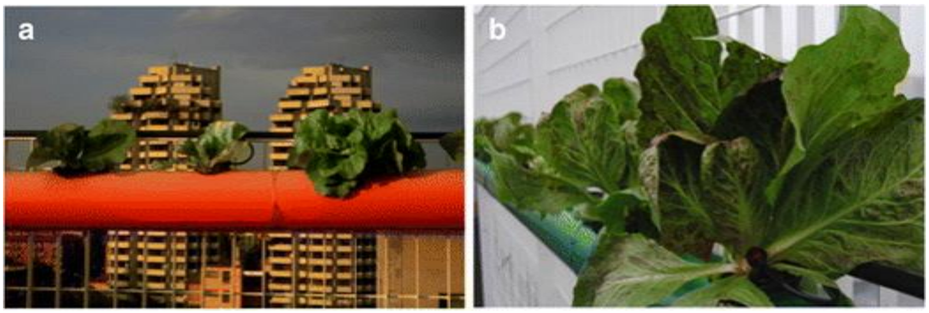



Figure 26. Linear growing system hung from railings. Source: Orsini et al., 2014

## 4.3 Urban farming model

This research developed an urban farming model for the site based on building form variables and environmental variables. The building form variables (footprint and perimeter) were used to calculate the total available area for farming. The environmental variables (rainfall and sunlight intensity), in conjunction with the building form variables, are used to determine the irrigation capacity and growable crops for the site. Figure 27 depicts the relationship between these variables. The subsequent sections elaborate on each of these calculations.

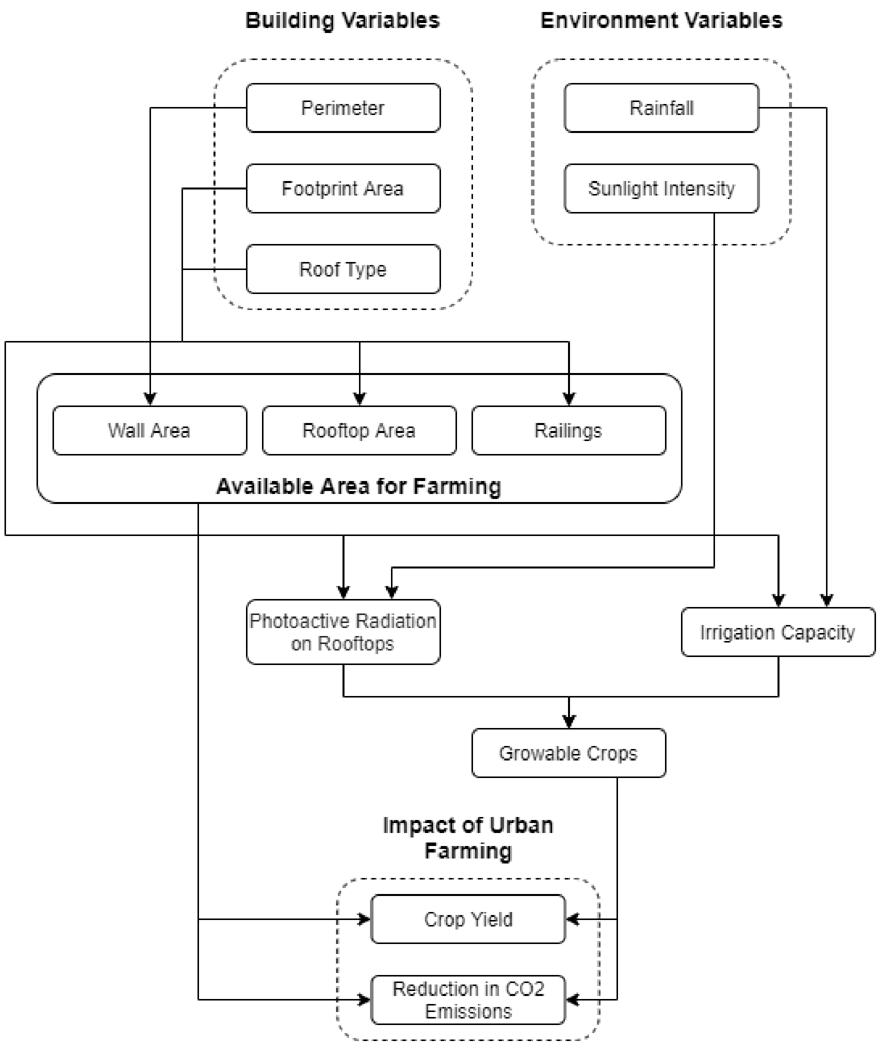



Figure 27. Flowchart. Source: By Author

## 4.4 Calculating available area for Urban Farming

The first step to determine the potential for urban agriculture in the target site is to calculate the area available for this practice. Based on the urban farming technologies discussed in chapter 2 and the previous section, three possible placements for farming on buildings were selected. The first, rooftop farming, can be applied to unused rooftop areas. The second, productive walls, can be applied to idle portions of a building's wall. The third farming technology considered for these calculations was linear systems that hang from rooftop and staircase railings. Figure 28 shows the farming areas available in each building according to building type.

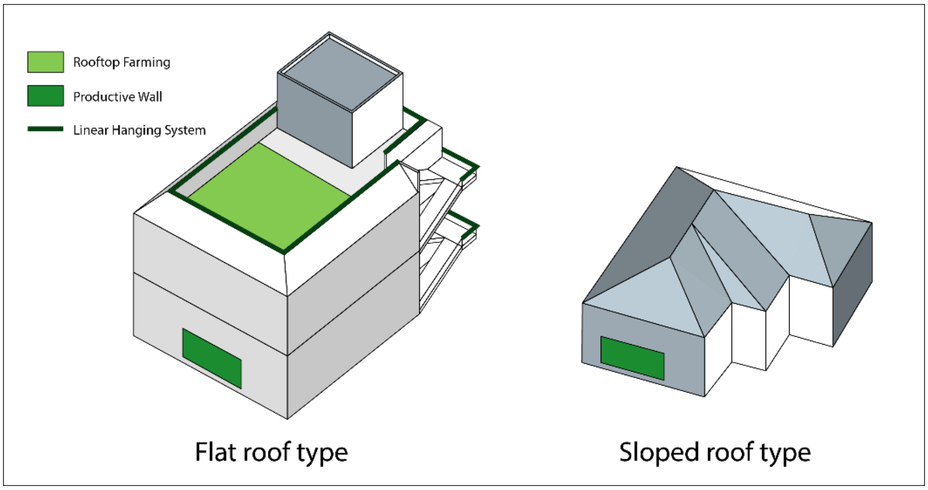



Figure 28. Location of farming space on buildings. Source: By Author

The previous figure shows how farming technology adequate for each building directly relates to its roof type. Buildings with a rooftop have available space that can easily be turned into a farming area. This building type tends to have at least two floors and an outdoor staircase to reach the higher levels of the house. The railing from both the rooftop and the staircase can be used to hang linear growing systems. On the other hand, buildings with a sloped roof are not able to sustain farming on the roof. However, they can be involved in agriculture by attaching vertical growing systems to their unused wall space.

Based on this, all the suitable buildings in the site were classified by roof type. Based on satellite imagery (Kakao Maps, Google Earth), 3D models of the site (VWorld), and in-person verification from the site visit, a total of 1163 residential buildings were classified by roof type into sloped, flat with rooftop, and flat with no rooftop (Figure 29). Table 2 shows the result of this sorting. Separating buildings by roof type proves useful not only to determine available space for farming but also to calculate rainwater harvesting potential. The rainwater collection potential from rooftops is discussed later in this chapter.

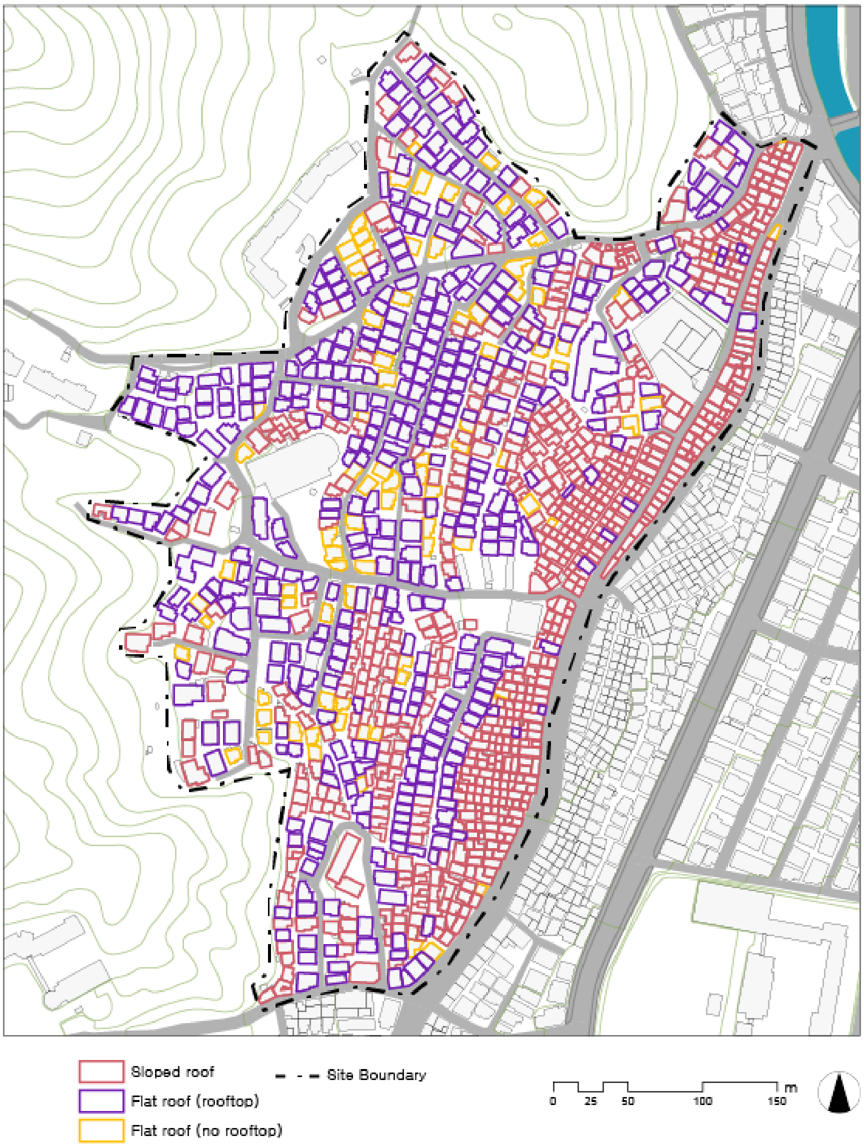



Figure 29. Roof type map. Source: By Author

Table 2. Buildings by roof type. Source: By Author

| Roof Type | Number of Buildings | Total Roof Area (m²) |
|---|---|---|
| Sloped | 672 | 36025.1 |
| Flat (Rooftop) | 405 | 26220.5 |
| Flat (No Rooftop) | 86 | 6158.54 |

### 4.4.1 Calculating available rooftop area

It is necessary to calculate the available rooftop space of any building since this is the area that can be turned into farming. The existing building data includes values for building perimeter and building footprint but none for the rooftop area. As such, the available rooftop area must be calculated by subtracting the area of existing structures (rooftop rooms, sheds, water tanks, etc.) to the building footprint area. Measuring every building to do this would be too time-consuming. Not only for this site but if the model is to be applied to the rest of the low-rise neighborhood in Seoul, measuring available rooftop space building by building would be incredibly tasking. Instead, a predictive model was obtained based on the random sampling of buildings in the flat (rooftop) category.

The rooftop area available for the entire site was calculated based on a model derived from a statistically significant number of building samples. To build this model, 50 out of the 405 buildings with rooftop were sampled. The area occupied by existing structures was measured for each building and subtracted from the building footprint area (BFPA) to obtain the available rooftop area (ARTA) and available rooftop percentage (RSP) per building. A high correlation ($R^2$= 0.84) relation was found between BFPA and RSP (Figure 30).

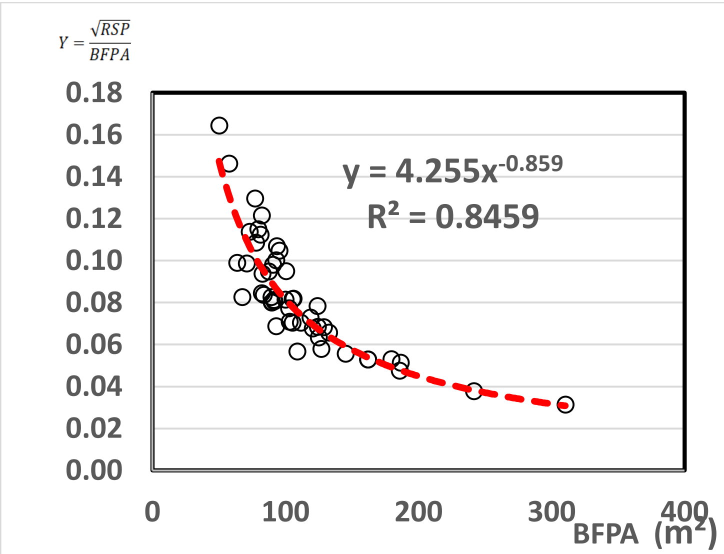



Figure 30. Relation between Building Footprint Area (BFPA) and Available Rooftop Percentage (RSP). Source: By Author

This model is generated from a random, representative sample of the buildings with rooftop. As such, it can be inferred that it is valid for the rest of the buildings in this group. The resulting RSP for when all 405 buildings are considered is 64.18 %. The result means the ARTA is 16828.31 m².

### 4.3.2 Calculating available railing area

The total available railing (TARL) was calculated based on a random sampling of 50 buildings in the rooftop group. Each of these buildings was measured to determine the total railing length where the linear farming systems can be hung. The measurements included rooftop railing as well as staircase railing. A strong correlation ($R^2 = 0.94$) was found between TARL and BFPA (Figure 29).

Subsequently, the model was applied to the 405 buildings in the rooftop group. The resulting TARL is 4247.99 m. A width of 0.5 m is assumed for these systems, which mean the area that can be dedicated to farming of this type is 2124 m².

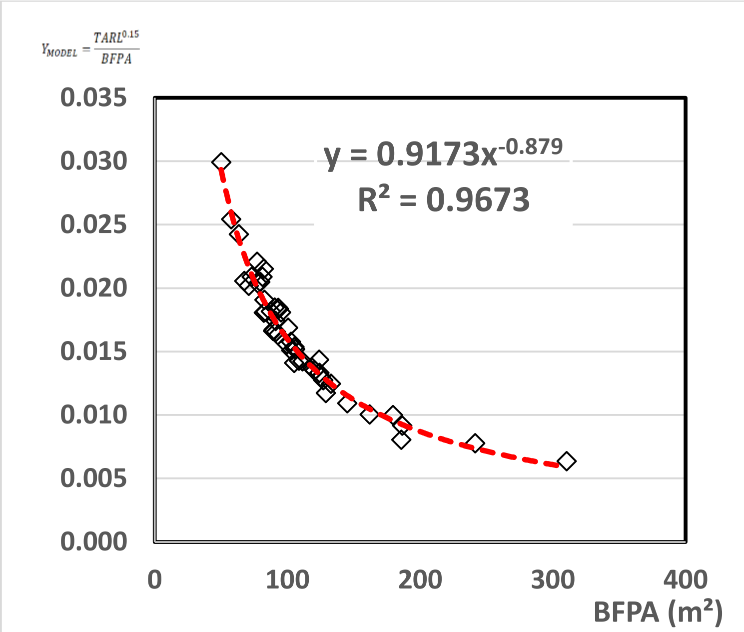



Figure 31. Relation between Total Available Railing (TARL) and Building Footprint Area (BFPA). Source: By Author

### 4.4.3 Calculating available wall area

A model was developed to estimate the available wall area (AWA) where vertical farming systems could be applied. Measurements based on actual recorded measurements from the site visit and estimated measurements from road view images (Kakao Maps) were derived for 50 randomly selected buildings. For this model, all building types (sloped and flat roof) were included in the sampling and total area calculations. The available wall area is in modules of 1.5 m² since the selected farming technology (ZipGrow farm wall) comes in modules of said size. This time, building perimeter (BPER) was determined to be the input variable with a higher correlation to AWA ($R^2$= 0.91). The mathematical relation between these variables shows in Figure 32.

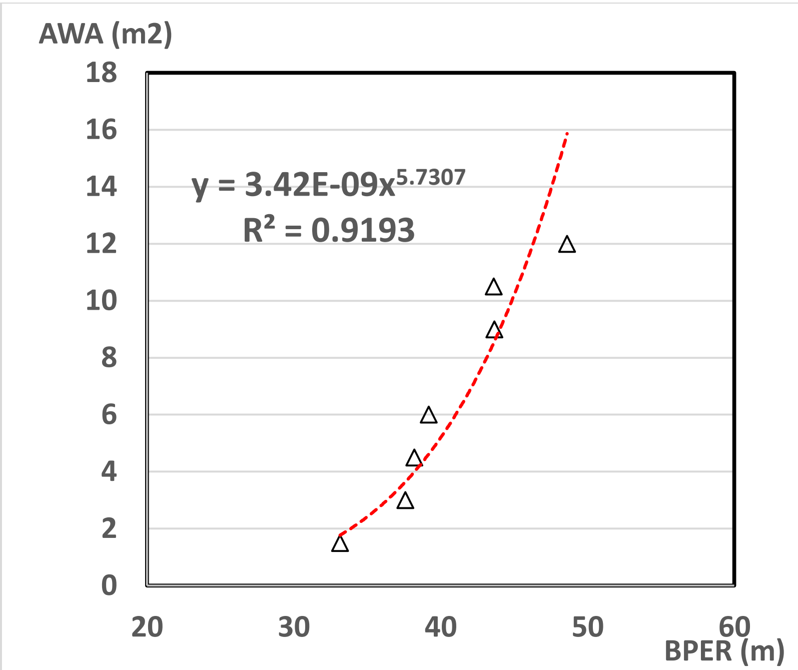



Figure 32. Relation between Available Wall Area (AWA) and Building Perimeter (BPER). Source: By Author

The result from applying the model to the 1163 buildings in the site indicates that 29431.5 m² are available for wall farming. While the area per building is smaller compared to rooftop farming, the area for wall farming is bigger because it can be applied to all buildings instead of the rooftop group exclusively.

#### 4.3.3.4 Farming area summary

Table 3 shows the area available according to farming type (rooftop, wall, and railing). The sum of the area available for these three types is 48383.81 m².

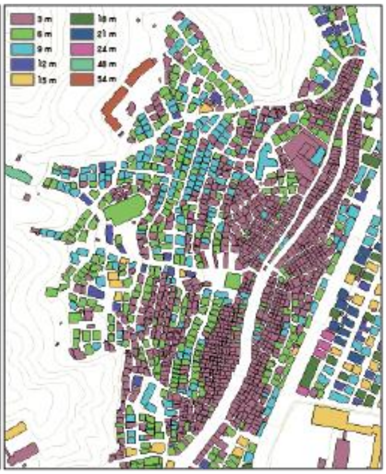
Table 3. Available area for farming. Source: By Author.

| **Farming Type** | **Number of Buildings** | **Available Area (m²)** |
|---|---|---|
| Rooftop | 405 | 16828.31 |
| Railing | 405 | 2124 |
| Wall | 1163 | 29431.5 |
| **All** | | **48383.81** |

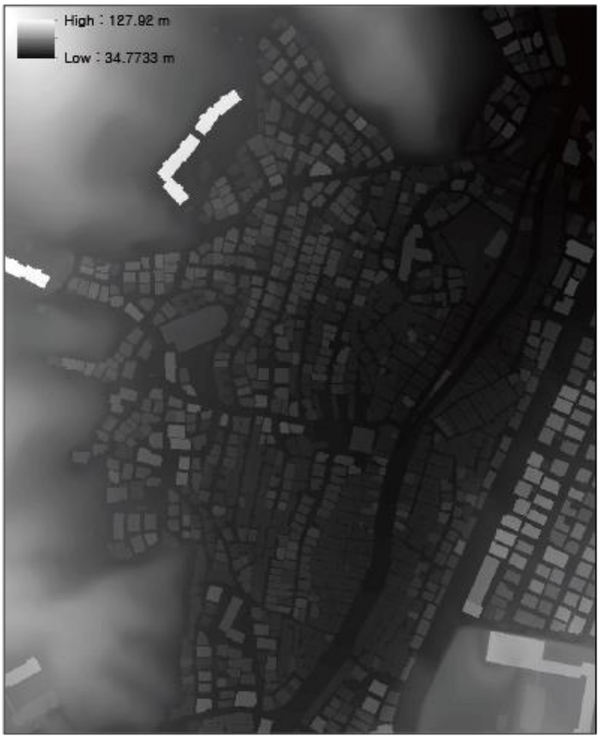
## 4.5 Calculating solar radiation for farming

Sunlight availability is a vital factor for plant growth. To determine the feasibility of applying urban farming in low-rise neighborhoods, we must also evaluate if enough sunlight can reach the farming areas on the buildings. Solar radiation can be modeled through GIS tools, but to do so, a high-resolution digital surface model (DSM) of the site is necessary as input for the calculations. The DSM of the site is not available from the various data portals provided by the Korean Government. However, a DSM can be made by adding the height of each building to the digital elevation model (DEM) of the site. The DEM is available for download, while the building height is calculated by assuming 3 m per floor. The Seoul building stock data includes the floor number per building. Figure 33 illustrates these steps in the modeling.


DEM




Building Height




DSM

Figure 33. Process to obtain DSM of the site. By Author

The Area Solar Radiation tool in ArcGIS is then used to calculate the average solar radiation per day throughout the year. Simulating the solar radiation for every month would require enormous amounts of time and computing power. Instead, four months representative of the change of seasons (January, April, July, and October) were selected for the solar analysis. Since the farming season in Korea is from April to October (FAO, 2020), the results are useful to determine whether solar radiation in the site is sufficient for plant growth. Figure 34 shows the daily average of solar radiation for the selected period in solar energy ($Wh/m^2$). The results evidence how radiation changes throughout the year, with April and July reaching much higher values than the other two months. The results also show that solar radiation on roofs is higher than radiation on the streets. That being said, since the site is mostly comprised of low-rise buildings that cast less shade that high-rise ones, sunlight still reaches street level consistently.

The resulting solar radiation must be converted into photosynthetically active radiation (PAR) to evaluate whether a range of radiation is beneficial for farming. PAR stands for the light intensity at which plants can photosynthesize. While it can be expressed in energy ($W/m^2$), it is usually defined in photons ($\mu mol/m^2s$) across the literature (Langhans & Tibbitts, 1997). To convert the results from the solar radiation analysis, first, they must be changed from $W/m^2$ per day to $W/m^2$ using the following conversion:

$$1\ Wh/m^2/\ day = 0.0416666667\ W/m^2$$

The results in $W/m^2$ are then converted to PAR values using the following equivalence from the literature:

$$1\ W/m^2 = 4.6\ \mu mol/m^2s$$

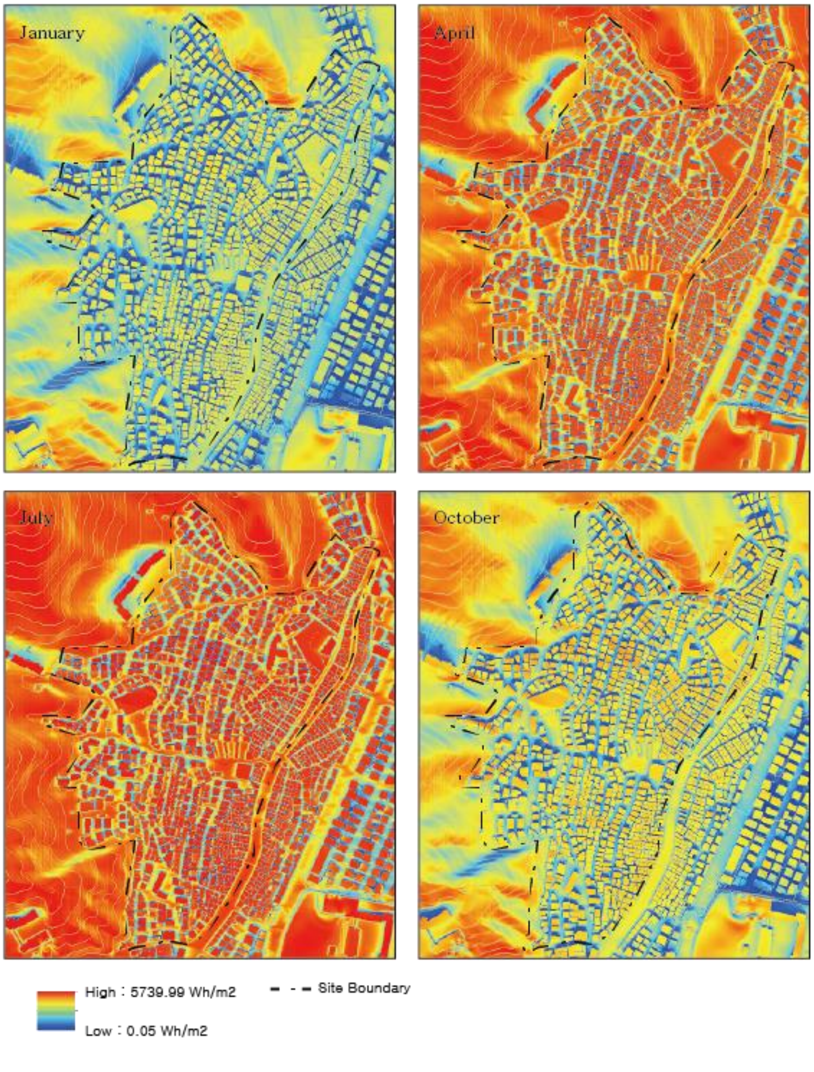



Figure 34. Solar radiation throughout the year. Source: By Author

Once the PAR values are calculated, the average light intensity per roof is obtained using the Spatial Join tool in ArcGIS to combine the building footprint with the solar radiation data. Figure 35 shows the ranges of sunlight intensity for the roofs on the site. It varies from low (under 40 $\mu mol/m^2s$) to high (over 170 $\mu mol/m^2s$) intensity.

The literature was searched to determine the crops that are suitable for each of the sunlight intensity ranges. Values were found for a variety of agricultural products such as micro-greens, leafy greens, herbs, tomatoes, onions, cabbage, among others (Mattson, n.d; Nestby & Trandem, 2013; Lu et al., 2015 and Brewster & Barnes, 1981).

Finally, the potential area for each type of crop was calculated based on the available rooftop area established in the previous section. Table 4 shows the result details. It is worth noting that only 6.24 % of the available rooftop area falls under the low-intensity threshold, which indicates that 93.76 % is farmable for crops that require more light. There is a variety of ranges present, which means several types of crops can be grown in the area.

As for the wall farming, since it occurs at street level, the sunlight intensity is less compared to the rooftops. Still, crops with lower sunlight demand such as herbs, micro-greens, and leafy green could grow in this setting. The documentation from the site visit also proves that leafy greens and herbs have no difficulty growing at the street level.

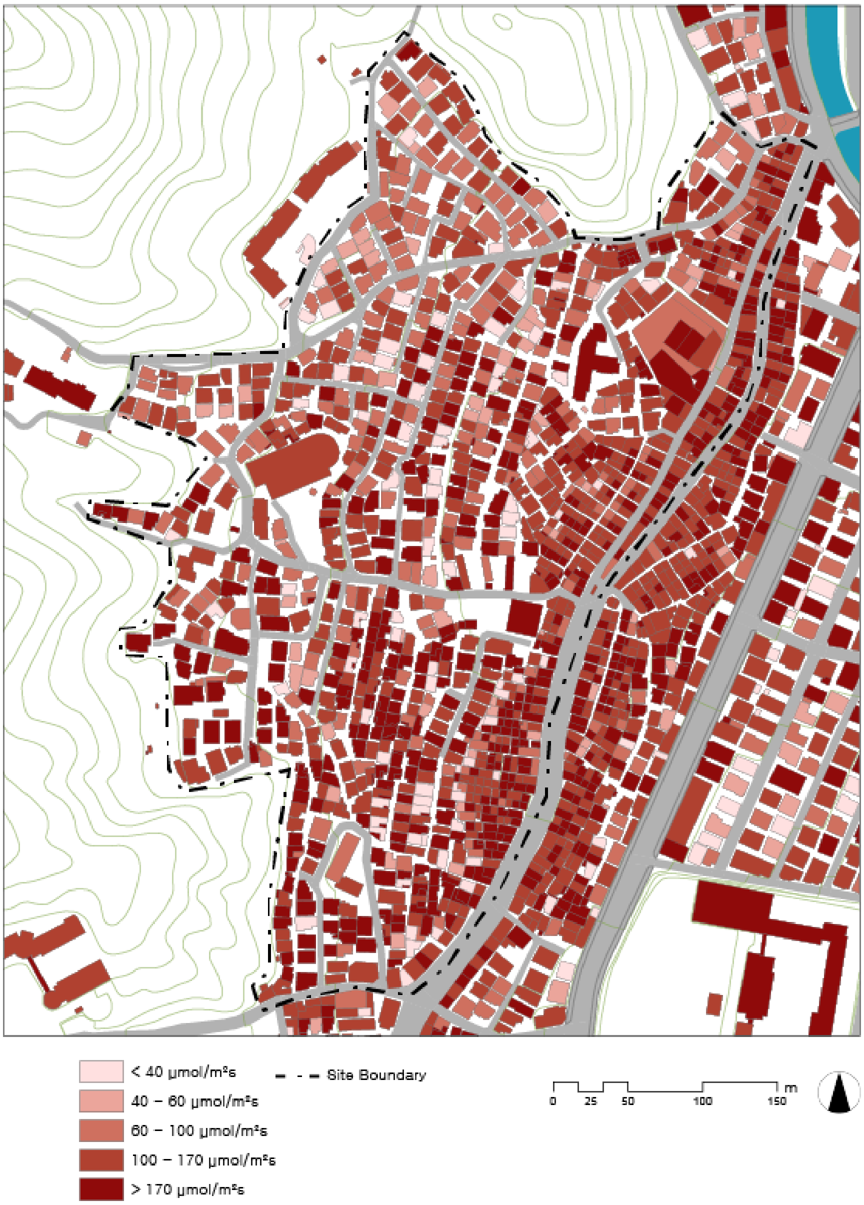



Figure 35. Sunlight intensity on roofs. Source: By Author

Table 4. Suitable crops for light intensity. Source: By Author based on Mattson, n.d; Nestby & Trandem, 2013; Lu et al., 2015 and Brewster & Barnes, 1981

| **Light Intensity (µmol/m²s)** | **Area (m²)** | **Percentage of total Available Rooftop Area** | **Suitable Crops** |
|---|---|---|---|
| <40 | 483.53 | 6.24 % | seedlings, cuttings |
| 40-60 | 338.62 | 4.37 % | micro-greens, small herbs |
| 60-100 | 1499.39 | 19.35 % | leafy greens |
| 100-170 | 2972.44 | 38.36 % | pepper, cucumber, eggplant |
| >170 | 2454.82 | 31.68 % | tomato, strawberry, melon, cabbage, onion |

The solar radiation analysis shows that, in terms of meeting sunlight demands, urban farming in the site is feasible and allows for cultivating a diversity of crops.

### 4.6 Calculating water harvesting potential

Other than space and sunlight, farming requires water. Rainwater can be collected from roofs and stored for later use in crop irrigation. Rainwater harvesting is widely studied in the literature as a way to cover water demand in urban areas. The standard formula for estimating water catchment is the following:

$$Wp = P \times A \times RC$$

Where Wp is the potential volume of water catchment in L/year, P is local precipitations in mm/year, A is catchment area in $m^2$, and RC is the runoff coefficient. The runoff coefficient accounts for a percentage of the rainwater that is lost in the catchment process and varies according to roof type. Table 5 shows the water catchment potential for the site according to the roof type. For this estimation, both sloped and flat roofs were included. Rainfall data from the Seoul City Open Data portal was used to calculate rainwater harvesting capacity per month based. The runoff coefficients are from Kumar (2004) and Ukai (2016). Table 6 details the water catchment potential per month. The results show the total rainfall days for the harvest season is 73, out of 104, and the rainwater catchment potential for the site is 74909.06 m3.

Table 5. Rainwater harvesting potential according to roof type. Source: By Author based on Kumar (2004) and Ukai (2016)

| **Roof type** | **Total Roof Area ($m^2$)** | **Runoff Coefficient** |
|---|---|---|
| Sloped tile roofs | 35971.85 | 0.75 |
| Flat bituminous roofs | 44795.65 | 0.7 |

Table 6. Rainwater harvesting potential per month. Source: By Author

| | **Rainfall (mm)** | **Rainwater Harvesting (m3)** | | |
|---|---|---|---|---|
| | | Sloped tile roofs | Flat bituminous roofs | All Roofs |
| **Jan** | 8.5 | 229.32 | 266.53 | 495.85 |
| **Feb** | 29.6 | 798.58 | 928.17 | 1726.74 |
| **Mar** | 49.5 | 1335.45 | 1552.17 | 2887.62 |
| **Apr** | 130.3 | 3515.35 | 4085.81 | 7601.16 |
| **May** | 222 | 5989.31 | 6961.24 | 12950.56 |
| **Jun** | 171.5 | 4626.88 | 5377.72 | 10004.60 |
| **Jul** | 185.6 | 5007.28 | 5819.85 | 10827.13 |
| **Aug** | 202.6 | 5465.92 | 6352.92 | 11818.84 |
| **Sep** | 68.5 | 1848.05 | 2147.95 | 3996.01 |
| **Oct** | 120.5 | 3250.96 | 3778.51 | 7029.47 |
| **Nov** | 79.1 | 2134.03 | 2480.34 | 4614.37 |
| **Dec** | 16.4 | 442.45 | 514.25 | 956.71 |
| **Total** | 1284.1 | 34643.59 | 40265.47 | 74909.06 |

Is this volume of water enough to satisfy the water demand from urban farming in the site? The literature was searched to determine the water demand for a variety of crops. The growing system has a significant impact on the water needed for farming, so the water requirement was based on that of hydroponic systems since that is the selected technology for this study. Table 7 shows the water demand for a variety of crops and the farming area that could be irrigated with the collected rainwater.

Table 7. Water demand per crop and irrigated area potential. Source: By Author, adapted from Das and Toppo (2018)

| **Crop** | **Crop duration (days)** | **Crop Water Demand (mm)** | **Total Water Crop Demand (m3/Ha)** | **Area Available for Irrigation (m²)** | **Irrigated Area from Rainwater Collection (%)** |
|---|---|---|---|---|---|
| Tomato | 120 | 700 | 7000 | 119588.43 | 192.07% |
| Pepper | 150 | 750 | 7500 | 111615.87 | 179.26% |
| Cabbage | 120 | 650 | 6500 | 128787.54 | 179.26% |
| Cauliflower | 120 | 700 | 7000 | 119588.43 | 206.84% |
| Broccoli | 120 | 700 | 7000 | 119588.43 | 192.07% |
| Onion | 150 | 600 | 6000 | 139519.83 | 192.07% |
| Chilli Pepper | 165 | 800 | 8000 | 104639.88 | 224.08% |
| Beans | 90 | 500 | 5000 | 167423.80 | 224.08% |

As seen in the previous table, the 74909.06 m3 of collected rainwater are enough to cover approximately double the demand of any crop, based on the available farming area of 48383.81 $m^2$ obtained previously.

On average, a flat roof house can collect 70.55 m3 of rainwater, while a sloped roof one can collect 59.91 m3 of rainwater. Because the water is captured over months, a small 50 L tank is enough to store it. For the flat roof type, it can be located on the roof itself, while it would be placed on ground level for the sloped roof type houses. A 50 L tank is small an even portable, a convenient feature when watering the crops.

The results suggest that water harvesting is useful for urban farming, as it can cover the high water demand without posing a burden on water and economic resources. The extra water that is not used for irrigation can be used for additional processes such as cleaning, cooling, and processing of the harvested crops.

### 4.7 Benefits of Urban Farming

The benefits of urban agriculture in the site were quantified in terms of crop output, coverage of yearly vegetable requirements for residents, and reduction in $CO_2$ emissions. The crop output is calculated based on the model developed by Lee et al. (2015) since this model is adapted to the conditions of Seoul. While yield per $m^2$ varies by crop, an average output of 5.06 $kg/m^2$ was used. This number considers a combination of crops that includes leafy greens and fruiting vegetables. The yearly vegetable consumption for Korean people is around 150 kg according to the OECD (1999). This quantity was used to calculate the number of locals whose dietary needs for vegetables could be satisfied with urban farming. Finally, the conversion developed by Lee et al. (2015) was used to calculate the tons of $CO_2$ that can be reduced from intra-city farming on the site. They estimate a reduction of 222.75 ton-$CO_2/km^2$. This model only accounts for the reduction in carbon emissions from transportation. It does not consider the carbon sequestering from the plants or energy savings in other stages of the farming process. Table 8 shows the impact of urban agriculture on the site.

The results show the crop output is significant and covers the yearly vegetable needs of 1632 persons, or 709.56 families based on a 2.3 persons per household average. The population for Samseong-dong is 25359 according to the self-reported resident data collected by the Ministry of the Interior and Safety. Urban farming would be able to cover the vegetable needs of 6.34 % of the neighborhood residents and 6.34 % of the families. As for the reduction in $CO_2$, the impact is quite modest. The consumption of a Seoul citizen is estimated at 10.1 tons/year consumption (Son et al., 2007). The $CO_2$ reduction for this model is only able to offset the carbon emissions of one Seoul resident. It shows that for urban farming to have a significant impact on the reduction of carbon emissions, it must be applied on a much larger scale.

Table 8. Impact of urban agriculture in the site. Source: By Author

| Farming Type | Farming Area ($m^2$) | Crop yield (kg) | Yearly vegetable needs covered (person) | Reduction in $CO_2$ (tons) |
|---|---|---|---|---|
| Rooftop | 16828.31 | 85151.24 | 568 | 3.74 |
| Railing | 2124 | 10747.44 | 72 | 0.47 |
| Wall | 29431.5 | 148923.39 | 993 | 6.55 |
| All | 48383.81 | 244822.07 | 1632 | 10.77 |

# Chapter 5. Conclusions

## 5.1 Conclusions and Discussion

This study shows that building-based urban farming is a feasible option for Seoul. Based on the premise that land is scarce and urban agriculture should be used as a tool for the resilience of residential communities, this research evaluated the possibility of implementing building-based agriculture in low-rise neighborhoods.

To measure urban farming potential, this study built a model that could determine the available area for agriculture, the sunlight intensity, and the water collection potential of a low-rise neighborhood. The neighborhood of Samseong-dong in Gwanak-gu was chosen as the site to base the model.

The available area for urban farming in the selected site is 48383.81 m2. The majority of the space available is on building walls, followed by rooftops, and railings.

This study found that solar radiation in the site is suitable to grow a variety of crops outdoors during the farming season. It ranges from low (under 40 $\mu mol/m^2s$) to high intensity (over 170 $\mu mol/m^2s$).

As for the water collection potential, the rainwater harvesting capacity in the site was 74909.06 m3. This amount of water is approximately double the irrigation demand of any crop grown in the available area for farming.

The crop yield for the site is 244822.07 kg, enough to fulfill the yearly vegetable consumption needs of 1632 residents or 709 families. As for the reduction in CO2 emissions as a result of intra-city farming in the site, it amounts to only 10.77 tons, equivalent to the yearly carbon emissions of one Seoul citizen. It shows that, while neighborhood-scale urban farming can have a significant impact on food security, its influence on the reduction of CO2 emissions is low.

The model developed in this research intentionally focuses on building form variables (footprint and perimeter) as the inputs to calculate the potential for urban farming. It is so the model can apply to other low-rise neighborhoods in Seoul since data for those variables are widely available. As such, it can be a tool for urban planners and designers to measure the potential for urban farming in an area and promptly determine whether it is a good option for the site.

This study highlights the importance of being innovative in our approach to introducing urban farming into dense cities like Seoul. Its value is in illustrating the impact of building-adapted urban agriculture and the opportunity in non-traditional, non-soil based farming practices for an urban context.

## 5.2 Further Research

Additional research should expand the model to include other forms of farming, such as indoor farming in basements. The model currently focuses exclusively on building-based farming, but it could expand to consider farming in open green spaces, vacant lots, and abandoned buildings. Another aspect to consider is the feasibility of introducing solar panels to make up for the energy spent on farming operations.

The current model does not account for variables such as initial implementation costs, operation costs, available workforce, and energy expenditure. A more precise model should be developed to account for these.

In the future, the sample size should be increased to make the model more robust. The model can also be fed with samples from other neighborhoods in the city to make it more reliable for the rest of Seoul. Finally, the feasibility of building-based farming should be calculated for all low-rise neighborhoods in Seoul.

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## Abstract in Korean

# 서울시 저층지역 도시농업의 적용에 관한 연구

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도시 인구가 급격히 증가하고 있다. 이와 같이 도시는 자원 소비와 환경을 보호하는 균형을 맞추는 도전에 직면해 있다. 그러한 자원 중 하나는 음식이다. 농산물은 수확지에서 최종 소비자로 멀리 이동한다. 이 거리는 고에너지 소비, 식량 가격 상승, 취약한 유통망, 농업 관행에 대한 집단 기억력 상실과 같은 몇 가지 문제에 원인이 있다.

최근, 도시 농업은 이러한 문제들을 해결하고, 도시의

지속가능성을 달성하기 위한 중요한 수단이 되었다. 도시 농업은 환경적, 경제적, 사회적 이익이 있다. 도시재생과 스마트시티 개발 전략으로 한국 정부의 높은 지지를 받고 있다.

이 연구는 서울의 저층지역의 도시농업 가능성을 평가했다. 서울 토지는 희소하고 도시농업은 주거공동체의 복원력을 높이는 소중한 도구인 만큼 이번 연구는 저층 주거지역에 건축기반농업을 시행할 가능성을 평가했다.

본 연구는 도시농업 가능성을 측정하기 위해 저층 지역의 농경 가능 면적, 일조 강도, 빗물 수확능력을 파악하기 위한 모형을 구축하였다. 이번 연구는 관악구 삼성동을 대상지로 선정됐다.

이 연구는 건축 형태 변수(건축면적과 건축둘레)와 환경 변수(강수량과 일조 강도)를 측정하여 인근 지역의 도시 농업 능력을 모형화했다. 이 연구는 또한 $CO_2$ 배출량 감소와 연간 채소 필요량 측면에서 도시 농업이 지역에 미치는 영향을 계산했다.

이 결과는 저층지역이 도시농업 도입 가능성이 크다는 것을 보여준다. 저층지역은 농사에 필요한 공간이 건물(옥상, 벽, 난간)에

충분하다. 그들은 또한 다양한 농작물을 재배하기에 충분한 빗물 수확능력과 일조 강도를 가지고 있다. 이 같은 건축 기반 도시농업은 지역 주민들에게 식량을 공급하기에 유용할 수 있지만 $CO_2$ 배출량 감소에는 한계가 있다는 결과가 나왔다.

**주요어:** 도시농업, 지속가능성, 서울, 단독주택, 저층지역, 건축기반농업

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