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Future Agri+Culture: Architectural conceptualization of modular vertical farming and its integration into the urban area

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Abstract

By 2050, 3 billion people are expected to live on Earth. This suggests that the construction industry needs to build its 3 billion new homes in urban areas. FAO estimates that by 2050, nearly 80% of the world's population will live in urban areas. This would require 220 acres of land to be used for food production. The use of pesticides, deforestation, and the large carbon footprint associated with food movement from rural to urban areas are all examples of the environmental impact of traditional farming methods. A new approach to overcome this is the idea of vertical farming, where food is grown in layers stacked vertically. This paper aims to conceptualize modular vertical farming as a basis for the collective interpretation of future agriculture and architecture. This modular design can support various activities, such as drone subscription delivery, local markets, zen spaces, and hydroponic systems. As well as it is to be adapted to different situations by analysing and researching existing cities using analytical tools to identify the best locations for intervention. As a consequence of integrating modular vertical farming into the urban area, the city and its people are becoming more connected.

Keywords: *Modular vertical farming; Future agriculture; Architectural conceptualization; Vertical farming technology ; traditional farming methods.*

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1 Introduction

The world of today is becoming more and more urbanised. The World Health Organization estimates that as of 2010, most of the world's population lives in cities for the first time. By 2050, seven out of ten people will reside in metropolitan areas. In addition, as the population grows, the United Nations predicts that by 2050, there will be 9.6 billion people on the planet, necessitating the habitation of cities by 6 to 7 billion people. We humans and cities cannot thrive without food. Concerns concerning food security should be at the front of our minds as we move toward the future because food is essential to a city's self-sufficiency, economy, and the health of its residents. Although most of us are unaware of it, the modern food distribution networks operate through a highly effective and intricate system vital to our daily lives, no matter where we reside. The Food and Agriculture Organization of the United Nations estimates that an increase in the global population will necessitate a 70% rise in food production, making the success of this infrastructure crucial. Upcoming issues cities will face traditional agriculture has several problems, in addition to population growth and the resulting increase in food demand. First off, external variables like weather and other uncontrollable environmental elements have a big impact on performance. Crops may suffer catastrophic damage from unanticipated drought, excessive precipitation, pests, etc., leading to severe financial losses for farmers and interruption of the food supply chains. Commercial agriculture has negative environmental effects as well. If species variety is lacking, land may lose nutrients after extensive commercial farming. Chemical fertilisers are overused and are causing land and water pollution. In addition, if more agriculture could be converted back to forests, it would aid our efforts to address the huge environmental issue of global warming. As the population grows, creating food security is a challenging aspect of agricultural technologies and an issue requiring immediate attention. The current classic agricultural techniques cause high food distribution costs, and many products go to waste while people remain hungry

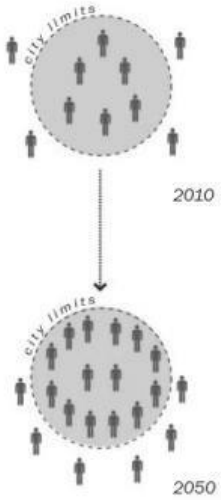


Fig.1: Population Size

worldwide (Cockrall-King and j, 2012). The distance required for food to travel from source to table and the abundance leftover in many supermarkets is the core of many of these concerns. How to mediate this issue is what agriculture development in the future must focus on. Examining various agricultural strategies in terms of their costs and benefits allows a comprehensive understanding of the best way to move forward to extinguish food insecurity and provide for the current and future population, whether it be remaining with organic farming or moving towards urban solutions such as modular vertical farming (Quinn and Harley, 2017). Modular vertical farming is often considered a suitable approach compared to other urban agriculture methods due to its advantages. It is a highly suitable urban agriculture approach due to its exceptional space efficiency, higher yields within limited space, year-round production regardless of weather, reduced environmental impact through resource conservation, minimised transportation costs, faster growth cycles, and the ability to customise growing conditions. Additionally, it offers steady employment, mitigates pest and disease pressure, and holds educational and aesthetic value. It is a comprehensive solution to address urban food challenges while aligning with sustainability goals. In conclusion, given the problems we face regarding population growth, urbanisation, food safety and scarcity of water, this study aims to investigate how architecture can help utilise modular vertical farming inside city centres by using modular timber construction (Abbasi, 2020).

2. Method

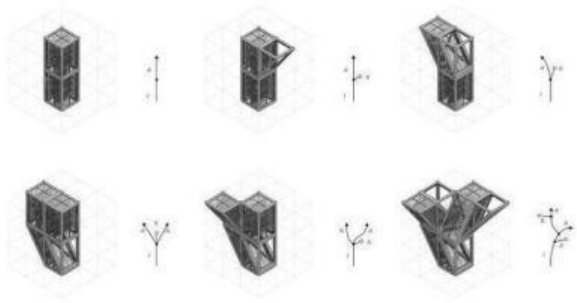
Modular vertical farming is currently the subject of a growing corpus of study. As shown in the references in this paper, studies and updates on the subject can be found in various formats, including academic papers, professional reports, news pieces, blogs, and websites. This essay combines various sources to provide answers to the problems raised above. It looks at a broad range of literature on agronomy, urban agriculture, vertical farming, rooftop farming, and modular vertical farming. In addition, it examines business strategies, cultivation methods now in use, and related technology. This study grew from anecdotal observations to a thorough analysis of the relevant technology and real and futuristic initiatives of modular vertical farming. The research was initially sparked and driven by Internet browsing (websites, blogs, and movie clips), which informed about current initiatives using cutting-edge technology. Using several online search engines and databases, such as Scopus, ProQuest, and Google Scholar, inspired a comprehensive investigation of general (secondary) and specialised (primary) literature on modular vertical farming. Researchers gathered data from over 100 sources. These sources included 30% peer-reviewed academic journal articles, 14% books and book chapters, 5% theses, 15% conference papers, and 20% websites. Most evaluated literature dates from 2009 to 2023, making it rather recent. Most of the projects under assessment are from North America, Europe, and Asia. Overall, this study uses a qualitative informative technique. The document compiles difficult technical details and makes them understandable to non-specialists. The study aims to provide a better knowledge of the philosophy and practice of modular vertical farming by collectively reviewing, organising, and compiling data from numerous sources.

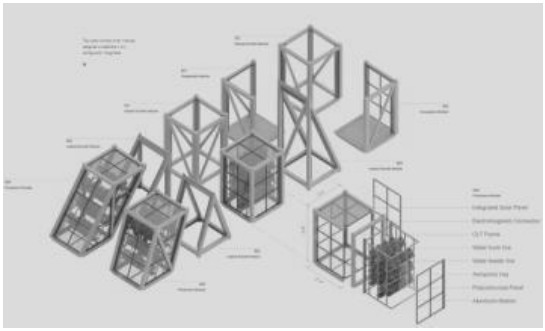
3 General characteristics of Modular vertical farming

Modular vertical farming is an innovative agricultural approach characterised by the vertical arrangement of cultivation units within a controlled indoor environment. This method optimises space utilisation by stacking multiple layers or modules, often using hydroponic or aeroponic systems to grow crops without soil. Controlled climate conditions, including lighting, temperature, humidity, and nutrient delivery, are tailored to specific plant requirements, resulting in year-round, high-yield production with reduced water and pesticide usage. The modular nature allows scalability and flexibility, enabling easy expansion or adaptation to various crop types. This approach holds promise in addressing urban food security, minimising transportation costs, and decreasing the environmental footprint of traditional agriculture.

3.1 Case Study

Brooklyn County has experienced explosive economic growth over the past decade. Between 2001 and 2015, the job creation rate in Brooklyn was nearly three times higher than in Manhattan (2.3% and 0.8%, respectively). This development has brought about many positive changes and created a high degree of social stratification –





leading to equally high nutritional inequalities. While the forces of the makeover mainly affected the neighbourhoods along the west waterfront - making this part of Brooklyn a foodie's paradise, the county has a high rate of insecurity. Food security is 20% - the highest in the city. Between 2009 and 2014, Brooklyn also had the highest rates of food insecurity. While that number fell by 11.8% in the Bronx, the city's poorest borough during that period, it increased by 8.7% in Brooklyn. Glasir is designed to intervene effectively in this landscape. The system was originally proposed to be rolled out in the po county's poorest and most food-insecure neighbourhoods like East New York, East Flatbush, Canarsie and the Flatlands. These are some of the biggest

Fig.2: Modular Analysis (Framlab, 2018). Fig.3: Structure Analysis (Framlab, 2018).

food deserts in the city, where access to affordable and nutritious food is limited. With studies demonstrating a direct correlation between food insecurity and health risks, Glasir's proposal to provide affordable, locally-grown produce has the potential To improve the nutritional composition of dieters and sow the seeds for society and the community. economic improvement of these neighbourhoods through their presence on the street, green structures also play an essential role in creating visibility and raising awareness about the importance of green vegetables.As a product-service system, Glasir applies different business models to targeted user segments: private households, community centers, schools and institutions, businesses, etc. This system is also suitable for the sharing economy as each production module can be shared among several subscribers, maximising available resources while minimising energy for production and transport. The module can be harvested using a digital application to a selected location. While the city's streetscape serves as a habitat for Glasir, each tree-like structure is also intended to act as a micro-habitat in its own right, serving as a communal anchor point. opportunities for the local community - create quiet spaces for people to meet and relax, provide shade and shelter during the day, and lightly illuminate sidewalks when dark. Since each green structure serves a local neighbourhood, the composition, type, and seasonal variation of the vegetables grown reflect the unique composition and characteristics of the community, underpinning the other. The neighbourhood's distinctiveness creates residents' pride (Framlab, 2018).

Fig.4: visualisation of modular vertical farm in urban scale (Framlab, 2018).

4 Modular vertical farming architecture:

Modular Vertical Farming is an innovative approach to agriculture that grows crops in vertically stacked tiers or racks, often in controlled indoor spaces. This method maximises space, reduces the need for large arable land, and allows crops to be grown all year round. There are also city-wide initiatives, such as local stores that deliver

fresh greenery for neighbours and citizens. As the system provides fresh green food inside, the public can set up local businesses to buy fresh vegetables, giving them access to cheap, healthy and nutritious food. increase. It creates money for system and building owners, empowers the masses, and promotes well-being and health in society. The system also includes a subscription service model for regular distribution of crops to homes, businesses and schools. An electromagnetic connection to the main system provides the drone module with the resources required by the main module. Indeed, modular vertical farming can be a game-changer in urban settings, especially when combined with other sustainable practices. Let's explore how each of these elements contributes to an integrated and sustainable urban farming system:

4.1 Ancient Japanese Architecture and Interlocking Timber Structure

Ancient Japanese architecture is known for its unique and sophisticated design, which often incorporates interlocking timber structures. These structures have been employed in traditional Japanese buildings for centuries, demonstrating the country's mastery of woodcraft and architectural ingenuity (Abbasi, 2020).

1. Benefits of the Structure (Abbasi, 2020).
    - Compared to steel and concrete, wood is regarded as a local and sustainable material globally and has a favourable effect on climate change.
    - Wood is an intelligent and user-friendly material that works best for DIY or modular building because iXt is simple to CNC mill and ship.
    - We can use fewer other resources by making the most of wood.

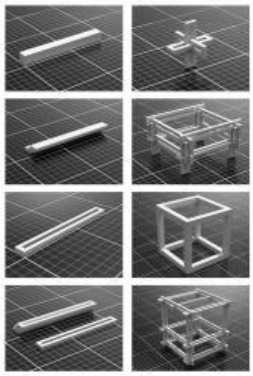


Fig. 5: Interlocking resilience (Abbasi, 2020).

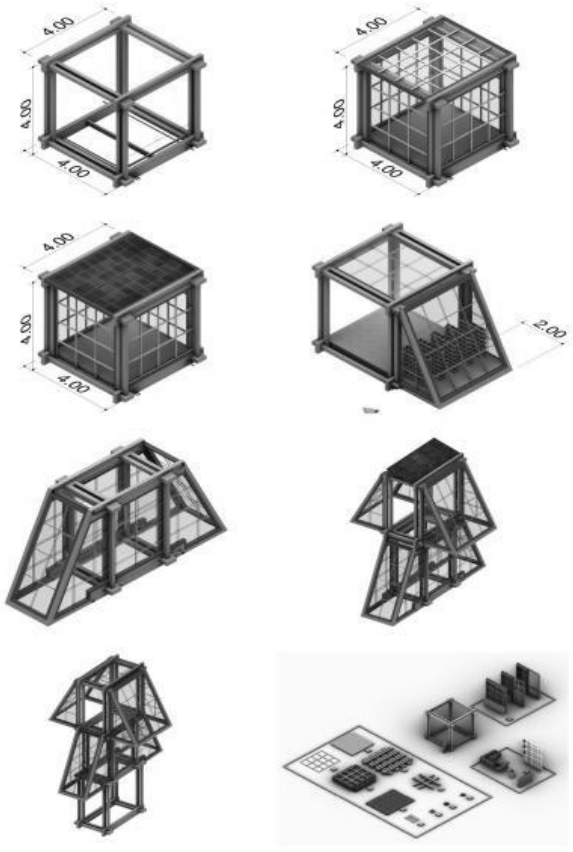
4.2 Structural adjustments and talking with engineers

Using a unique fastener called sw-d double thread wood screw, after discussing the designed module and project goals, we further discussed the structure, which is structurally more effective, more torsion and load resistant, and moisture The design has been improved to be more reliable for Martinson engineer (Abbasi, 2020).

4.3 Forming Modules:

For many modules, research is based on industry standards. This module has dimensions of 4m x 4m and uses design fundamentals to create a module suitable for different activities. The dimensions of the building are flexible, even if the design element size is 4 x 4 m. Since the core of the building is hollow, all services are provided through the system regardless of activity above the deck core (Abbasi, 2020).

- The double-glazed polycarbonate glass panels shield the modules from the outside environment. With apertures, it may be opened in the summer to allow people to enjoy the summer breeze while being sheltered from the environment during colder seasons.
- Transparent polycarbonate glazing can be replaced with modules that combine solar panels to produce sustainable energy for the system. The integrated lights for aeroponic farming will now be lit, and the power will also be utilised to heat the system. Any extra electricity may charge electric scooters, bicycles, and cell phones.
- The size of modules is smaller. They are intended to increase the adaptability and flexibility of the modular system.
- Modules are used for aeroponic trays or lateral growth of the system when the extension is at the corners.
- Due to the features LCA (Life Cycle Analysis), prefabrication and modular architecture reduce waste generation, construction speed, and environmental effects (Abbasi, 2020).



4.4 Floor System

A method known as a suspended timber floor with groove and tongue is employed for the floor system. The system is suitable for modular and prefabricated systems since it can be readily moved and adjusted on-site and delivers good sound insulation alone. It does not require

additional sound insulation layers. It is also easily mountable and dismountable by Swiss sound insulation requirements. The design also includes a middle-mounted timber joist with mechanical fasteners for added structural stability of the floors (Abbasi, 2020).
Fig. 6: Modular Architecture (Abbasi, 2020).

4.5 Final design:

Fig. 7: Final Modular Unite (Abbasi, 2020).

Modular vertical farming creates a holistic and sustainable urban farming ecosystem by integrating solar energy, algorithmic analysis, aeroponic farming, bio-sphere assessment, zen spaces, local markets, subscription-based food delivery, and sustainable agricultural practices. This cohesive system bolsters food security, preserves the environment, and fosters a healthier urban lifestyle. It enriches the lives of residents and offers a replicable blueprint for other cities striving to adopt sustainable agricultural methods, paving the way for a greener and more resilient urban future.

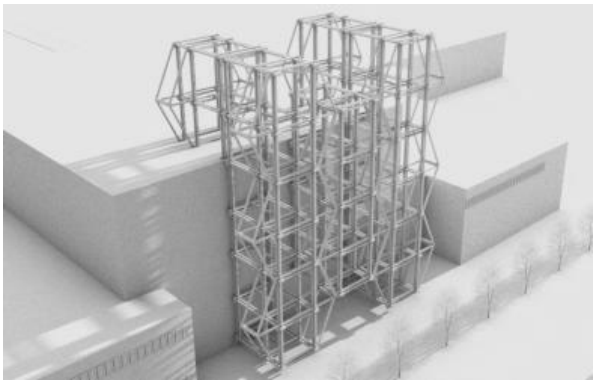


Fig. 8: Road Site installation (Abbasi, 2020).

5 Discussion

As part of an architectural investigation, the systems also offer various internal programming options to the general public that can help revive metropolitan areas and deserted city boundaries. It offers opportunities to those who utilise the buildings and those who use the nearby urban environment. The interior of these new spaces can create a new social bond among residents, give rise to activities like Yoga and meditation, and

Fig. 9: interior new social space (Abbasi, 2020).

Fig. 10: interior new social space (Abbasi, 2020).

introduce new Zen areas for the building and its surroundings because the project is designed to add existing buildings and uses green walls to enclose some spaces. Urban environments often have limited space for traditional agriculture. Modular vertical farming takes advantage of vertical space, making growing a significant amount of produce in a small footprint possible. With vertical farms throughout the city, residents can access fresh and locally grown produce, reducing the time between harvest and consumption. This freshness enhances the nutritional value and taste of the crops. The broader adoption of modular vertical farming hinges on technological advancements and policy support to overcome challenges and enhance feasibility and sustainability. Key technological shifts encompass efficient LED lighting, automation, real-time monitoring, precise nutrient delivery, pest management, energy efficiency, crop optimisation, and recycling systems.

Complementary policy changes involve financial incentives, adaptable zoning, research funding, quality standards, workforce development, collaboration, sustainable practices encouragement, and market access facilitation. These combined efforts can drive the expansion of modular vertical farming, making it more practical, profitable, and ecologically responsible. However, it is essential to consider specific challenges while integrating modular vertical farming into urban areas:

1. Initial Investment: Setting up vertical farms can require significant upfront costs for infrastructure, technology, and equipment.
2. Technology and Expertise: Advanced technology and skilled personnel are necessary to manage the intricacies of vertical farming efficiently.
3. Market Demand and Pricing: The success of vertical farms depends on market demand and competitive pricing compared to conventionally grown produce.
4. Zoning and Regulations: Local regulations and laws may not be adapted to accommodate vertical farms. Working with policymakers is crucial to create a conducive environment for urban farming.
5. Crop Selection: Not all crops are suitable for vertical farming. Careful crop selection is vital to ensure optimal yield and return on investment.

Despite these challenges, modular vertical farming presents a promising solution for sustainable urban agriculture, offering numerous benefits to cities and their residents. As technology and practices continue to evolve, we can expect even greater integration of this approach into urban landscapes in the future

6 Conclusion

In conclusion, the conceptualisation of modular vertical farming presents a promising solution to address the challenges of food security, resource efficiency, and urbanisation. This innovative approach to agriculture leverages limited urban space by stacking cultivation units vertically, maximising land utilisation while reducing the need for expansive farmland. Integrating modular vertical farming into urban areas offers a range of benefits, including reduced transportation distances for fresh produce, decreased carbon emissions, and increased community access to locally grown, nutritious foods. The research has highlighted the multifaceted advantages of modular vertical farming systems. These systems can achieve higher crop yields with less water, fertilisers, and pesticides by optimising environmental conditions through controlled environments. Additionally, the modular nature of the approach enables scalability and adaptability to various urban settings, accommodating diverse architectural designs and available spaces. In conclusion, modular vertical farming represents a progressive approach to merging agriculture with urban living. Its potential to enhance food resilience, reduce ecological footprints, and reconnect communities with the origins of their sustenance makes it a concept worth further exploration and implementation. As cities evolve, embracing innovative solutions is crucial for creating sustainable and thriving urban spaces facing global food security and environmental challenges.

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