19th International Conference on Business Management

(ICBM 2022)

INTEGRATING URBAN FARMING INTO THE SRI LANKAN RESIDENTIAL ARCHITECTURE AND BUILT ENVIRONMENT

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ABSTRACT

Sri Lanka is facing a devastating food crisis in the recent years due to the economic collapse in the country. Day by day, the access to food is decreasing while the prices are increasing. Urban agriculture is viewed as a workable solution for urban food issues in developed nations. However, Sri Lanka is still in the early stages of urban farming. There is still need for investigation about the potential applications of urban framing technology in Sri Lanka's built-up urban environment. The project will examine how to set up urban farming systems that might be used in high-rise structures, homes with yards, and low-income slums, as well as develop instructions for the general public on urban farming. Additionally, it will look at how urban farming practices might be related to residential building architecture. Following the preliminary research, a series of product prototypes will be made using soilless farming techniques. These will undergo testing and modifications to

Keywords: Building construction technology, urban agriculture technology, urban farming, architectural design

INTRODUCTION

According to the FAO Publications Catalogue 2021, one of the greatest challenges facing the globe now is food insecurity. According to recent estimates, 750 million people worldwide (9.7% of the world's population) experienced serious food insecurity in 2019.("The State of Food Security and Nutrition in the World 2021," 2021) While the 746 million people who are suffering from severe food, a further 16% of the world's population, which is 1.25 billion individuals, have suffered from moderate food insecurity. Those who are moderately food insecure do not regularly have access to nutritious

and sufficient food, even if they are not hungry.(FAO et al., 2020) According to the United Nations' 2020 report, Asia has the most food-insecure people, but Africa has the fastest-growing number of people facing a food crisis. The COVID-19 pandemic pushed over 130 million more people into chronic hunger by the end of last year (IBRD & IDA, 2022)

And Sri Lanka is no exception when it comes to the food crisis. Sri Lanka faces several socio-economic issues, including the impact of a nutritional "triple burden" that includes undernutrition, obesity, and vitamin and mineral deficiencies(UNICEF, 2020). According to Asian Human Rights Commission Sri Lanka "repeatedly tops the lists in South Asia when it comes to hunger,". In the years between 2006 and 2010, the number of children facing malnutrition was estimated to be 843.913, or 21.4 per cent of the total, with a rate of 15%, wasting among children under the age of five is among the highest in the world (Fernando Basil, 2022). When the latest Demographic and Health Survey was published in 2016, undernutrition rates had remained mostly stable for nearly a decade (Department of Census and statistics, 2017).

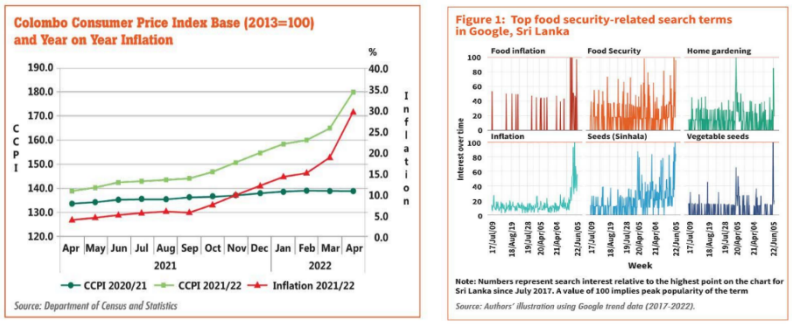
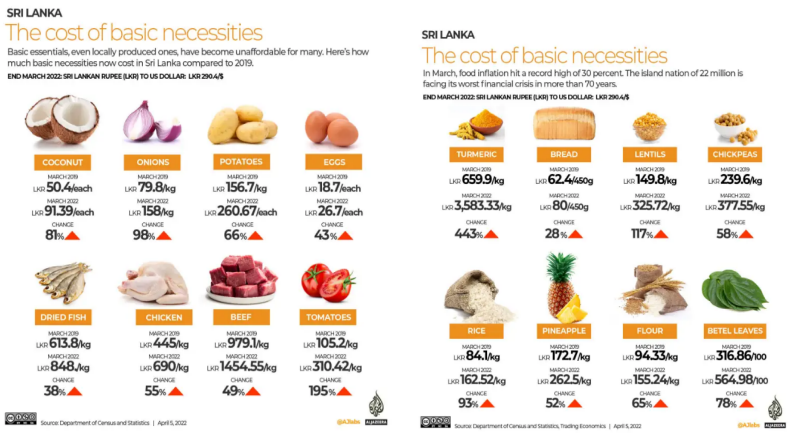


Figure 1: Statistics of food crisis in Sri Lanka.



In terms of food security, Sri Lanka is ranked poorly on both the Global Food Security Index (GFSI) (The Global Food Security Index, 2020) and the Global Hunger Index (GHI) ("Global Hunger Index 2021: Sri Lanka," 2021). With an average of 192 Kcal per day from 2014 to 2016, Sri Lanka had the worst caloric shortage in South Asia, according to FAO statistics. Afghanistan (26.8 percent) is the only nation in South Asia to have a higher prevalence of malnutrition than Sri Lanka (22 percent). Furthermore, Pakistan (30.5 percent) and Afghanistan (36.6 percent) are the only two countries in South Asia that have higher rates of food insecurity than Sri Lanka (29 percent) (Harding et al., 2018)

Additionally, the capacity of households to buy enough food, both in terms of quantity and quality, was significantly reduced as a result of the numerous income shocks (Pieters et al., 2013). Disruptions in the supply chain were a factor in the prolonged high levels of food prices that followed the initial period of mobility restrictions. Economic shocks become a more major cause of food crises in 2020 as the indirect result of COVID-19 (Swinnen & Vos, 2021). Supply chain disruptions worsened food price increases, particularly in the early aftermath of travel restrictions, and prices stayed high for a very long time afterward (Aday & Aday, 2020). Extreme weather conditions did contribute to food crises, albeit to a lesser extent than the other two main causes. Even so, in 15 countries in 2020, weather extremes continued to be the leading contributor to acute food insecurity, with about 16 million people experiencing a Crisis or worse (FAO, 2015).

Slums and informal settlements, where socioeconomic development is frequently already less than in rural areas, will continue to be particularly vulnerable to rising food insecurity in urban settings (Szabo, 2015).

The agricultural land available in Sri Lanka is around 45% of the country including home gardens, which is 18.18% (*Department of Census and Statistics*, 2022). The yield is unable to cope with Sri Lanka's current demand. Therefore, to cope with the demand our country imports food products from countries like India, Canada, Russia, Australia, and 90 other countries. The total sum is 352.03 million dollars for vegetables, certain roots, and tubers for the year (World Integrated Trade Solutions, 2017). As a country with a negative trade balance, this number is taking a toll on our economy.

Urban agriculture is viewed as a workable solution to the urban food crisis in many affluent nations. Urban agriculture significantly reduces urban food insecurity issues, which are only likely to become more important as poverty

and population urbanization in developing countries continue to rise in prevalence (Kulatunge S et al., 2021) Urban agriculture has the potential to significantly contribute to alleviating urban poverty and food insecurity, although this potential should not be overestimated given that its revenue share and overall agricultural production are often very small. But its significance should not be understated, especially in most of Africa and in many other countries where agriculture is a major source of income for the urban poor (*Unlocking Africa's Agricultural Potential*, 2013).

Food production in cities is not a novel concept. Farmers in ancient Mesopotamia and Persia may have set off parcels of land within towns to grow food and dispose of waste, according to archaeological data (Mccauley, 2020). In both Asia and Europe, city farming has a long history. It was formerly popular because it kept the products near to the user at a time when transportation was difficult, and communication was weak (Khaled & Mcheick, 2019). City farming was formerly a means of survival. today it is still a means of existence for many of today's poor urban people, but it also gives freshness, dietary variety, and nutritional food.

Rural agriculture cannot offer advantages that urban agriculture can. It can occur on rooftops, in backyards, in communal fruit and vegetable gardens, and in underused or open areas. Urban farms frequently raise a variety of produce, including fruits, vegetables, herbs, and spices. Urban gardening is thought to directly benefit or make money for at least 100 million people (Medici et al., 2020a) Urban agriculture has a number of significant benefits. Some of these include increased income for farmers, as a way to combat unemployment, environmental advantages such as reduced runoff, the opportunity to avoid spending money on wastewater treatment and solid waste disposal, the reduction of the need to import food, and a reduction in urban poverty (FAO, 2001).

According to a survey conducted in Africa, urban and peri-urban agriculture at home or in public places significantly contributes to food security, additional income, and a healthy diet. Market gardening, according to the FAO, has an impact on the food supply and the way of life of people in several nations with the greatest potential for future growth (FAO, 2017)

And in a case study analysis on urban farming in rooftop gardens, rooftop greenhouses, and a community rooftop garden in Bellaterra, Spain, it was revealed that the economic cost and environmental cost is significantly lower. Life cycle cost and life cycle assessments proved that urban agriculture could

improve both environmental and economical sustainability. It also prompts the discussion of the importance of the techniques and management needed in urban farming (Sanyé-Mengual et al., 2018). Another study was conducted in Beijing, China to calculate the difference between the carbon footprints of traditional farming systems and urban farming systems. Home delivered agriculture projects had a lower Carbon footprint per unit of profit (0.093e0.097 kg CO2-eq per CNY) than conventional farming (0.111 kg CO2-eq per CNY). The traditional farm's lower Carbon Footprint per unit of product weight was largely attributable to high yield, whereas the HDA initiative's lower CF per unit of profit was primarily owing to superior economic performance through income optimization (FAO, 2018)

RATIONALE AND JUSTIFICATION OF THE RESEARCH PROBLEM

Urban agriculture is a concentrated enterprise that uses horticulture, animal husbandry, aquaculture, and other techniques to produce fresh produce, other agricultural items, both in urban areas and the peri-urban areas that surround them. Urban agriculture systems can be found in ground-level farming, rooftop farming, hydroponics, greenhouses, and other cutting-edge technologies. Urban agriculture could produce food for local use, especially for perishable foods and high-value crops. A growing trend in urban environments is the commercial-scale production of non-food crops like flowers and green walls. Urban agriculture, a phenomenon involving urban economies, culture, science, and technology, is significant for food security and is present in smart cities. Urban agriculture is a sign of an advanced economy in a city. Contrary to traditional agricultural methods, urban agriculture takes substantial use of resources like money, infrastructure, manpower, and technology. In order to increase agricultural production and interregional trade, it also practices industrialized, market-oriented agriculture that can benefit from established markets, information, and transportation networks in other countries (Medici et al., 2020b).

Urban agriculture is less common in developing and lower-middle-income nations, but it has a considerable growth potential in these regions. The success of urban agriculture in cities like Hanoi, Shanghai, Beijing, Mexico City, and Dakar has shown how agricultural education can aid in reducing poverty, ensuring food security, improving nutrition, generating additional income, protecting the environment, and raising awareness of the importance of agriculture. Up to 80% of the fresh vegetables in these cities may come from Hanoi and the area around, according to the Netherlands' Resource

Centres on Urban Agriculture and Food Security Foundation (Teng Paul, 2020).

When taking the scale of commercial urban farming projects, complexity, and budget of the current urban farming projects globally into consideration, it is rather hard to implement these projects in a context like Sri Lanka. The urban farming buildings should be provided with sufficient energy for plant growth. This additional cost should be taken into consideration in such projects. It is not effective to use solar panels in such projects in the urban context as there will be shade from other buildings surrounding it. And as the building interiors have less access to light, artificial lighting should be provided. This artificial lighting will interfere with the air conditioning systems, so again there will be high energy costs. Additionally, transporting supplies such as fertilizer up onto the towers or hauling artificial growth equipment, water, or other resources down as needed (Ellingsen Eric & Despommier Dickson, 2008) And in tall structures, particularly heavy amounts of water will be transferred to higher floors (Perez Victor Mendez, 2014). Water transportation is crucial for controlling the sewage system in addition to supplying the building with the necessary water supply. However, it is possible to derive ideas and transform them into functional systems for Sri Lankan urban concepts.

GENERAL AND SPECIFIC OBJECTIVES

General Objective

This study's overarching goal is to incorporate urban farming tactics and infrastructure into residential design and the built environment. It will look into how Sri Lanka's urban residential design and built environment may include green agricultural practices.

Specific Objectives

1. to determine how urban farming in Colombo can be included into the architecture of residential structures.
2. to determine how Colombo's present residential built environment may be merged with urban farming.

THE SIGNIFICANCE OF THE RESEARCH

We haven't yet looked into how urban framing technology might be used in Sri Lanka's urban residential built environment. Looking into the possibility of urban farming at the residential level of buildings will be advantageous as a solution to Sri Lanka's urban food shortage because the current research on urban farming focuses on high-tech and large-scale structures.

Numerous production techniques, including conventional and organic ones, are included in urban farming. A regionally connected system of methods for producing plants and animals will have the following long-term effects:

- generating enough human food, animal feed, fiber, and fuel to satisfy the needs of a growing population.
- environmental preservation and increased access to natural resources
- The economic viability of agricultural systems will be preserved.

Due to the current situation, a new food economy is forming in Sri Lanka. Urbanization, the loss of agricultural land, and growing consumer awareness and appreciation for high-quality foods were the catalysts. Large farms have chosen to leave the urban perimeter for cheaper land further away from the city core as cities expand into rural (Gamhewage et al., 2015). Small family farms struggle to thrive due to a lack of resources or a desire to relocate.

Through this research, a household solution to urban food scarcity will be developed using straightforward systems and architectural techniques. It will improve the nutritious value of the food that is eaten and the standard of living for those who reside in unlicensed low-income settlements. Urban farming will appeal to consumers who favor the development of an alternative, more sustainable food economy. These organic and soilless techniques will be able to start a new trend in farming. Additionally, it will be able to foster a rewarding leisure activity and a sense of community.

Three household categories will be the primary targets of the devices and initiatives.

- High rise apartments
- Housing with small scale gardens
- Low-income settlements and illegal settlements

Additionally, the strategies will be developed so that they will address certain issues unique to each type of residential housing.

RESEARCH PROBLEM AND RESEARCH QUESTIONS

Sri Lanka has a significant rural agricultural engagement whereas urban agriculture is still at its emergence stages. Although academics, the government, and non-governmental organizations have identified the potential for urban agriculture in Sri Lanka, the economic potential for urban agriculture is still unknown. Thus, Sri Lanka's existing urban agriculture practices are mostly for recreational purposes (Ranasinghe, 2010). The regulations and bylaws of the City of Sri Lanka prohibit economic activity. This promotes and supports this hobby activity. There is no research specifically examining this aspect of urban agriculture, despite the fact that academics and agriculture specialists in Sri Lanka have expressed interest in assisting entrepreneurial urban agriculture in working papers, theses, and assessments (Gamhewage et al., 2015).

Therefore, this research intends to provide answers to the identified research problem.

1. What are the urban farming systems that can be created to be implemented in urbanized areas as a part of residential building's architecture – what are the outdoor as well as indoor architectural strategies and systems that can be used in an urbanized setting as a part of the residential building and the separate systems that can be involved.
2. How to adopt and develop the technology of using green farming and building construction technology into Sri Lankan urban residential architecture and the built environment.
3. How to apply urban farming systems at different scales, to suit space available and the user's economical level – Space available in different residential spaces of different economic sectors require specific urban farming systems.

LITERATURE REVIEW

Urban agriculture's present revival has its roots in community gardens from the 1970s (Maciej Serda, 2013). The actual revival started in the middle of the 1990s when American communities began linking urban farms and gardens to addressing food insecurity, claims Glowa. Later, urban agriculture became more associated with environmental justice activism, local food promotion, urban sustainability initiatives, community health campaigns, and food justice activism (Grewal & Grewal, 2012)

Modern Technology

As the name suggests, vertical farming is a sort of agriculture that enables agricultural production to occur inside vertical structures like buildings. Large-scale versions are frequently incorporated into existing structures, including office buildings, and are typically constructed from numerous vertically stacked surfaces. Additionally, they can be constructed within converted warehouses, shipping containers, or greenhouses (Vyas, 2021).

For a variety of reasons, vertical farming is a cutting-edge and possibly more environmentally friendly kind of agriculture. For instance, it consumes up to 95% less water than conventional farming, which is a substantial difference. This is true because a portion of the water used can be recycled and utilized again. Furthermore, evaporation losses are decreased (IGrow-Indoor Vertical Farming News-IGrow, 2021).

Additionally, it occupies less area (especially on the ground) and has little to no effect on the region's native soils. The Vertical Farming Institute asserts that 50 square meters (538 square feet) of conventionally farmed land yields roughly the same amount of vegetable crops as one square meter (10.76 square feet) of vertical farming floor space (VERTICAL FARMING - Vertical Farm Institute :: Leading Research Network, 2022).

Without using pesticides and herbicides, which have the potential to be very harmful to the environment, vertical farms can be operated. Vertical farms typically enable year-round crop growing due to the regulated environments they provide (Ku, 2019).

Hydroponics

Most methods of vertical farming use hydroponics, a method of plant cultivation that is widely used and is rising in popularity. Unlike traditional farming, where plants are grown in dirt, organic farming grows plants in nutrient solutions. In this kind of vertical farming, the plants' roots are submerged in a nutrient-rich solution that is circulated and occasionally checked (vertical roots, 2020).

Figure 2: Hydroponic system

Source - https://amhydro.com/learn-hydroponics/

Aeroponics

This method involves growing plants in an environment without soil or much water, such as an air or mist environment. In aeroponics, seeds or seedlings are "planted" in foam pieces placed into tiny pots that are exposed to light on one end and nutrient spray on the other. The foam holds the stem and root mass in place as the plants grow. One of the most water-efficient vertical farming techniques is aeroponics, which uses over 90% less water than even the most efficient hydroponics setups. Because they are kept in the water, the nutrients are also recycled. Additionally, it has been demonstrated that plants grown in this way absorb more vitamins and minerals, possibly improving their health and nutritional value. Plants grow more quickly because water contains more oxygen (Vyas Kashyap & Posch, 2021).

Figure 3: Aeroponic system

Source: https://www.advancednutrients.com/articles/aeroponics-beyond-hydroponics-in-high-tech-gardening

Aquaponics

Another kind of vertical farming is aquaponics. In this technique, fish in indoor ponds excrete nutrient-rich waste that is used as a food source for plants grown in vertical farms. The wastewater is cleaned and filtered by the plants in return, and it is then recycled back into the fishponds. Microbes are essential for turning fish waste products into nutrients that plants can eat. They coexist with fish and plants (Chaudhry & Mishra, 2019).

Figure 4: Aquaponics

Source: https://www.treehugger.com/best-plants-for-aquaponics-5186557

Urban farming in Sri Lanka

The only program in Sri Lanka that promotes the urban agriculture system is Divi Neguma home gardening (Jayampathi Senanayake NSB Epakanda SMA Samarakoon, 2014)Following announcements in Mahinda Chinthana – Vision for the Future and Budget 2011, the Ministry of Economic Development launched the Divi Neguma program, which aims to help family units become self-sufficient, financially stable, and less reliant on the market for their daily food needs. The Divineguma Programme | Social protection was undertaken in three phases (Social Protection Organization, 2017)

1. Agriculture phase – home gardening

2. Small scale industry phase – industries, handicraft sector
3. Livestock phase –fishery, poultry and dairy sector

The Divi Neguma program's main goal is to improve people's economic standing and reduce their reliance on the market for their food needs. In addition, the program intends to

1. increase nutritional intake
2. Households' living costs reduction.
3. 25% increase in vegetable and food production
4. Increase per capita vegetable consumption from 134 to 175 grams per day
5. provide additional sources of revenue for families by selling surplus produce.
6. encourage village-level entrepreneurship

Agriculture was the program's initial phase, with the goal of producing 1 million home gardens. Based on household interest in participation in the program, 100 household units were chosen in every Grama Niladhari division. Seeds, fertilizer, and advice were provided by the government to help people start their own gardens at home. 987,416 fertilizer packages and 1,112,236 seed baskets have been handed to the people by 2014 (Jayampathi Senanayake NSB Epakanda SMA Samarakoon, 2014)

A study was done in the administrative capital, Sri Jayawardenapura kotte. As a part of 'Divi Naguma' programme 384 urban women were assumed to be engaging in Urban farming. A sample group of 82 women, with 50% participating in Urban farming and the rest not, was taken for the survey. The survey was structured using Likert scale. Women farmers inside the city have embraced urban agriculture as a feasible option as a way to produce microcredit and that urban farming is a viable option for tackling climate change in the event of a food shortage. The non-farmers had a poor opinion towards the concept of urban farming. The results indicate that urban women Farmers were aware of the potential of urban agriculture and its ability to begin and end at any time of the year and it can be effectively managed with the resources at hand. The non-farming urban women were unaware regarding this potential(Gamhewage et al., 2015) In addition, urban women farmers have recognized the fact that urban agriculture is a viable option. It is a method of landscaping that is also beneficial to the mind. They also do

not contemplate urban agriculture as a source of annoyance in their private lives and responsibilities. Most importantly, urban farming women believe that their role in food security is crucial.

METHODOLOGY

After the problem identification and defining of research questions are completed a thorough data analysis will be conducted using literature review. Areas of focus will include but will not be limited to history of urban farming, modern technology of urban farming, materials that are used in urban farming as well as urban farming in Sri Lanka. The data gathered will be compiled into an inventory. A data inventory is a catalog of datasets that includes metadata that identifies the dataset's contents, source, licensing, and other relevant details. The data inventory is a useful tool for any organization or project that deals with a variety of data types and sources (Beale, 2018).

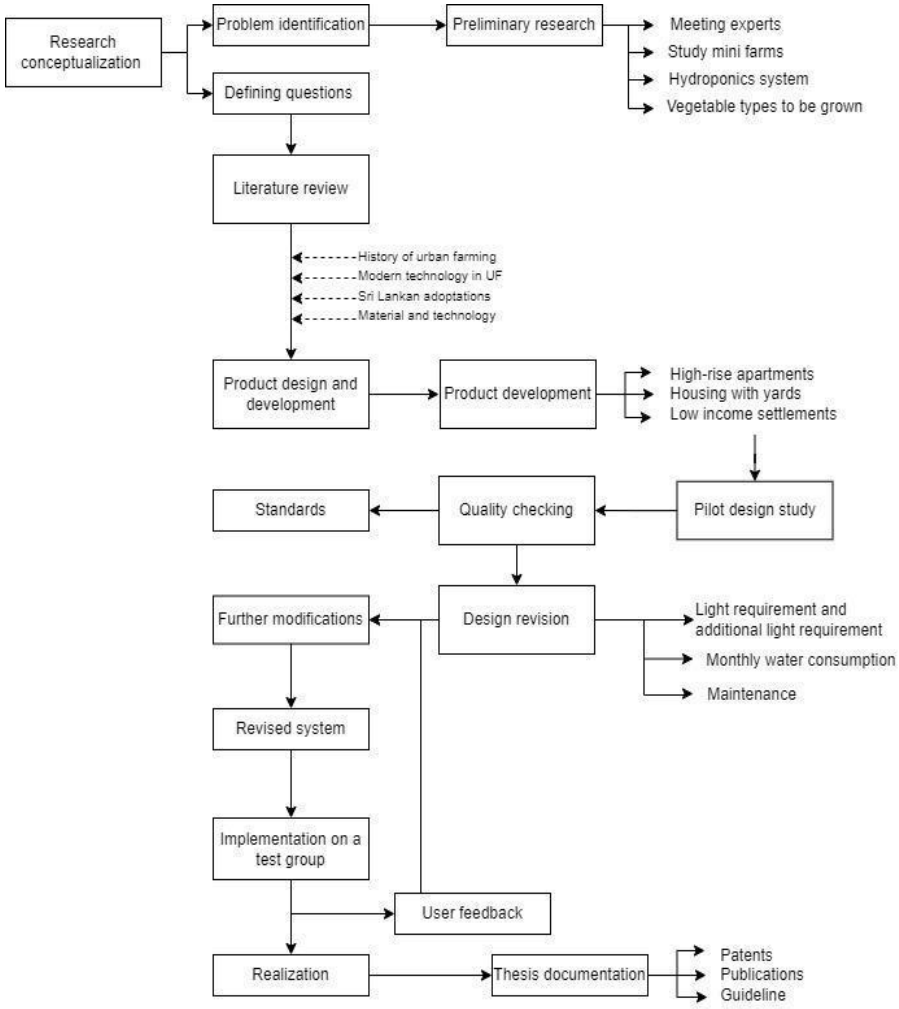


Figure 5: Focus areas of the literature review

Data Collection

Study Site

An initial survey will be conducted in the administrative capital of Sri Lanka, the Sri Jayawardenapura area. The sampling groups will be selected at random to ensure the external and internal validity and it will also eliminate the sampling bias (McLeod, 2019). Sampling groups will cover three groups, residents of luxury apartments, middle class families, low-income families that are living in the areas.

Preliminary Survey

Both multiple-choice and Likert scale items will be included in the survey. The survey is intended to be conducted with 90 participants. The poll will provide 30 participants from each neighborhood the option to take part. The survey will concentrate on elements that are crucial for designing micro farms.

i. Availability of a balcony, rooftop, rear space, garden, and indoor space.
ii. Number of residents
iii. Time that can be allocated for an urban farming project

To gain a comprehensive understanding of the knowledge and needs of the neighborhoods, interviews will be performed. There will be 30 participants in the interview, 10 from each type of residential setting. A transcript of the material gathered will be kept for future use.

Design and Development

Using the information gathered, prototypes of the systems will be created. The designs will be an integration of techniques like vertical farming using hydroponic, aquaponics and aeroponic methods. The prototypes will be further developed into functionable mini farms of various scales.

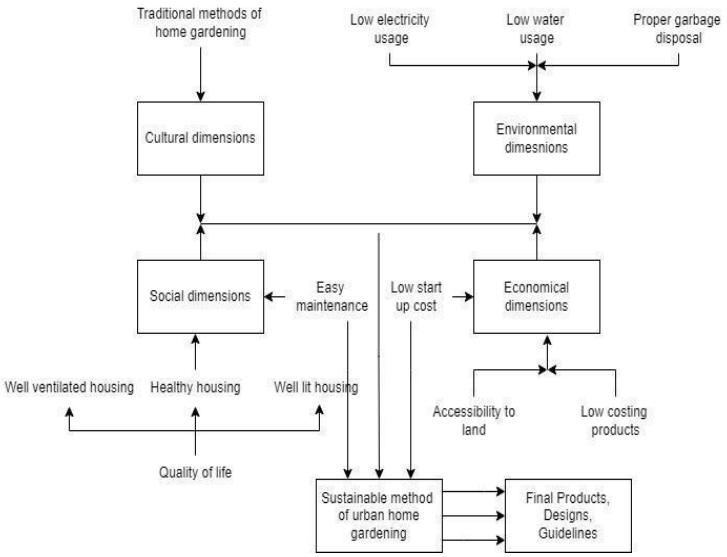


Figure 6: Design breakdown

Testing

The pilot design will be tested against sets of standards to check its durability and structural stability. The monthly water and electricity consumption will be calculated. The demands of these systems such as water consumption and light requirements will be calculated. Modifications will be done to lower the energy usage of the systems.

Implementation on a test group

The revised systems will be implemented on a small test group. The users will be selected based on the previous sector spanning across all three neighborhood types. after the systems have been in operation for a month a survey will be conducted among the test groups to get an insight of real-world application of the systems and devices. From the information gathered via user feedback further modifications will be done. And the quality testing procedure will take place before the systems reach the public.

Documentation and expected outcomes

The findings will be recorded and documented. A set of guidelines on the systems will be published targeting the public of different neighborhoods as well as architects and designers. A set of publications and articles will be produced along with the PhD thesis.

Dissemination of knowledge and proposed outcome

Potential audience

The key audience includes the following categories.

- Real Estate Industry
- Architects and building designers
- Civil Engineering
- Urban design industry
- Government officials that are making decisions
- Government bodies related to agriculture
- People living in high rise buildings
- People living in houses with a small garden
- People living in slums or low income settlements

The dissemination plan would use techniques including graphical, electronic, print and demonstrations. Newsletters and events would be held for study participants. A multiple channel dissemination will be chosen to disperse the knowledge to a broader audience. While the publications and journals might address a group of audience, having events, demonstrations will have a higher impact on some of the intended audience categories.

The research outcome will include publications, journal articles, PhD thesis as well as devices, designs and patents. This will in detail explain the ways of enforcing urban farming techniques to urban planning.

ACKNOWLEDGMENTS

This research was financially supported by the Research Council, University of Sri Jayawardhanapura, research grant no: ASP/01/RE/MGT/2022/43 and the Center for Real Estate Studies, Department of Estate Management and Valuation.

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