The High Garden:  
An architectural exploration on how to integrate vertical farming and modular architecture inside city centres

Farid Abbasi  
Studio 12  
UMA5 Thesis  

Umeå School of Architecture  
Umeå University
Abstract:

The High Garden

The state of the world is changing. By 2050, The earth’s population will increase by 3 billion and building sector is asked to construct 3 billion new housing units inside urban centres. Since one of the fundamental needs is food, agriculture sector also needs to adjust itself to this growing number of people. Nevertheless, in 2019, Agriculture used 50 per cent of all earth’s habitable land and experts estimate that we need 10^9 hectares more land to cultivate however this amount of habitable land is approximately the land which is represented by the country of Brazil and 20 per cent more. Moreover, the Food and Agriculture Organization of the United Nations states that water use grew twice as much as population increase and agriculture already is using approximately 70 per cent of the global freshwater. At this point, experts like Professor Dickinson Despommier suggests that the only way humanity can tackle its future food safety issues is to find ways to introduce vertical farming inside Urban centres. The High Garden project is resulted by the world state today and is trying to find an architectural solution to the mentioned issues. It starts firstly by studying the issues more thoroughly and then tries to form a framework which includes and transcends them. It studies how the construction sector is acting now and how it can reorient itself to the situation whilst limiting its negative environmental impact. Then the thesis tries to understand the basics of vertical farming methods compared to the conventional geoponics farming as it is practised today and how it can integrate the better cultivation solution inside city centres. The last step of the theoretical studies of the project is to look at the history of integrated farming and EcoArchitecture. After understanding the theories of the issue, then the thesis starts to form itself as an architectural intervention using the architectural tools and methods and combining the studied disciplines. The result of the thesis is a modular configuration which can accommodate various activities such as aeroponic farming, local markets, zen areas, and drone subscription deliveries etc. Because of the modular construction of the project, it can adapt and adjust itself to different situations and it uses an algorithmic tool to analyse and study existing cities to find proper intervention points. Then it is attached to the existing buildings as a sustainable green extension solving some issues and revitalizing the dead city edges.

Keywords: State of the World, rapid urbanization, population growth, geoponic agriculture, Co₂ emission, greenhouse gas emission, aeroponic farming, modular architecture, sustainable architecture, EcoArchitecture
The High Garden Written Thesis
Farid Abbasi

Bibliography ...................................................................................................................................................................................... 36
Online Resources............................................................................................................................................................................... 38

Figures

Figure 1 Brazil Boundaries. https://www.google.com/maps/place/Brazil/@-5.882638,-55.9976133,17887636m/data=!3m1!4m5!3m4!1s0x9c59c7ebcc28cf:0x295a1506f2293e63!8m2!3d-14.235004!4d-51.92528 accessed and generated by Author from google maps (08/03/2020) ............................................................................................... 8
Figure 3 Cement and Steel attribution to climate change, https://www.researchgate.net/publication/302061863_Long-term_model-based_projections_of_energy_use_and_CO2_emissions_from_the_global_steel_and_cement_industries Accessed (23/04/2020) ........................................ 10
Figure 4 Global Land Use for Food Production. Source FAO (Food and Agriculture Organization of the United Nations). Retrieved from https://ourworldindata.org/land-use Accessed (22/04/2020) ......................................................................................... 11
Figure 5 Global GHG emissions from food. retrieved from https://ourworldindata.org/food-ghg-emissions by author. accessed 08/03/2020 ..........................................................................................................................................
Figure 6 Global share of buildings and construction final energy and emissions, 2018 ..................................................................................................................... 12
Figure 7 United Nation’s Sustainable Development Goals chart. Retrieved directly from UN’s Website at https://sustainabledevelopment.un.org/?menu=1300 (23/04/2020) ............................................................................................ 13
Figure 9 Project Border of Influence. retrieved from https://ourworldindata.org/food-ghg-emissions. Redrawn by author. combined with other resources accessed 08/03/2020 ..................................................................................................................... 13
Figure 8 Project Scope of influence on UN’s Sustainable Development Goals ................................................................................ 13
Figure 11 World map depicting percentage of land area dedicated to commercial forestry Retrieved from ........................................ 16
Figure 12 World map depicting annual decrease and increase in forest cover Retrieved from ....................................................... 16
Figure 17 World Food Building. All rights reserved Plantragon. retrieved from Dezeen website. https://www.dezeen.com/2018/01/15/video-skyscraper-plantagon-urban-farm-world-food-building-movie/ ................. 23
Introduction:

State of The World

By the year 2050, approximately 70 per cent of the earth’s population will reside in urban centres\(^1\) and by applying the most conservative estimations by the UN, the earth’s population will increase by about 3 billion\(^2\) and consequently, 3 billion new housing units are needed to be built\(^3\). Whilst this massive 3 billion new houses are needed, construction sector and its commonly used materials namely concrete and steel have proven to have a devastating impact both on the global CO\(_2\) and greenhouse gas emission and on climate change and water and energy use\(^4\). Furthermore, in 2019, agriculture used 50 per cent of earth’s habitable land\(^5\) and an estimated 10\(^9\) hectares of new land will be needed to grow enough food to feed this new growing population\(^6\). According to FAO (Food and Agriculture Organization of the United Nations), Water use grew at almost twice the rate of the population increase and on average, agriculture accounts for 70 per cent of the global freshwater withdrawals\(^7\). Concurrently, World’s Health Organization (WHO) estimates that 844 million people lack basic drinking water service and by 2025, 50 per cent of the earth’s population will be living in water-stressed areas\(^8\). Although the growing population will require more food to lead an active and healthy

---

4. For more information see appendix 1. Abbasi, Farid, Architecture for the age of Big Data: Studying the impacts of the rise of Big data and artificial intelligence on architecture practice, P. 7-8.
8. Drinking-water , https://www.who.int/news-room/fact-sheets/detail/drinking-water accessed by Author (08/03/2020)
life, our current agriculture and its water-intensive methods are causing issues rather answers and professor Dickinson Despommier on his book ‘The Vertical Farm’ argues that by 2030, one of our most challenging problems is regarding food safety in urban centres. He argues the only way we can overcome this issue is to find alternative ways to introduce vertical farming inside our cities⁹.

In conclusion, given the problems we are facing regarding population growth, urbanization, food safety and scarcity of water, this thesis tries to investigate how architecture can help to utilize vertical farming inside city centres by using modular timber construction and mass computations resulted by Dataism in Architecture¹⁰.

This thesis consists of these chapters:

Chapter I: Necessity of Change. This chapter investigates the problems regarding Urbanization, population growth, agriculture and its waste, construction sector negative impact.

Chapter II: Wood as the construction material of our time

Chapter III: Vertical Farming: Past and Present. A history of vertical farming, what it means, how it has been practised and how beneficial it is.

Chapter IV: Vertical Farming within Architecture. A brief look at the work of architects trying to integrate biomimicry and farming inside their projects. Commonly known as EcoArchitecture.

Chapter V: The High Garden. This chapter illustrates how Architecture as a multi-disciplinary practice can integrate vertical farming, modular Architecture and Dataism in one project.

Chapter VI: Conclusion

⁹ See (4) and http://www.verticalfarm.com/.
¹⁰ For more information see the appendix, Chapter I, P5.
CHAPTER I

Necessity of Change

1: Problems

1.1: Farming and Land:

Briefly mentioned in the introduction, The Earth’s population is increasing every day and, more land is needed to feed this growing population (1)(2)(3). FAO statistical pocketbook of 2019 illustrates how our traditional farming methods are going to be neither efficient nor successful to provide sustainable food for the population (5)(7)(8). For instance, it is estimated that 109 hectares of new land (about 20 per cent more land that is represented by the country of Brazil) will be needed for farming (6).
1_2: Wasted Food and Water:

Farming as it is practised today will require a lot of freshwater resources, approximately 70 per cent of all freshwater withdrawals (7). Moreover, FAO statistics show that on a global average, 14 per cent of the world’s food is wasted11.

Figure 2 wasted food. Retrieved from http://www.fao.org/state-of-food-agriculture/en/ by author. This work is made available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; https://creativecommons.org/licenses/by-nc-sa/3.0/igo). accessed 08/03/2020. Created by author.

1_3: Construction and demolition waste (CDW) and its Co₂ footprint:

We are needed to build 3 billion new houses (3) and simultaneously CDW is one of the most voluminous streams of waste generated globally and in the EU. For example, in the EU, it accounts for 25 – 30 per cent of all waste generated12. Moreover, Concrete and steel are the

most commonly used materials in the construction sector and concrete is already responsible for between 5 to 8 per cent of Global Greenhouse emissions. Furthermore, we produce approximately 3000 kilos of concrete for every person each year. Lastly, our second most used and common material in construction is steel and whilst it is less carbon-intensive compared to concrete, the production of steel results in 4 per cent of global energy use.

Figure 3 Cement and Steel attribution to climate change, https://www.researchgate.net/publication/302061863_Long-term_model-based_projections_of_energy_use_and_CO2_emissions_from_the_global_steel_and_cement_industries

1.4: Agriculture and Construction global CO₂ and greenhouse gas emission:
Whilst it has been argued that agriculture is already using a vast majority of earth’s habitable land and freshwater resources, it has huge attribution toward global CO₂ and greenhouse gas emissions. 

https://ec.europa.eu/environment/waste/construction_demolition.htm

13 For more information see appendix page 7
emission. It is estimated that 26 per cent of global greenhouse gas emission is because of the food sector, its transportation and waste.

14 Ritchie H, “Food production is responsible for one-quarter of the world’s greenhouse gas emissions”, Published online at OurWorldInData.org. Retrieved from: ‘https://ourworldindata.org/food-ghg-emissions’ [Online Resource], Accessed (08/03/2020)
In 2018, the buildings and construction sector was accounted for 36% of final energy use and 39% of energy and process-related carbon dioxide (CO2) emissions\(^\text{15}\).

In conclusion, it is evident that given the population growth, we need more agricultural land, more freshwater resources, and more houses. Agriculture and construction are already two major contributors in CO2 and GHG emission, together accounted for 65 per cent of all global emission and whilst the common trend of the world’s state will demand more of this sectors, We cannot continue our practised methods concerning these two sectors if we want to successfully deal with our environmental crises and sustainable development plans \(^\text{16}\).

\[\text{Figure 6 Global share of buildings and construction final energy and emissions, 2018.} \]


\[^{16}\text{For more information see } \text{https://sustainabledevelopment.un.org/?menu=1300 accessed (23/04/2020)}\]
The Project Scope of influence concerns 13 out of 17 UN’s Sustainable Development Goals.
Given the result of the findings, The High Garden project’s paramount purpose is to find and study alternative ways of farming which require less land and water resources, construction materials with lower Co2 and GHG emissions and then try to integrate both inside one project as an architectural intervention inside city centres and by doing so, it tries to have a direct impact on sectors accounted for 65 per cent of the Co2 and GHG emissions (6)(9).
Chapter II

Wood as the Construction Material of our Time

The construction sector is asked to build 3 billion more housing units, yet it cannot continue the ‘business as usual’ notion and continue construction with concrete and steel; not unless with catastrophic results for the environment (3)(4). Nevertheless, Engineered Timber industry expansion and its breakthroughs in common years in manufacturing Glulam, LVL and CLT products have been able to transform wood into a sustainable material for construction since the producer of wood is the Sun 17. Although a critic toward building with wood has always been about ‘we do not have enough trees’, through Sustainable Forestry in North America, Scandinavia, and Australia, governments have been able to increase their forest’s land coverage and quantity whilst providing the construction sector with massive supplies of engineered timber products18.

17 For more information See appendix 1 and (3) (4)
This figure of [Commercial forestry land use] have been removed in this publication due to copyright reasons.

*Figure 11* World map depicting percentage of land area dedicated to commercial forestry Retrieved from


This figure of [annual decrease and increase in forest cover] have been removed in this publication due to copyright reasons.

*Figure 12* World map depicting annual decrease and increase in forest cover Retrieved from

Through sustainable forestry and engineered timber industry, not only forests are not in danger but also because of the carbon sequestration ability of the wood, when we use woods as construction materials, we make its carbon sequestration ability longlasting\textsuperscript{19}.


In conclusion, current construction sector procedure whereby we dominantly consume concrete and steel have had a devastating impact on our environment. Concurrently, there are significant reasons why we can see wood as a sustainable alternative for concrete and steel therefore, The High Garden thesis has chosen wood to be the paramount construction material of its modules.

This figure of [Carbon Cycle] have been removed in this publication due to copyright reasons

CHAPTER III

Vertical Farming: Past and Present

3_1: PAST

The idea of using a large multi-storey building to cultivate agriculture products is not a new concept. Vertical Farming first was introduced by an American geologist, Gilbert Ellis Bailey which in his book titled Vertical Farming (1915/2011), Bailey considered this method and his breakthrough as an answer to our current environmental crisis and food security and equity, decades before their occurrence20. He wrote in his book Vertical Farming in 1915:

‘Enables the farmer to farm deeper, to go down to increase area, and to secure larger crops. Instead of spreading out over more land he concentrates on less land and becomes an intensive rather than an extensive agriculturist, and so learns that it is more profitable to double the depth of his fertile land than to double the area’21.

3_2: Present

Dickson Despommier, PhD, is a microbiologist, an ecologist, and emeritus professor of Public and Environmental Health at the Columbia University22. He believes that every person’s birthright at the minimum should be 2.3 litre of safe drinkable water per day and 1500 calories of safe food every day23. He argues that because of the population growth and urbanization, this mere minimum of birthright is not guaranteed and soon the situation will become worse even for the people inside cities (11)(14). He argues that practising vertical farming on a large scale in urban centres has great potential to help us achieve:

23 Despommier, Dickson, The vertical Farm, TEDx Windy City, 2010, retrieved from: https://www.youtube.com/watch?v=XIdP00u2KRA&t=171s , Accessed 10/03/2020
1. sustainably produce enough food to comfortably feed all humankind for the predicted future.
2. allow large portions of land to remain and to become part of the natural landscape restoring ecosystems
3. safely and efficiently use the organic portion of human and agricultural waste to produce energy through methane generation and at the same time, significantly reduce the population of vermin (e.g., rats and cockroaches).
4. re-mediate black water creating a much-needed new strategy for the conservation of drinking water
5. take advantage of abandoned and unused urban spaces
6. break the transmission cycle of agents of disease associated with a focally contaminated environment.
7. allow year-round food production without loss of yields due to climate change or weather-related events
8. eliminate the need for large-scale use of pesticides and herbicides.
9. provide a major new role for agrochemical industries (i.e., designing and producing safe, chemically defined diets for a wide variety of commercially viable plant species.
10. create an environment that encourages sustainable urban life, promoting a state of good health for all those who choose to live in cities. All of this may sound too good to be true, but careful analysis will show that these are all realistic and achievable goals, given the full development of a few new technologies.

In conclusion, Since conventional agriculture (Geoponic) cause a wide range of different problems, vertical farming methods can be alternatives. In general, vertical farming methods are Hydroponics, aeroponics and aquaponics. By using these methods, we can lower the water and land usage of agriculture. Aeroponics systems, for example, can reduce the water usage by 98 per cent, fertilizer usage by 60 per cent, pesticides by 100 per cent whilst maximizing crop yields to only 9 per cent (24).
**Hydroponic farming:**
In the hydroponic system, plants grow with added nutrients in a certain nutrient tray and without soil. Hydroponics uses only water and nutrients fertilizer to cultivate plants\(^{24}\).

**Aeroponic Farming:**
Aeroponics is a subgroup of hydroponics. The main difference between the two methods is that in aeroponics, there is no growing medium or tray and the plan grow by misting and spraying rich nutritious water.

**Aquaponics Farming:**
Aquapones farming methods rely on the relationship between animals and plants to mimic and produce a stable aquatic environment. Hence the Aquaponics is the intersection point of the aquaculture (raising fish) and hydroponics (soilless growing of plants).

Table 1 percentage of water and fertilizer consumption, vegetables yield percentage and the percentage of water productivity for different new farming systems as compared with conventional farming system retrieved from: https://asrjetsjournal.org/index.php/American_Scientific_Journal/article/view/2543/1028 accessed (23/04/2020)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Hydroponic system</th>
<th>Aeroponics</th>
<th>Aquaponics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Media Soilless system</td>
<td>Nutrient solution system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open</td>
<td>Closed</td>
<td>Open</td>
</tr>
<tr>
<td><strong>% Irrigation water saving</strong></td>
<td>80</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td><strong>% Fertilizer saving</strong></td>
<td>55</td>
<td>80</td>
<td>68</td>
</tr>
<tr>
<td><strong>% Productivity increase</strong></td>
<td>100</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td><strong>% Water productivity</strong></td>
<td>1000</td>
<td>1600</td>
<td>2000</td>
</tr>
</tbody>
</table>

CHAPTER IV

EcoArchitecture\textsuperscript{25} or (AGRITECTURE):

EcoArchitecture: In early 1980, a Malaysian architect named Ken Yeang was the first architect in the history who introduced Bailey (21) ideas into the realm of architectural design. He believed that all human activities even the ones whereby agricultural products are grown should be based on eco-mimicry ( the notion that to be completely sustainable, all built or devised human environments should mimic the characteristics, attributions, patterns and cycles of natural ecosystems whereby there is no waist and the waste produced by one entity is the food for the other (25).

Agritecture:
A unique way of combining urban agriculture, innovative technical solutions, and architecture to meet the demand for efficient food production within cities\textsuperscript{26}. This term is introduced and practised by an architectural firm called Plantagon where the company recycles and revitalize urban wasted lands and parking lots into cultivation lands (26). Their projects range from unused parking lots to the world's first office building capable of producing organic food for its employees in Linköpin, Sweden called World Food Building.

\textsuperscript{26} \url{http://www.plantagon.com/}

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{World_Food_Building.jpg}
\caption{World Food Building. All rights reserved Plantagon. retrieved from Dezeen website. \url{https://www.dezeen.com/2018/01/15/video-skyscraper-plantagon-urban-farm-world-food-building-movie/}
Accessed (24/04/2020)}
\end{figure}
EcoArchitecture of Ken Yeang:
Eco Architecture of Ken Yeang is based on biomimicry and a diagram he later introduced as the base of his design called Biosphere [Author] (25).

The EcoArchitecture is based on using technology, materials, shading, and already existing systems inside ecosystems and can be illustrated by showcasing one of Ken Yeang projects.

The Editt Tower:
The Editt tower is a Vertical Eco-infrastructure where Ken Yeang tried to mimic nature within an architectural project which was a competition entry.27

This figure of [Key Yeang’s Original diagram] have been removed in this publication due to copyright reasons.
In conclusion, Ken Yeang was one of the first architects who tried to limit the devastating impact of the built environment by using Biomimicry. Through technologic studying of the sun, bio-diversity and vegetation align with architectural techniques such as passive design, etc, he was successful, however, knowing that concrete and steel were still imposing threats to nature, he was limited to the technology of his time since timber engineering was not yet ready to be seen as an alternative. Through studying his work and agenda, we can study the basics of EcoArchitecture and combine the findings with more sustainable materials for the High Garden project. [Author]
Chapter V

The High Garden

Figure 25 The High Garden. Produced by Author
**Methodology:**

The high Garden Thesis is resulted by the issues discussed in chapter I. The immediate need for more buildings, more sustainable food supplies and environmental threats of no action or continuing the business as usual. By trying to thoroughly investigate the issues, the methodology was to learn and adapt. [State of the world and Chapter I]

The methodology of the project’s intervention is chosen to be a sustainable extension of the existing buildings rather than proposing a new building to limit material usage and CDW (construction and demolition waste). [Chapter I]

The dominant material of the project is chosen to be wood for the first intervention’s location in Scandinavian countries since wood is a local material, is harvested through sustainable forestry and the suitable climate. [Chapter II]

By choosing Technologic modern vertical farming methods instead of conventional Geoponic farming, we can lower the cropland yield to 91 per cent, reduce the freshwater usage by 98 per cent and fertilizers by 60 per cent and pesticides by 100 per cent. [Chapter III]

Analysing the work of master architects such as Ken Yeang and studying the fundamentals of EcoArchitecture then formed the structural and architectural properties of the proposition. Affecting it to choose a Modular Architecture approach and combining architecture with technology and environmental analysis. [Chapter IV]
Manifesto:

The High Garden Manifesto. An Architecture that realizes the state of the World and tries to frame a holistic approach as an architectural project to solve some of the concerns and issues. An architecture which is cautious on its material usage and CDW and concerns civics and people presence inside city centres. [Author and the Designer]
Dataism and The High Garden:

Generative Urban Lens Tool:

Affected by the impacts of IoT and technologies on Architecture and the prospected future paradigm shift of the profession and the new tools for the architects\(^{28}\) [appendix], The project starts by coding its algorithmic tools to enhance the analysis process of the project to find possible intervention sites within urban centres.

\(^{28}\) For more information read appendix.
Multi-Layer Analysis of Urban Plots

One part of the project is an evolutionary analysis algorithm which takes city plots and analyses population and building's density and concurrently, it analyses the buildings within the site and realizes which one has more daily sun exposure on its facade. [for more information see appendix].

Figure 28 Multi-Layer Analysis of Urban Plots

1. Analysis results in pinpointing sites with maximum daily sun exposure, density and distance to main routes.
2. Analyzing each building's facade and courtyard daily sun exposures.
3. Analyzing buildings with environmental data such as Sun path exposure, wind, density, etc.
5. Main city roads with high traffic and transportation rate.
6. The starting point of the analysis. Data feed on maps like Google® maps.
Ancient Japanese Architecture and Interlocking Timber Structure:

The interlocking structure of the system is based on the Japanese concept of interlocking geometries [Appendix].

Figure 29 Modular Architecture. Interlocking resilience. The High Garden. [Author]
Modular Architecture:

With the interlocking elements, we can form different modules and configurations all following the standards of the market. The modular Architecture results in more sustainability of the project and because all the parts are screwed, it can be dismantled and be adjusted to the future needs. [Author]
CHAPTER VI

Conclusion:

The high Garden project aims to raise awareness. The Earth’s eco-system is changing, and humanity is the cause of it. For centuries, humanity used the earth’s resources as though they were infinite and changed their surrounding eco-systems. This thesis has been written during the Corona Virus pandemic of 2020 and amid the crisis, it is evident how much we are dependent on each other, our surroundings, and our environment. Climate change threat is imminent and dangerous. We can only overcome the climate change issue through collective inter-disciplinary collaboration and the high garden project tries to illustrate that. Architecture cannot save the world by itself as any other field and in 2020, we need to understand that. We must understand the core of the problem and direct our resources and attention toward it. If you analyse the situation correctly, you can ask the correct question and through collaboration, you can solve it. [Author]

April 2020
Bibliography


Brooks, David. ‘Opinion | The Philosophy of Data”. The New York Times. ISSN 0362-4331.


Harari, Yuval N, ‘Yuval Noah Harari on big data, Google and the end of free will’, Financial Times


Online Resources

Columbia University, Mailman school of Public Health, https://www.mailman.columbia.edu/people/our-faculty/ddd1

Despommier, Dickson, The vertical Farm, TEDx Windy City, 2010, retrieved from: https://www.youtube.com/watch?v=XIdP00u2KRA&t=171s


https://ourworldindata.org/food-ghg-emissions. Redrawn by author. combined with other resources

https://sustainabledevelopment.un.org/?menu=1300


Ritchie H, “Food production is responsible for one-quarter of the world’s greenhouse gas emissions”, Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/food-ghg-emissions'

https://ourworldindata.org/food-ghg-emissions

Drinking-water, https://www.who.int/news-room/fact-sheets/detail/drinking-water


https://www.openstreetmap.org/#map=4/65.26/-14.41
