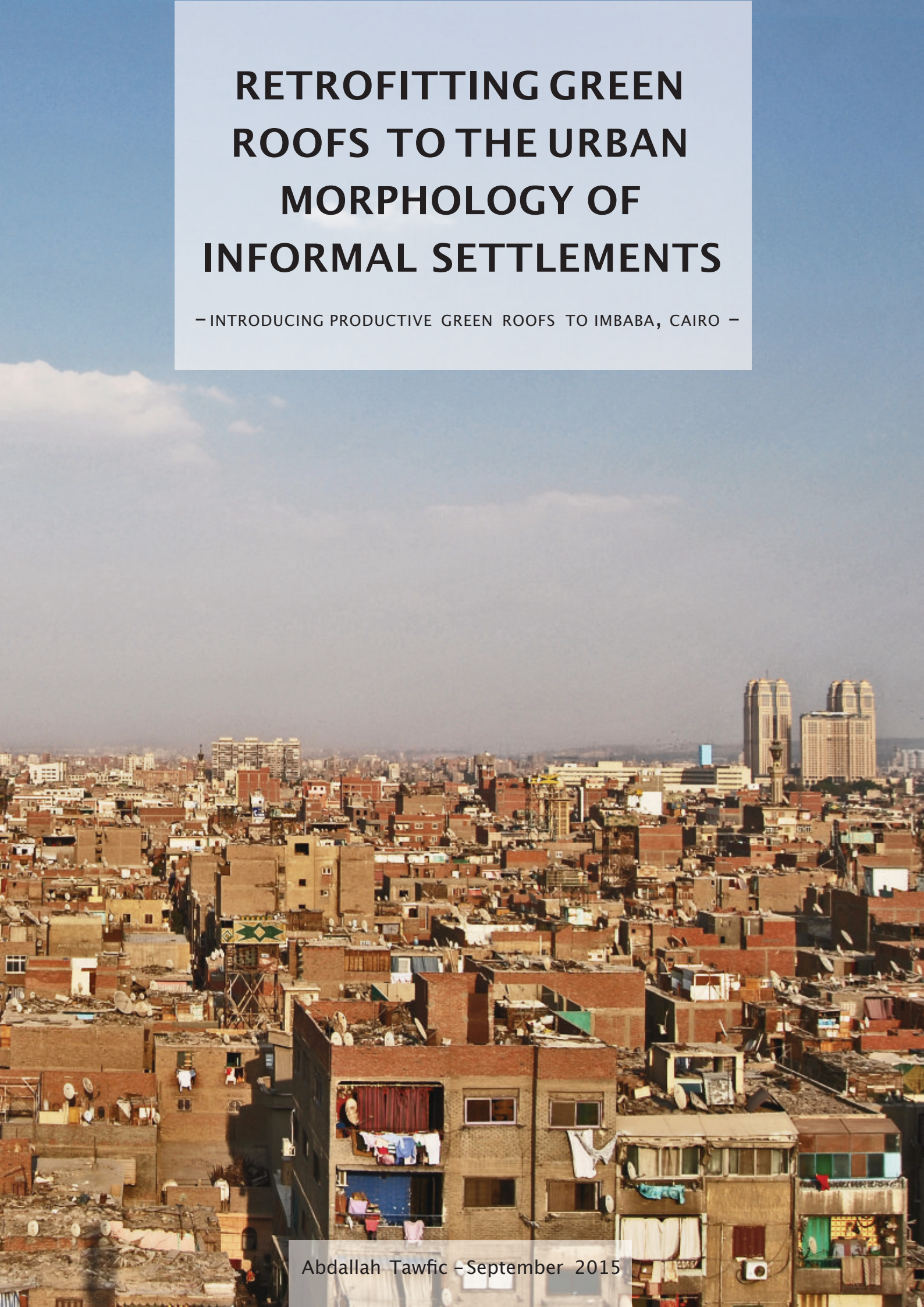
RETROFITTING GREEN ROOFS TO THE URBAN MORPHOLOGY OF INFORMAL SETTLEMENTS

– INTRODUCING PRODUCTIVE GREEN ROOFS TO IMBABA, CAIRO –



Abdallah Tawfic – September 2015

RETROFITTING GREEN ROOFS TO THE URBAN MORPHOLOGY OF INFORMAL SETTLEMENTS

– INTRODUCING PRODUCTIVE GREEN ROOFS TO IMBABA, CAIRO –

A thesis presented to:
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Prepared by :
Abdallah Tawfic

In Partial Fulfillment of the Requirements for the Degree:
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Resource Efficiency in Architecture and Planning

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September 2015

Approved by:
Professor Wolfgang Dickhaut
Professor Heba Khalil

(Date) (Signature)

In the name of God, the Compassionate, the Merciful:

"And My success is in the hands of God"

Hud 011 –Verse 88

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DECLARATION OF AUTHORSHIP

To the best of my knowledge I hereby declare that I have written this thesis submitted in part of the fulfillment of the Master of Science degree in Resource Efficiency in Architecture and Planning to the Hafencity University, without any help from others and without the use of documents and aids other than those cited according to established academic citation rules, and that it has not been submitted at any other university for any degree.

(Date) (Signature)

PROLOGUE

The urban growth of Cairo over the last few decades has resulted in a deteriorated and defective urban fabric. Cairo has experienced a tremendous urbanization in the form of informal settlements in the past 5 decades. A recent study showed that more than half of Cairo's built up area is unplanned construction [15] . Complemented by a massive population growth, informal settlements is one of the most environmentally degraded urban areas in Cairo. Those areas have expanded over a huge portion of agriculture land resulting in the loss of valuable production opportunities. Additionally, this unplanned transformation that follows the agricultural basin subdivision resulted in a compact construction pattern that lack open or green spaces.

Urban agriculture is increasingly spreading in towns and cities. Cities has shifted the use of existing parks, vacant lots and building rooftops to urban agriculture practices, in an attempt to serve the enormous demands of urban food supply. Urban Agriculture has been presented in many literature as a resilient strategy that provides multidimensional benefits for urban dwellers. UA has proved to impact food security in urban areas, stimulate local economies through generating jobs, and positively impact the environment through introduced green spaces.

This thesis investigates the urban morphology of one of Cairo's densely populated informal settlement, presenting an attempt to utilize urban agriculture concept as a tool to redefine open spaces, generate income and provide healthy food for the locals through rooftop farming practices. However, the dissemination of rooftop farming in informal areas would require further research due to the lack of strategic guidelines and instruments that could manage and formalize rooftop food production on a district scale.

Keywords: urbanization, informal settlements, open spaces, urban agriculture , rooftop farming, food security, local economies, income generation

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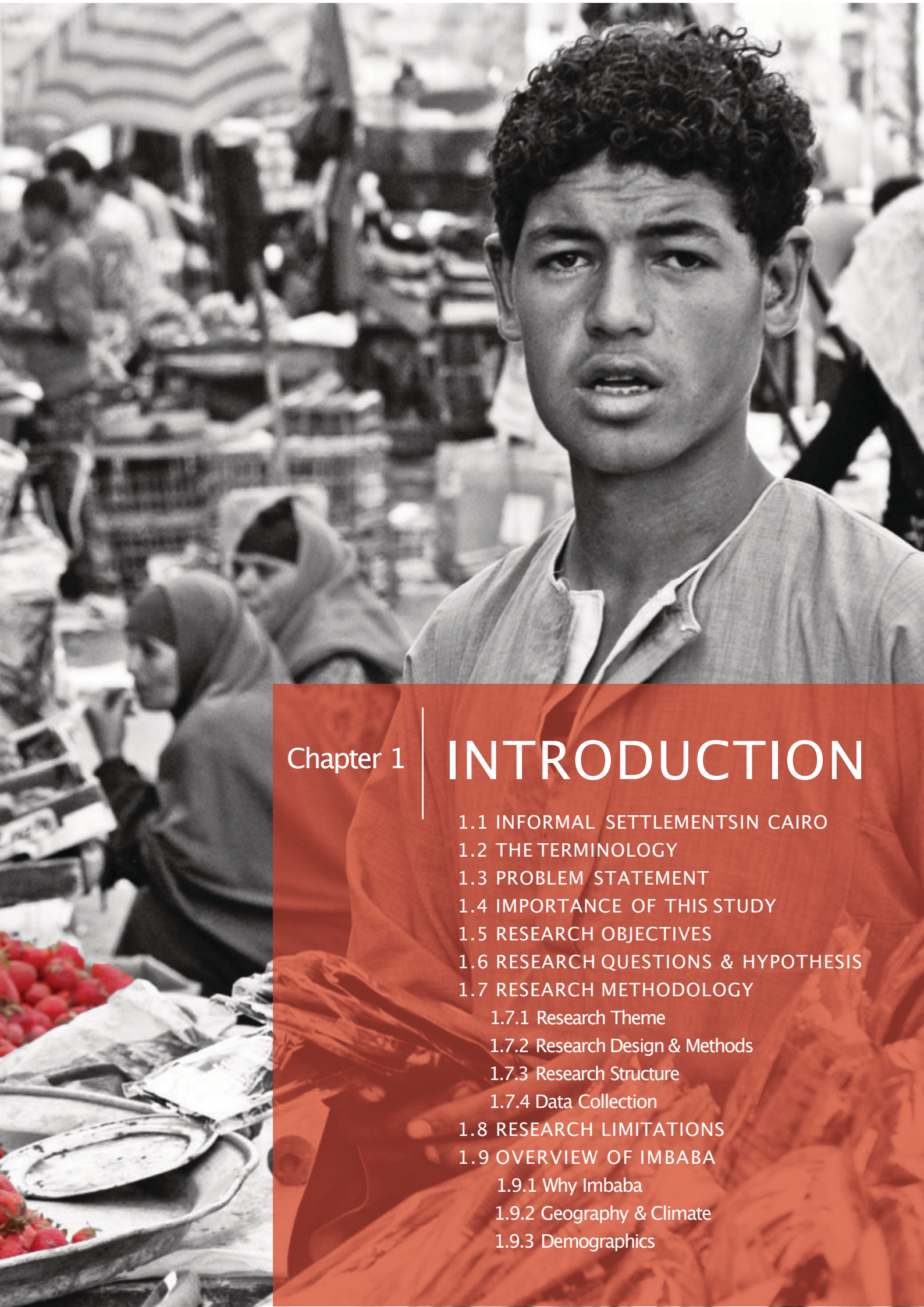
ACRONYMS

5LF	5 Level Framework
AGR	Agricultural Green Roofs
CBO	Community Based Organization
CSA	Community Supported Agriculture
CSR	Coporate Social Responsibility
DE	Diatomaceous Earth
DO	Dissolved Oxygen
FSSD	Framework for Strategic Sustainable Development
GCR	Greater Cairo Region
GHG	Green House Gas
GIZ	Gesellschaft fur Internationale Zusammenarbiet
GOPP	General Organization for Physical Planning
ISDP	Informal Settlements Development Program
ISDF	Informal Settlements Development Fund
LAI	Leaf Area Index
LECA	Light Expanded Clay Aggregate
MBI	Market Based Instrument
MURIS	Ministry or Urban Renewal and Informal Settlements
NFT	Nutrient Film Technique
NGO	Non Governmental Organization
PAH	Polycyclic Aromatic Hydrocarbon
PDP	Participatory Development Program
PI	Persuasive Instrument
PGR	Productive Green Roof
SP	Sustainability Principles
UA	Urban Agriculture
UHI	Urban Heat Island
UUU	Urban Upgrading Unit

.. to all people living in informal settlements.

Souq el Bouhi , Imbaba , Cairo



Chapter 1

INTRODUCTION

1. INTRODUCTION

The demand for housing opportunities is increasing in urban areas. It is expected that the rise of urban population in the whole world will cross 6 billion inhabitant within the coming 40–70 years [82]. The desire and need for immigration to urban areas is more concentrated in the developing nations compared to developed ones [45]. A study conducted in 2008 to comprehend the urbanization behavior through the years 2000–2005 concluded that the total increase in urban population in developed nations is 500,000 inhabitant/month,with a growth rate of 0.54% compared to the developing world, which accounts to an increase of 5 million inhabitant/month with a growth rate of 2.67% [45]. Housing problems escalated more in developing countries as a result of the disability of governments to provide adapting solutions to the rapid increase in the demand. In other cases the solutions are provided, but does not suit the needs. These actions drive immigrants to search for "their" solutions to this problem. With the lack of regulations and guidelines, demands are relatively fulfilled, but not in the formal way.

–Informal growth is the dominating pattern in the urbanization process all over the developing world. It is the way how people supply their needs where their governments fail to do –

" Dr. Heba Khalil –Smart growth & Informal areas"

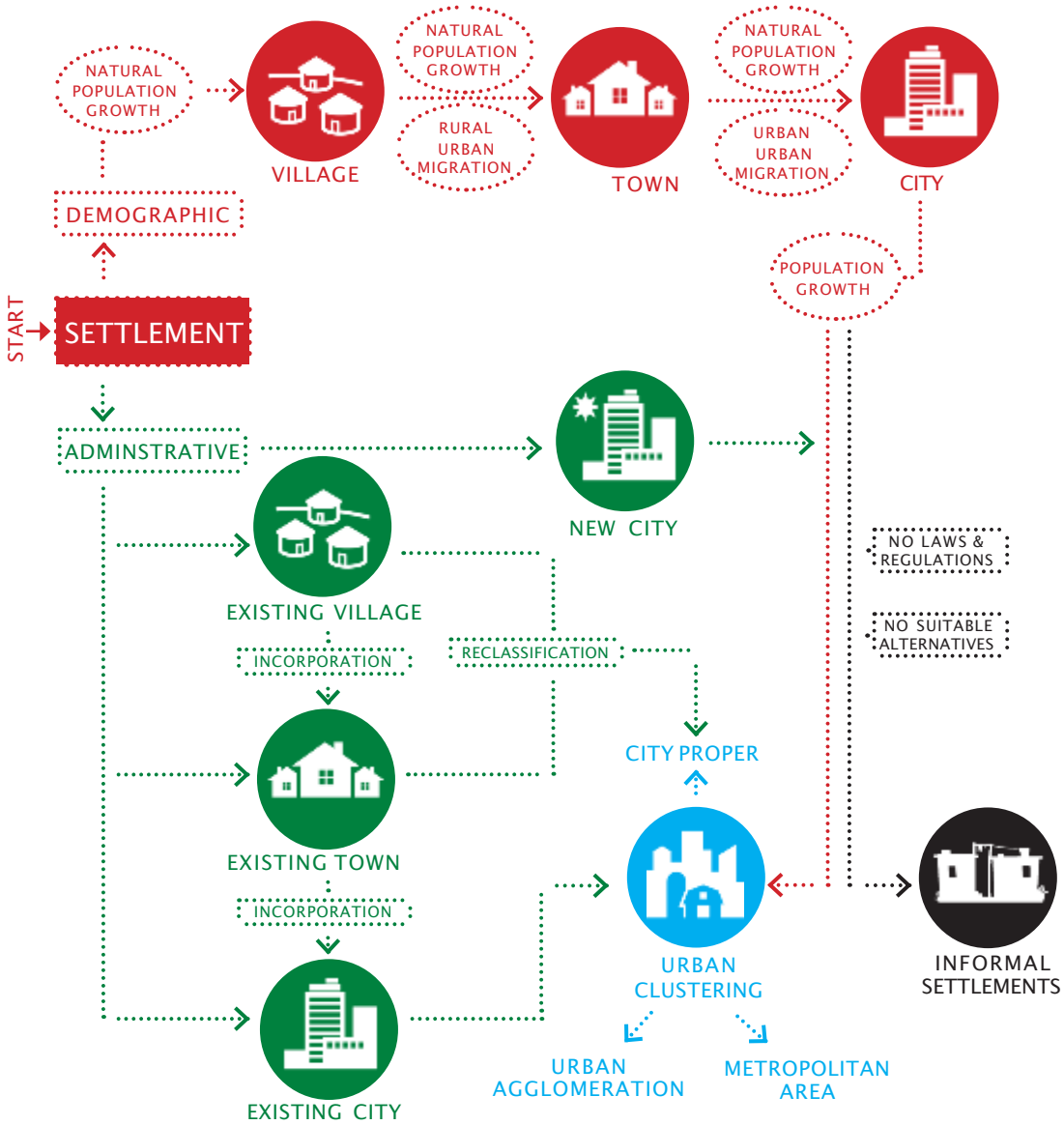


Figure 1:
The different facets of urbanization processes

Authors's presentation inspired by The World Urbanization prospects diagram ,The 2014 revision , United Nations. [83]

1.1. INFORMAL SETTLEMENTS IN CAIRO

Informal settlements are a fast growing phenomenon spreading all over the developing world. In Egypt, urbanization is concentrated heavily in the capital city of Cairo. About 60 % of all migrants leaving rural areas are headed to the capital [14].

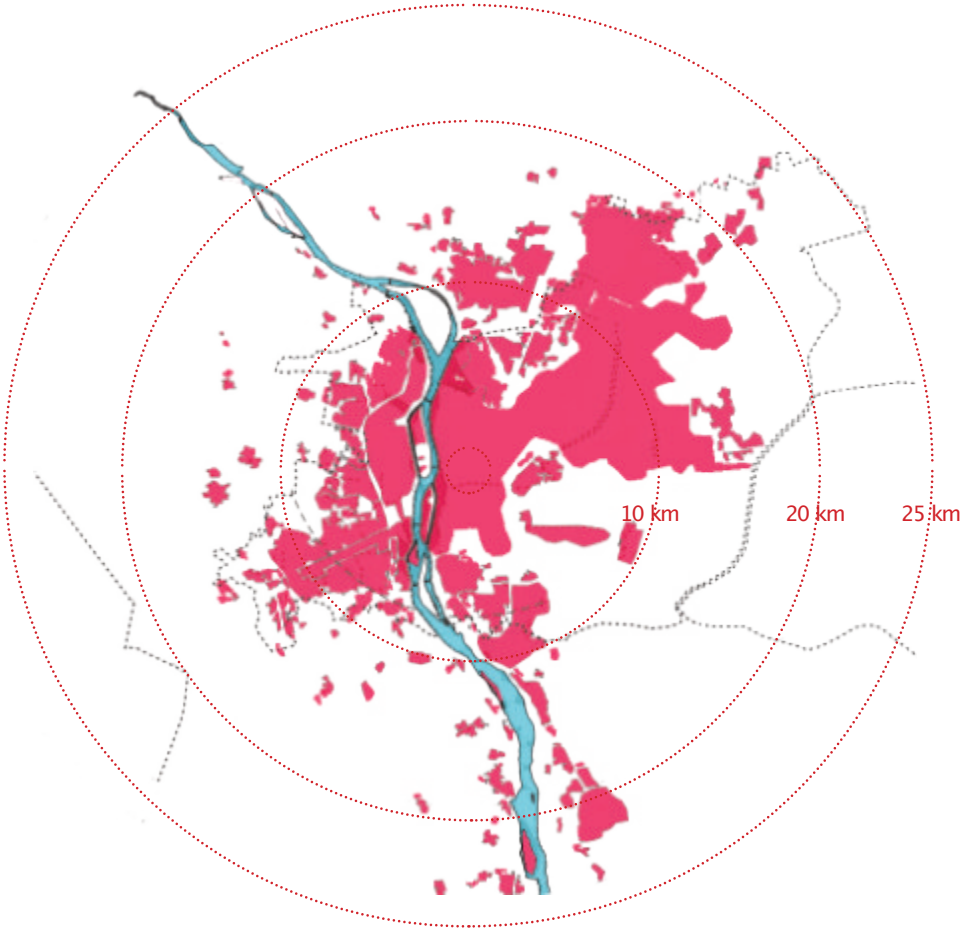


Figure 2:
Schematic map of the Built-up Area of Greater Cairo Region (GCR) in 2012

Authors' presentation Based on maps derived from "The Parallel City" in 2012 by Noheir El Gendy [15]

Migration of individuals from the delta and upper Egypt to Cairo started after the Second World War in search for better jobs and proper living standards, causing housing pressure to become a critical situation [26]. The phenomenon of Cairo's informality started growing in the early 60s as a result of the government's apathy towards the alarming need of housing. In addition, the government was preoccupied with the formation of new socialist zones and prestige heavy industries, ignoring the few unregulated development taking place [15]. Before 1967, the rental control law that froze housing rent to ensure affordability, caused the withdrawal of the private sector from the housing market, resulting –on the long-run– in a deficit in housing stock mainly for lower-income groups [34].

During the period of the war (1967–1973), the government's financial resources was directed to rebuilding the military forces [34], resulting in a long pause in the formal construction sector [15]. However, the informal construction was continuing to grow to serve the continuous need of immigrants, especially the ones evacuated from the Suez Canal zone [15].

In the mid seventies, the government withdrew from the housing market, leaving the stage to the private sector which was only developing new luxury housing for the middle/high income strata [26]. Families with low income have no choice but to build their houses with their available resources. This caused a housing opportunities gap between low and higher income strata, which eventually led to the spread of informal settlements [34] [26].

In the late 70s, and with the obvious increase of informal settlements, the government produced a series of decrees and laws which inhibit the encroachments against what has been recognized as valuable agricultural land, which are converted by new settlers into building plots [15]. With the rising gap between supply and demand and the government neglect and non–effective solutions, informal housing was the only available resort for the low income strata. Until 1986, studies concluded that almost 40 % of urban population lived in informal settlements occupying 62 % of Greater Cairo's area [26]. The population growth in Cairo dropped from 3.1% to 1.8% in the 70s –90s period [15]. During the 90s, Cairo's urbanization started to slow considerably, forming a new pattern of what is called "stabilization", as a result of urbanization of large villages and the vast growth of small towns outside the fringes of Cairo [6], resulting in an obvious decrease in rural–urban migration rates [15].

In the year 1994, the government started to acknowledge the problem and launched the first stage of the "Informal Settlement Development Program" (ISDP) to provide basic urban services (electricity , water , sanitary , road paving) for 325 informal settlements all over Egypt [16]. Those efforts were criticized as "slowly coming" and "substandard" and "different from one place to another" as for example many of the wastewater lines in some areas were installed by the settlers' self efforts [15]. The efforts perceived by the government gave the informal settlement a sense of legalization even though this informal construction activity was lacking land tenure legalization and formalization [34]. It encouraged the phenomenon of agricultural land encroachments since the basic services will be eventually provided [15].

–Informal settlements in Cairo have departed the stage of bieng neglected or margenlized, as they begin to claim for their rights, not just in facilities and services , but also as a part of the city –

"Noheir El Gendy –The parallel City"

A study in 2002 concluded an increase in Cairo's informal areas with an annual rate of 3.4 % and population growth of 3.2% (200,000 person) per year compared to the population growth of formal areas which was only 0.8% [15]. In 2004 the government initiated the second stage of the ISDP program under the name of " Informal Settlements Belting Program", aiming to develop robust efforts for the restriction of growth of informal areas [16].

In October 2008, a part of "El Deweka" informal settlement was buried under a huge rock that slid from Moqatam hill ,resulting in the death of more than 100 tenants. This accident directed the government to establish the "Informal Settlements Development Fund"(ISDF), a new program under a presidential decree #305/2008 [16]. The main goal of this program is to ensure safe housing in Egypt by improving the quality of life of the

residents of unsafe areas [16]. Today it is estimated that more than 60% of Cairo's built up area is informal [1] , accommodating between 12 –17 million inhabitant [34]. The informal areas of Cairo are continuing to grow to absorb the vast increase in population, transforming from a transient phenomenon to a dominant urban fabric.

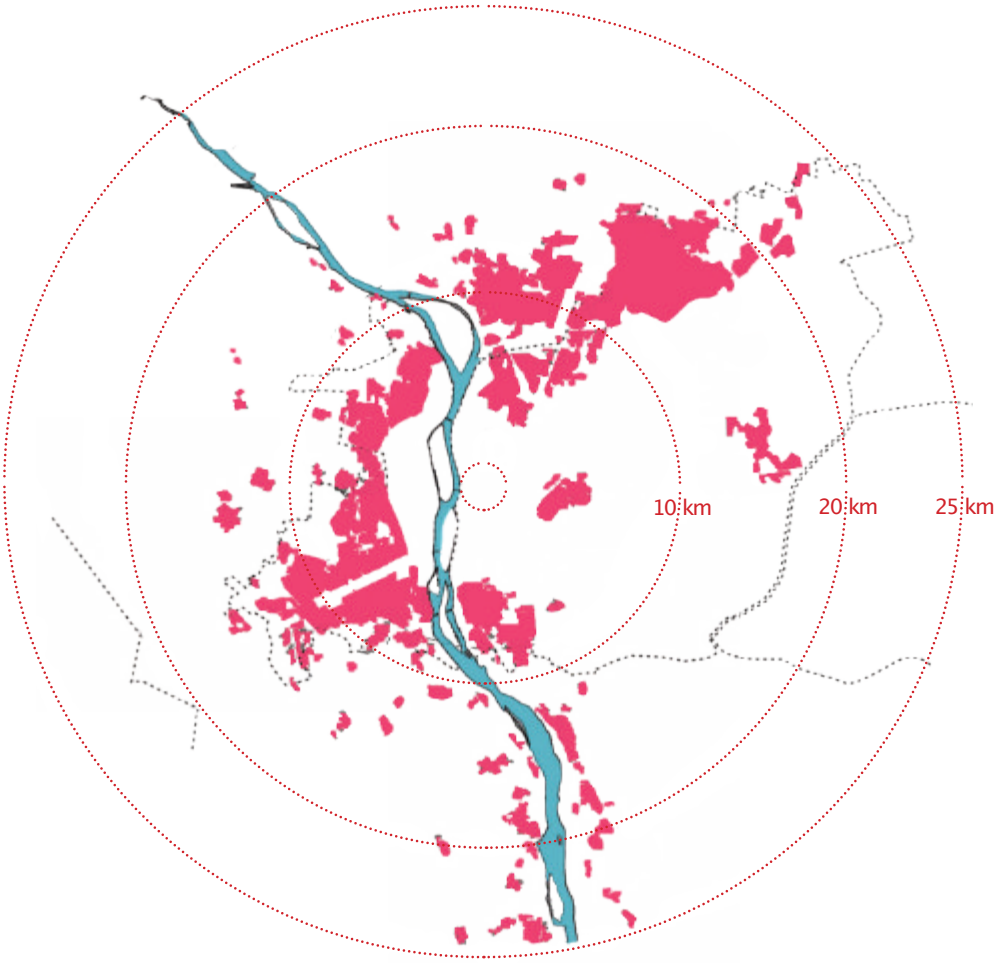


Figure 3:
Schematic map of the informal settlements of Greater Cairo Region (GCR) in 2012

Authors' presentation Based on maps derived from "The Parallel City" in 2012 by Noheir El Gendy [15]

1.2. THE TERMINOLOGY

The term Informal or "Ashwae" refers to a random or a haphazard activity. Informal settlements or "Ashwaeyat" in Egypt is a term used to indicate deteriorated or underserved urban areas [17]. Throughout the evolution of Ashwaeyat in Egypt, the terminology has been differently interpreted to explain this urban heterogeneous phenomenon. Informal does not have to be unpredictable, unprogrammed or unplanned. On the contrary, it could be explained as the suitable activities in some parts of the city which are opposite to the will of the formal authorities [15].

A common misperception always connect the definition of "informal" to the "Third world slums"–shantytowns, hutments or bidonvilles which are very rarely found in Cairo's informal areas [27] [15] [66]. A state of relative "inner formality" following a mechanism of certain norms and codes could

be tracked and analyzed in the what so called "informal" areas, thus the generalized definition of informality is not particularly accurate.

After the Deweka accident, the planning regulations in Egypt produced a unified law (#119/2008) concerning all the terms and definitions related to planning and urban development [17]. This law stated that the term "Ashwaeyat" or informal settlements is no longer used by the law and has been replaced by either "unplanned" or "unsafe" [17]. Unplanned areas representing 60 % of urban areas while unsafe represents only 5% [16]. A general description of informal settlements in Cairo are illegally built up areas, violating one or more laws regarding land use, construction and land subdivision [14] [45].

Although informal settlements or Ashwaeyat are often stigmatized and surrounded by many myths describing it as the "negative" or "undesired" part of the city, it is growing extensively to be the norm not the exception [15]. Calling it informal or not does not overlook the potential of growth of this entity ,which represents an obviously recognized sect of the Egyptian urban fabric.

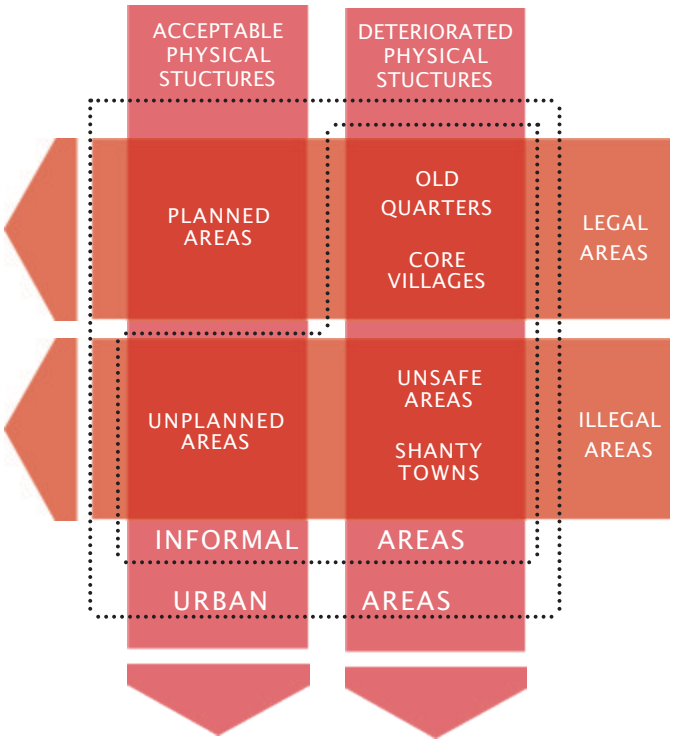


Figure 4: Classifications of The Urban Areas and The Informal Areas of Cairo

Authors' presentation based on the diagram retrieved from "Improving Informal Areas in Cairo" by GIZ [28]

1.3. PROBLEM STATEMENT

Informal settlements are covering more than half of Cairo's urban area [26]. Almost 12 million inhabitants which represents 70 % of Cairo's population live in so called informal areas [27]. The failure of the government to provide suitable, affordable and viable housing opportunities for middle–low income strata is the substantial reason behind this phenomenon to spread. This resulted in an illegal or semi illegal housing systems built on private or public land [27]. Another reason is the leniency of the law

in dealing with violators [14], encouraging them to build their desired settlements without thinking about the repercussions.

The most common type of informal settlements is the one built on privately owned agricultural lands, which represents 83% of all informal areas of Cairo [15], covering almost half of the total residential areas in Greater Cairo [73]. They are illegal not because of land squatting, since they are privately owned, but because of the violation of different laws regulating land use, land subdivision, sale of lots and construction[14].

This phenomenon started in the 60s when agricultural land owners started selling their relatively small plots to individual house builders [73]. These plots were previously inherited and fragmented into smaller plots following the Islamic law of inheritance [65]. They were sold when the stage was reached that the plot of agricultural land was too small for the owner's self catering [65].

–Informal housing is not 'backward' or opposed to modernity as many have come to believe. Nor does it house unproductive members of society. Rather, it is a creation of productive members of society when the formal sector cannot or does not provide housing for them. –

"Shawn ODonnell –Are Ashwaeyyat really a problem"

The main reason encouraging the investment in agricultural land tenure is the property ownership, which is considered a source of security and a cultural tradition in the Egyptian heritage [14]. The location of the informal settlement which is usually near an employment area and the availability of water which is a key factor for livability are the reasons behind the formation of this type of settlements on agricultural land [14]. This type serves a wide range of demography which are not only the urban poor , but middle class educated families, public sector employees, artisans, workshop owners, doctors and lawyers [58] [15] [27] .

This type of informal settlements is characterized by very narrow long streets, regular block shapes according to the agricultural basin subdivision ,units with constant depth, different street frontage and heights depending on the affordability of the owner [1]. Apart from some inner pockets in some remote areas, the overall construction quality of this type of informal settlements are reasonably good [15] [27].

The governmental lack of sufficient investments in upgrading or extending networks and maintaining public facilities accumulated lots of challenges regarding both physical infrastructure and social services. Adding to that the overburden of the existing utilities as a result of population growth. These utilities include water & sewage systems, electricity, transportation, garbage disposal, accessibility, public/open spaces, health, employment and education [1] [27] [15] [26] [17] [60] .

Urbanization and extreme population densities negatively affect the environment by causing pollution and the modification of the local climate of the city [70] [60] [71].The lack of urban planning and the high density of construction in informal settlements of Cairo is resulting in an increased Urban Heat Island (UHI) effect [71].

Green spaces are very limited all over Cairo, rarely located in the formal neighborhoods and almost absent in informal areas [71].Urban green spaces are considered the respiratory lung of a city. They reduces

the high rates of air pollution –normally existing in cities –through the vegetation trapping of carbon, dust and smoke particulates [35]. Moreover, they promotes biodiversity and provide a linkage between rural and urban areas [36]. They also encourage economical growth and investments by increasing surroundingland and property value [22]. Nevertheless, they have many benefits for human health ,providing recreational areas for sports activities thus reducing obesity, stress, rates of airborne diseases and asthmas [36] [35].

With the lack of urban planning and the ability to construct on the total area of land with no minimum setback requirements or open spaces regulations, informal settlements are facing a considerable matter of scarceness of green areas and open spaces.

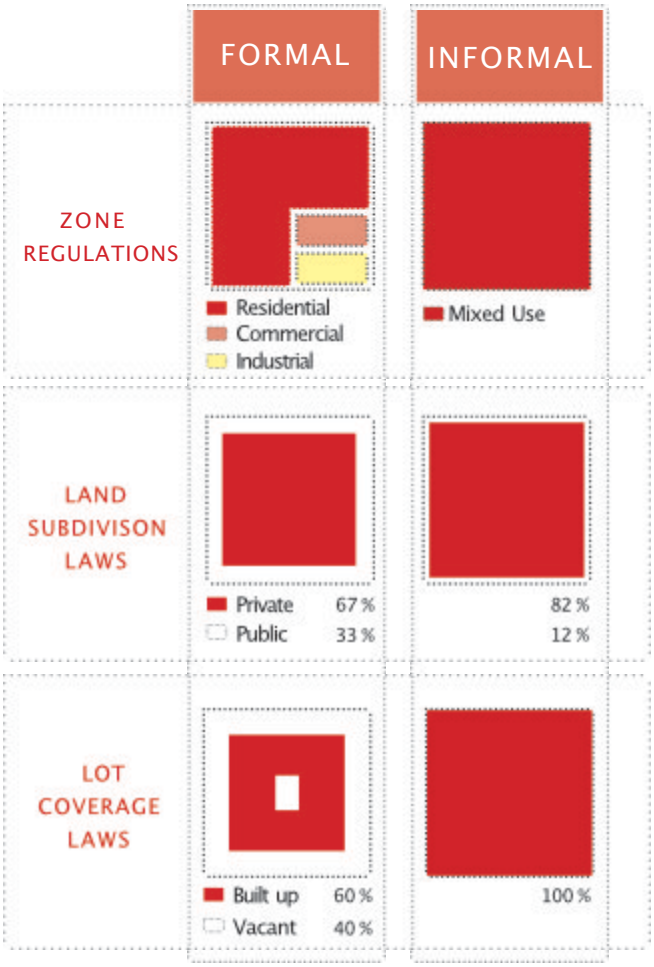


Figure 5:
Formal Vs. Informal Building Standards

Authors' presentation based on a study Retrieved from "Urban–ization of Agricultural land" by: Mahmoud El Sioufi [14]

The effect of climate change on poorly designed urban areas and the insufficient open spaces affect the health conditions of the tenants of informal areas. A study on the impacts of climate change on household health conditions in 4 informal settlements in Cairo concluded the deterioration of existing health problems, particularly rates of arthritis ,asthma ,skin rashes ,cold and fever [67]. This study pointed out that the most vulnerable group affected are always little children ,elderly people ,tenants living in top floor apartments and people working outdoors in the sun [67].

Food insecurity is one of urbanization's negative impacts affecting the Greater Cairo Region (GCR) [2]. The constructionof more residential areas on agricultural land reduced the productivity of the agricultural sector, while the vast growth of population increased the demand for food [90]. The reliance on the supply chain that convey food items from rural areas is another reason especially with the shortage and rising prices of gas that makes it difficult to satisfy the needs for the transportation sector [90].

There is a significant correlation between income poverty and poor access to food [86]. Although the highest poverty rates remains in rural upper Egypt, significant levels of poverty and food insecurity are increasing in urban areas (40% between 2009–2011) [86], which are affected by the fluctuations in food prices and the food supply chain more than rural areas [90].

The constraints within which informal areas grow, their location on agricultural land or in unsafe geographical areas, the entrepreneurial initial subdivision, and the ex post facto introduction of infrastructure have all led to several major shortcomings in the quality of life for those living there

"GIZ –About Cairo & its Informal areas "

GCR has a larger population of poor (3.8 million) compared to the poor areas of Upper Egypt [86]. The rising rates of poverty in urban areas forces households to cope with strategies that have a negative impact on nutritional values, relying more on less expensive calorie–dense food [86]. Inspite of the countries' self sufficiency of fruits and vegetables, they registered large increase in the prices (139% and 102% respectively) during the period of 2004–2008 [23]. As a result, very low quantities of fruits and vegetables were consumed by the low income groups in comparison to higher income ones [23] [86]. The results of malnutrition in the poor areas are higher rates of obesity ,stunting and anemia in children [86].

The spread and overpopulation of informal settlements, which are suffering from disparate patterns of poverty complemented by environmentally threatening conditions calls for prompt actions that requires addressing it as a priority focus in the future sustainable development plans of Cairo's urban structure.

This study concentrates on the challenges facing Cairo's informal settlements, investigating some of the problems that exacerbated in the past decades ,specifically lack of green spaces, food security, unemployment as well as the environmental challenges resulting from urbanization and the formation of those areas.

1.4. IMPORTANCE OF THIS STUDY

Covering more than 60% of Cairo's overall built up areas [1] and accommodating between 12–17 million inhabitant [34], Informal settlements have shifted from being an exceptional phenomenon to the normal trend [15]. This requires developing resilient strategies that ensure its adaptation with the contemporary changes especially that informal settlements are no longer serving only the urban poor, but various demographic layers of the Egyptian society

1.5. RESEARCH OBJECTIVES

The main objective of this research is to study and analyze the urban morphology of informal settlements, addressing the problems and investigating smart and sustainable strategies that can mitigate the environmental, social and economic challenges facing it.

Imbaba was chosen for this study as one of the oldest informal settlements in Cairo with population crossing 1 million inhabitant, covering an area of 1930 acres [65]. The extremely high urban density of Imbaba oriented this research to study and analyze the building typologies with respect to the structural properties and the materials used in construction. This study also covers a streets hierarchy study which includes an analysis of the quantity and quality of open spaces and green areas.

This research explores green roofs technologies through presenting the basic components of the different available systems. In addition, it focuses on rooftop agriculture; a strategy that can provide multi–layered solutions for urban areas affected by food insecurity, lack of green/open spaces, unemployment and poverty. Furthermore, it could provide a mitigation solution for some environmental challenges like UHI effect, GHG emissions and minimizing water losses through stormwater management or the reusing of treated greywater. Additionally, rooftop agriculture can promote social integration between families through interaction and knowledge exchange.

This research intends to find a retrofitted green roof system that integrate roof top agriculture with the urban context of Imbaba. The expected impacts could be multidimensional, connected together under the umbrella of improving the livelihood of the tenants. It could also serve as a guide for diversified stakeholders working in the informal settlements' development sector and aiming to disseminate the concept.

Research Objectives

The presented research objectives help to narrow down the topics that need to be investigated

1.6. RESEARCH QUESTIONS & HYPOTHESIS

The hypothesis of this study states that the continuous encroachments on agriculture land due to the rapid expansion of informal areas and the lack of green/open spaces is threatening the environmental quality and affecting food availability ,quality and prices. This study will investigate the ability of rooftop agriculture to mitigate these problems.

Main Research Question

Is rooftop farming a suitable solution to mitigate the transformation in the urban morphology of informal settlements which is suffering from deterioration of open space, environmental challenges and poverty? how can rooftop agriculture in informal settlements provide a mutual benefit between the tenants and the environment? What are the main obstacles

facing the development of open space in informal settlements?

Green Roofs Technologies

1 –Which green roof technologies can be the mostbeneficial and fits–in terms of technical aspects–in the context of Imbaba to achieve a sustainable development? (load bearing –structural system –wind uplift – waterproofing –irrigation–drainage..etc)

2–What are the differences between the technologies that works for agricultural practices & the one used for aesthetic and amenity practices ? (substrate depth–extra elements –maintenance..etc)

Retrofitting Rooftop farming to Imbaba

3–How would people of Imbaba react to the concept of rooftop farming ? Is agricultural background an importantaspect for acceptance of such concept? Is financial profit from selling the crops the main stimulating element for the success of this concept? what are other stimulating elements that could drive the people to work for the success of this concept?

4–Is there any similar rooftop farming projects in other informal settlements in Cairo? to what extentare they successful(if they are)? what are the dimensioning parameters of the systems used in those projects ? who implemented/ financed those project? what are the aspects taken in consideration to assure the ongoing maintenance and the sustainability of the system? how are those projects marketed to spread the awareness of such system?

5–How can we transfer success stories of rooftop farming from other countries to the informal settlementsof Cairo (Imbaba) although the systems,conditions and needs might differ? what are the constraints/ obstacles that might limit this transfer?

Productive Green Roofs for Informal Settlements

6–To what extent can we introduce the concept of Productive Green roofs (PGR) for informal settlementswith new parameters which not only provide the normal benefits of conventional green roofs, but also promote the value of food security, job opportunities and economical benefits in the developing countries ?

7–To what extent can the produce of PGRs competes with the ground agricultural produce in termsof Quantity/ Quality ?

8–What are the challenges, obstacles and limitations that can face the implementation? to what extent can it be accepted by the community, the local authorities and the private sector?

9–How can PGRs be institutionalizedto provide a legal framework as well as a sustainable guide for governmentsand developers to facilitate its management and the crops produced?

Research Question & Hypothesis

The hypothesis and research questions help further define the type of information needed to investigate the focus topic

1.7. RESEARCH METHODOLOGY

This part of the research investigates the guidelines adopted to create the foundation that holds this study together. The Framework for Strategic Sustainable Development (FSSD) was the chosen theme to guide this project through all its stages. The basic understanding of applying the FSSD is presented and then reflected on the focus of this study. The structure of the research is then developed, followed by exploring the process by which the data was collected.

1.7.1. Research Theme

Our planet consists of different balanced layers that are integrated together in a system of a certain harmony. Since the beginning of the industrial revolution this system has been suffering from increasing pressure of human society [4]. Climate change , pollution and social inequality are harming the capacity to sustain our ways of life [69]. The "funnel paradigm" is a representation of our systems' decreasing capacity to support the increasing society in relation to time. Increasing in population have led to the increase in the demand of resources. Moreover, the declining resources due to improper practices will impose higher threats to our socio–ecological system [69].

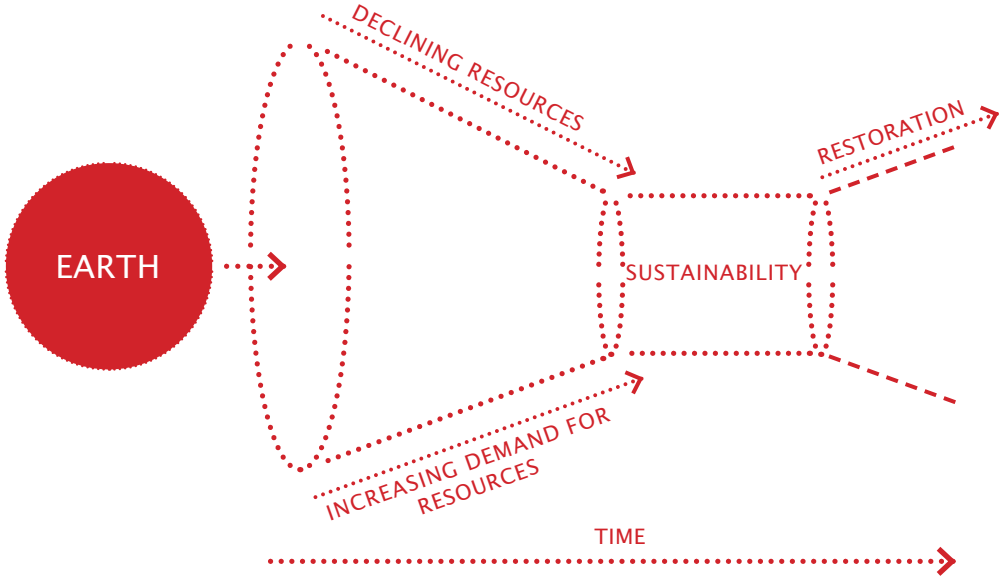


Figure 6:
The Funnel Paradigm Diagram

Author's presentation based on diagram retrieved from "Strategic leadership towards Sustainability" by Joseph Alsford [4]

The Framework for Strategic Sustainable Development (FSSD) is a professionally strict peer reviewed model for managing complexity in planning towards sustainability [69].It is based on a Generic 5 Levels Framework (5LF) which is used in planning any complex system or project [85].

The first level of this framework is the "system", which is the entity or the place which contains the project that exists within the biosphere and its relationships with the global socio–ecological system [85]. The second level is "success", which is simply the conditions that must be met in order

to define a successful outcome of the project, while eliminating any contributionsto violations of Sustainability Principles (SP) [85].The SPs should be taken in consideration as the base of success of the project. It mustbe assured that nature is not subjected to systematically increasing in the :

- Concentration of substances extracted from the Earth's crust.
- Concentration of substances produces by the society.
- Degradation by physical means.

and that People are not subject to conditions that systematically undermine their capacity to meet their needs [85].

–It is important to not get 'captured' by the 5LF or the FSSD. Rather, capture it and put it to use –

"David Waldron–Guidlines for the FSSD"

The third level of the 5LF is "Strategic Guidelines" which are the guidelines followed in order to achieve success (Level 2) in the system(Level 1). It follows the concept of "backcasting" from success level [85]. Backcasting is a planning procedure by which a desired futureis imagined followed by the question: 'What do we need to do today to reach this desired successful futuregoal?' [69].

The fourthlevel are the "Actions" that will follow the guidelines (Level 3) that should help move the project or the system toward success (Level 2) and sustainability [85]. The fifth is the "tools" level, which are the additional techniques, instruments, measurements and management tools that used to guide the actions towards achieving the targeted success and moving the project or system towards sustainability [85].

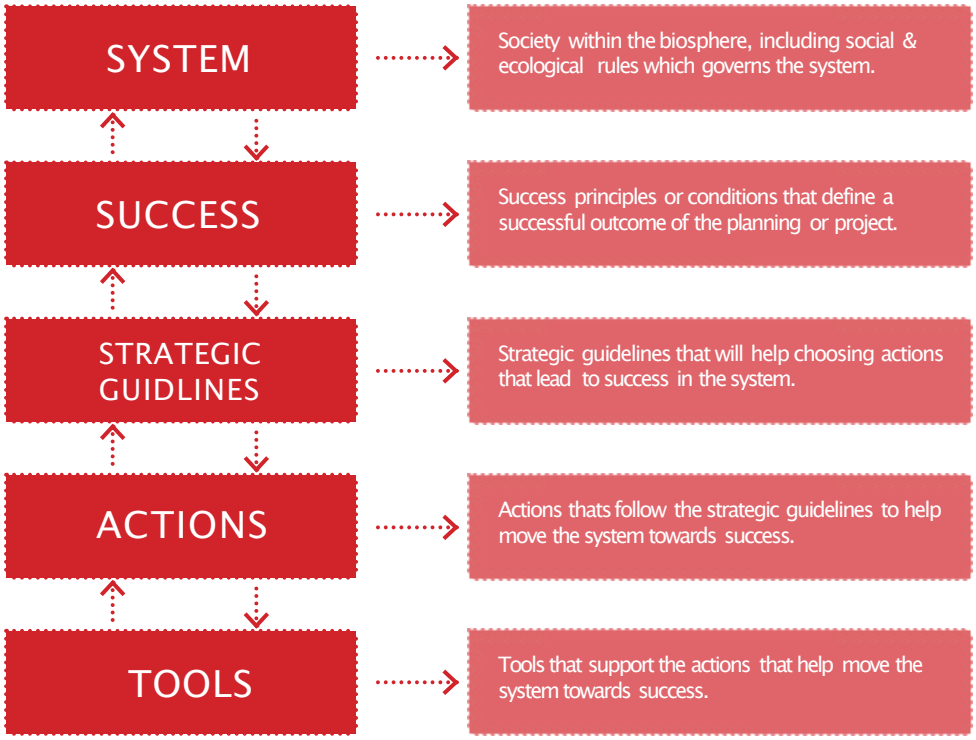


Figure 7:
The Generic 5 levels Framework explaning the Framwork for Strategic Susutainable Development (FSSD)

Authors' presentation based on the data retrieved from "Guidelines for FSSD" by David Waldron [85]

1.7.2. Research Methods & Design

The methodology of this research adopts the 5LF as the guideline to build the structure of the study inorder to have a holistic overview of the project planning. Informal settlements generally and Imbaba specifically represents the system of study. for the convenience of the reader the research methods & design are presented in the following figures.

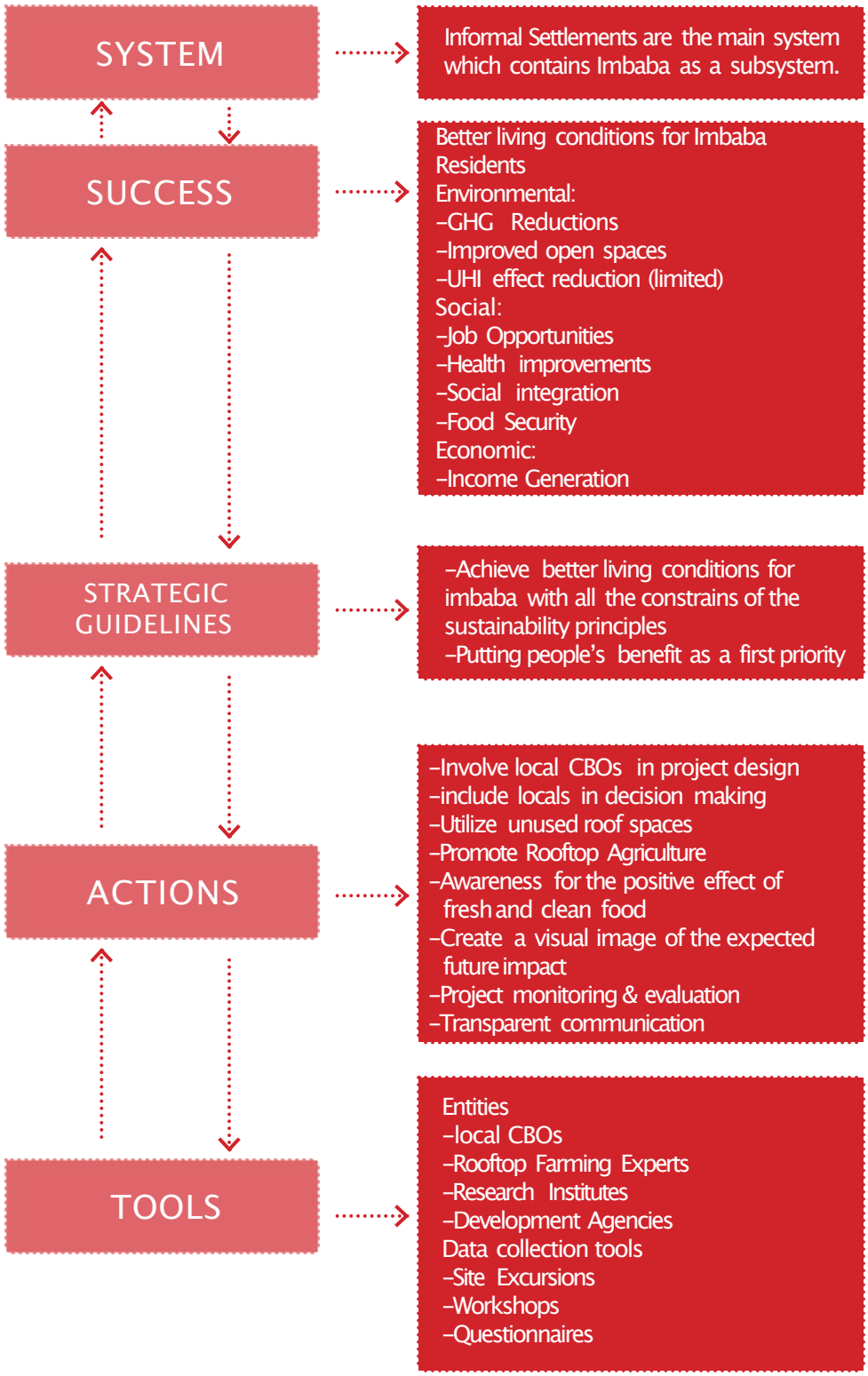
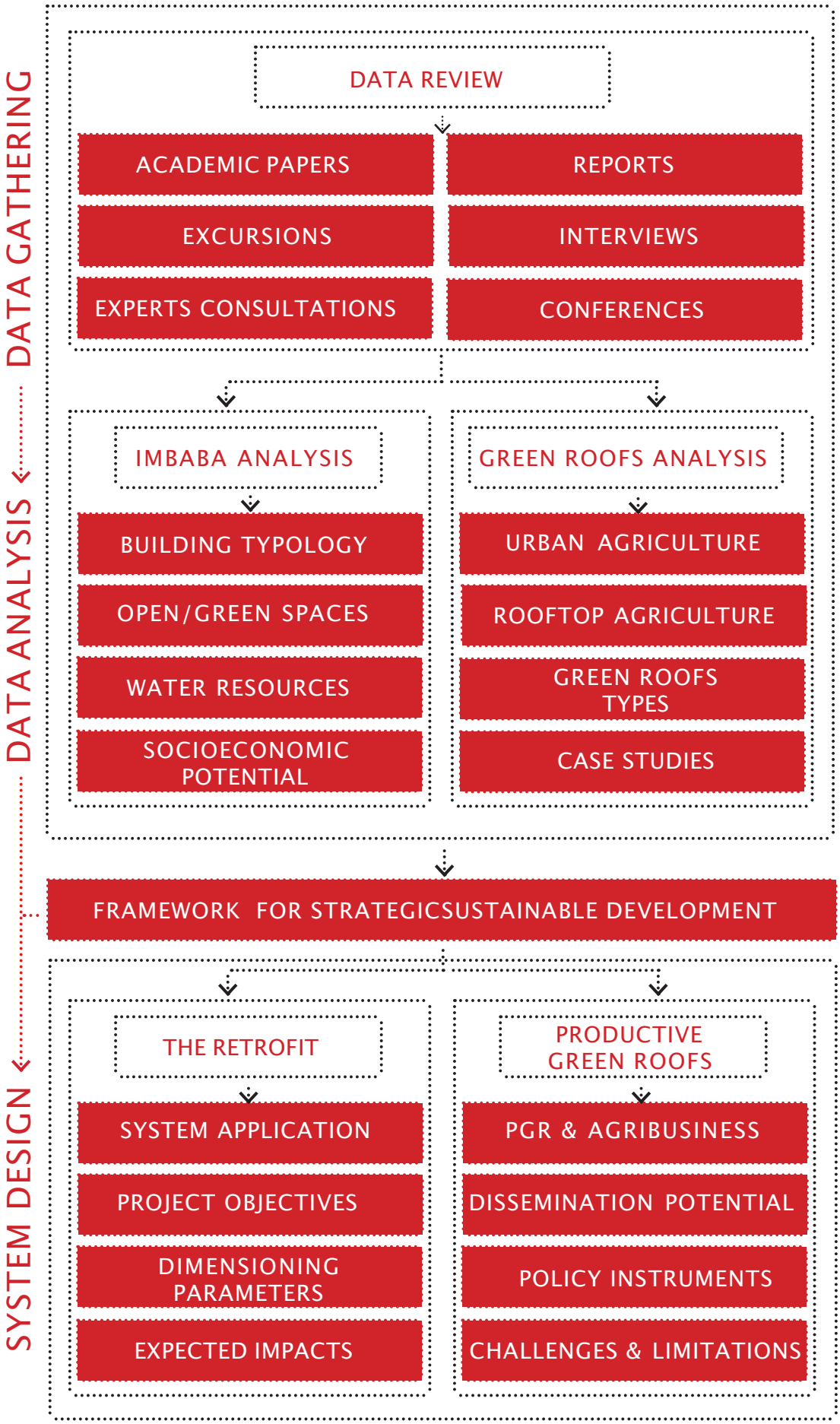


Figure 8:
The Generic 5 levels Framework applied to the research topic

Authors' presentation inspired by the data retrieved from "Guidelines for FSSD" by David Waldron [85]

Figure 9:
The sequence that created the structure of the research

Authors' presentation



1.7.3. Research Structure

This thesis consists of 6 chapters arranged according to a systematic order.

Chapter 1. Includes the previously presented introduction of informal settlementsin Cairo, its history and the main problems facing it. Research question and hypothesis are then presented , followed by the methodology adopted and the research systemdesigned. A general overview of Imbaba is presented to give the reader an overall idea of the focus area.

Chapter 2. Includes a more detailed analysis of Imbaba, covering the building typologies and construction systems, focusing on materials used and building heights. Water resources and its properties are investigated followed by the social and economic conditions of imbaba's residents. This chapter also investigates the streets hierarchy of Imbaba and analyzes of the availability, quality and quantity of open/green space .

Chapter 3. Includes a study of all green roofs systemsincluding geoponic and hydroponic types with a focus on rooftop agriculture and the systems that can adopt it. This is followed by two case studies of rooftop farming in an informal settlementin Cairo and an international case study "Lufa farms" in Montreal ,Canada.

Chapter 4. Representsan integration between chapter 2 and 3, where a retrofit of green roofs is integrated with the context of informal settlements in the formof a project called "Imbaba Farms", adopting the FSSD as a planning guide. This chapter presents the systemapplication, objectives and the parameters of design of this project as well as the expected impacts that this project could present.

Chapter 5. This chapter introduces the concept of Productive Green Roofs for informal settlementsand how it can contribute in terms of quantity and quality to the Agricultural business sector. Moreover, this chapter discuss the strategies applied for the dissemination of this concept as well as the obstacles, challenges and limitations that can face it.

Chapter 6. Is the general conclusion of this study, presenting the main findings of the research and the futureworks that can be suggested.

Research Structure

The sequence of the research structure is designed to ensure the understanding of the presented topics

1.7.4. Data Collection

The data collected for this studywere used to obtain different perspectives from diverse layers of experts in all the related fields of study. The data collected is divided as follows.

Literature Review

The literature reviewed was divided in to 2 sections, literature related generally to Informal settlementsin Cairo and specifically Imbaba, while

the other was related to green roof technologies and urban agriculture, concentrating on rooftop agriculture.

Excursions

Several excursions took place to visualize, comprehend and analyze the ongoing conditions of Imbaba. Excursions allowed for more creditability of the study, as it naturally approached the daily lifestyle of the locals living in the area. This helped avoiding any misleading information and overstatements that could affect the integrity of the study.

Data Collection

The data collected represents the repository for the different study topics of this research

Conferences

Attending the 4th International Green Roof Conference in Istanbul presented by the International Green Roof Association (IGRA) and partners as well as the 1st Egyptian Urban Forum (EUF) in Cairo brought more insight to the research and provided a more comprehensive view of green roofs and its latest technologies as well as Cairo's urbanization and informal settlements.

Experts Consultations

Various experts in the field of Urban Development, Water Management, Environmental Studies, Agriculture and Horticulture in Egypt were consulted for the specific case study of Imbaba.

Interviews

Interviews were done to build upon the data collected previously. The selected interviewees were divided into 3 sections. The first section includes International Development organizations working in development projects in Egypt. The second represents Green Roofs experts working in the field of research as well as specialists working in the horticultural and agribusiness sector in Egypt. The third section represents the public, specifically CommunityBased organizations (CBO) members in Imbaba.

1.8. RESEARCH LIMITATIONS

This research faced some challenges regarding data. The concept of rooftop agriculture in developed countries is still in its infancy. The lack of research in this area prevented this study from overviewing various global point of views and studies that can lighten up the path for this project. The project being in a developing country generally and informal settlements specifically diminished the chances for proper data finding and international parallel success stories. Other challenges like the lack of accurate data regarding the area's carbon footprint or a proper existing analysis of open/green spaces in Imbaba resulted in a weaker argument in some cases, thus affecting the accuracy of the study.

1.9. OVERVIEW OF IMBABA

This section presents a general overview of Imbaba to provide the basic information about the area of focus to the reader.

1.9.1. Why Imbaba

Imbaba is considered one of the famous informal settlementsin Giza governorate, being the eye witness of the early formation of informal settlementsin Egypt generally and Cairo specifically.

The history of informal settlementsin Imbaba started in the early 50s after the launching of a social housing project called "Workers City". This project was executed by the Egyptian government, accommodating 6000 governmental workers and their families in 100 units in a formally planned area of 330 acres [65]. This project was designed to expand in the future but the many small sized land parcels surrounding the project made the expropriation of land a difficult process for the government [65]. It was assumed that the first informal dwelling in this time was built by the construction workers working on the formal part of the project for the reason of its affordability and proximity to work. In the late 70s during the period of the economic boom, mostlyall parcels were occupied allowing only for futurevertical expansion [65].

Today Imbaba is one of the mostdensely populated areas not only in Giza but in all of Egypt [18]. Vertical expansions has reached its limits which led to more encroachment on valuable agricultural lands surroundingit, to keep up with the rapid increase in population and the strongneed for housing [65].With a density ranging around 236 inhabitant/acre, Imbaba is considered a dense hub for displaced people coming from the countryside and Upper Egypt because of its low rents ,affordability and proximityto services [1].

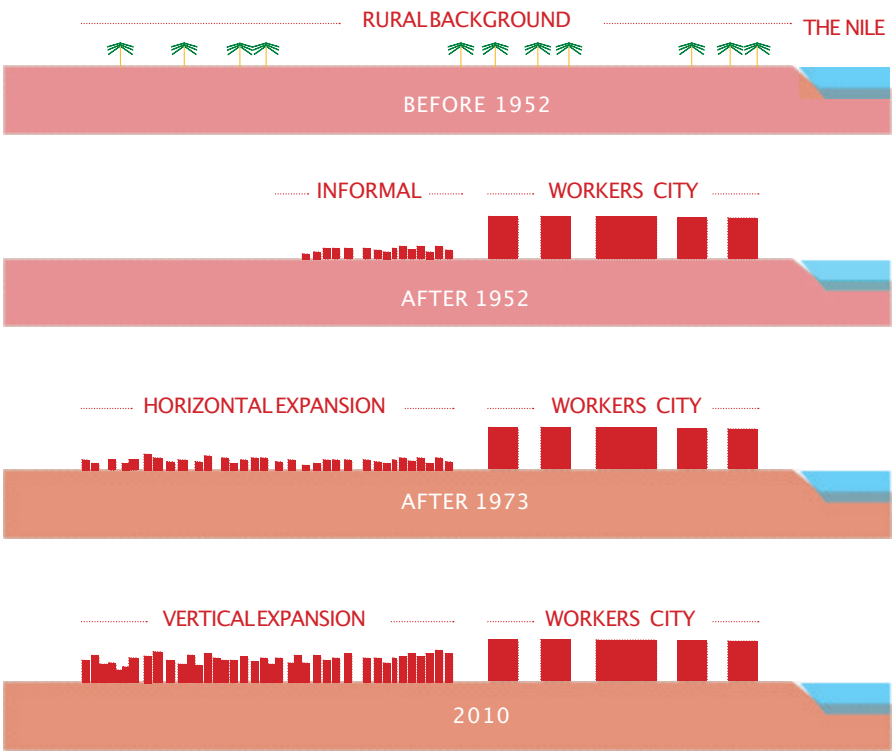


Figure 10: Schematic overview of the Urban Development in Imbaba through time

Author's presentation based on the images retrieved from "Imbaba Analysis" By Basel Studios [65]

1.9.2. Geopraphy & Climate

Imbaba is located in the Northern part of Giza governorate on the West side of the river Nile and the Northwest of downtown Cairo. Imbaba is surrounded by 2 other informal settlements, specifically El Waraa' from the North and Bashtil form the West, while the nearest formal area is Mohandseen located directly in the South

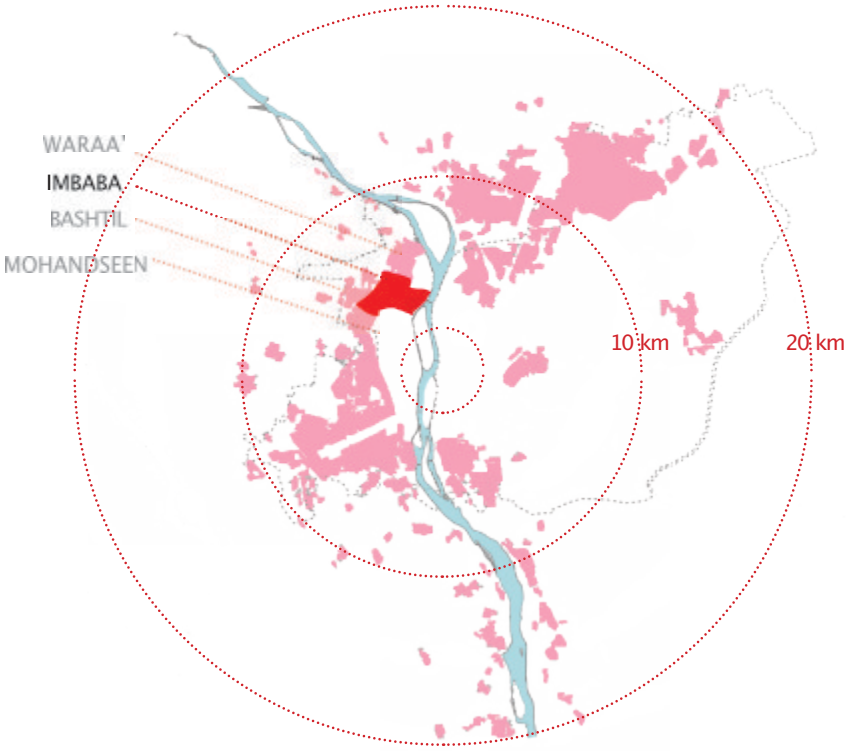


Figure 11: Location of Imbaba in the Greater Cairo Region (GCR)

Author's presentation based on the image derived from "The Parallel City" By Noheir ElGendy [15]

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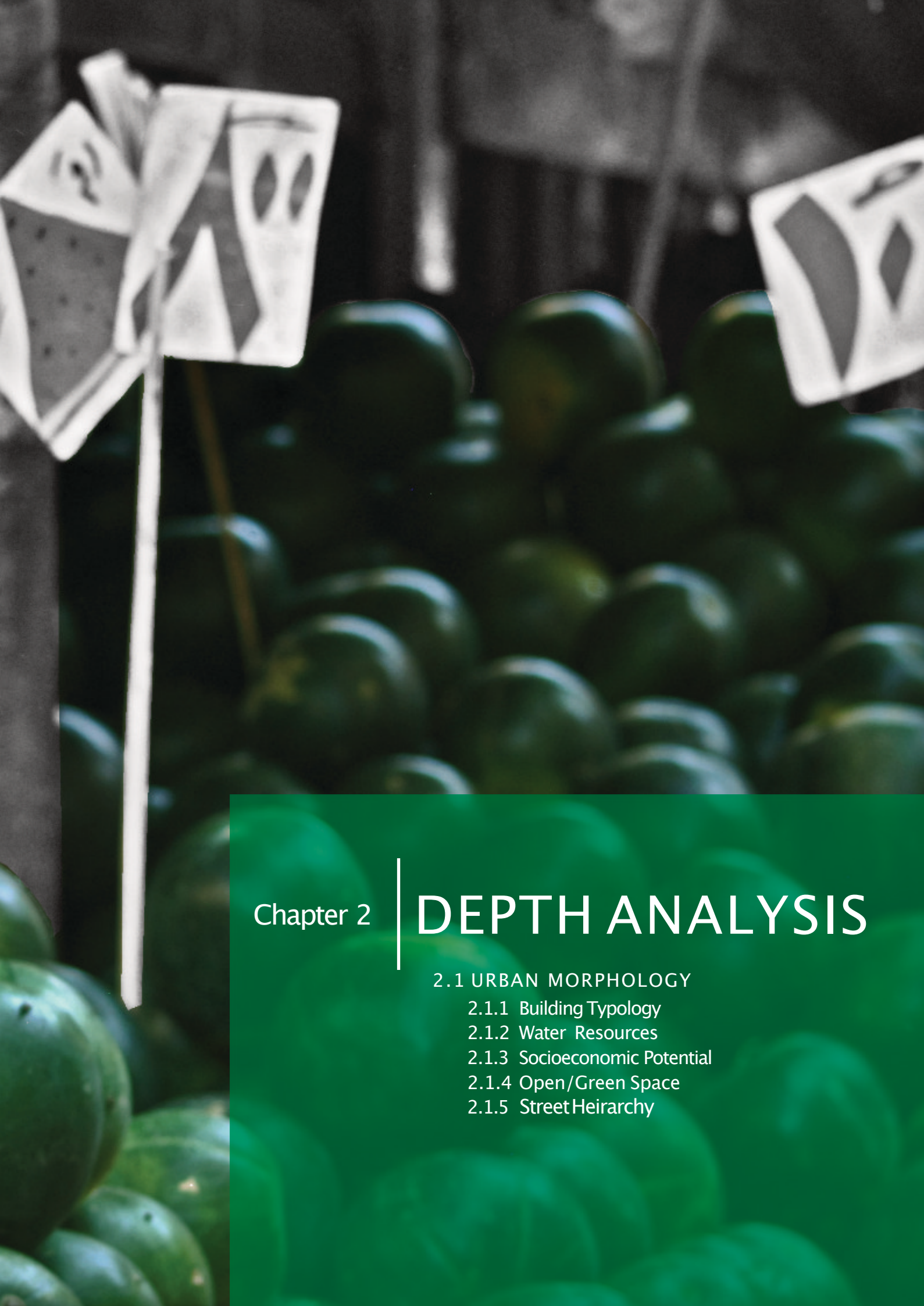
Imbaba is considered to be a part of Greater Cairo Region (GCR). Greater Cairo is in the subtropical climatic region. The weather is characterized by the heat waves that frequently occur in transitional seasons of spring and autumn[70]. In spring, a particularly unpleasant phenomenon is a hot, dry and dust laden "Khamaseen" wind that pass over the desert area [70] . In winter, the climate of the Greater Cairo region is cold, moist and occasionally rainy, while during summer the predominant weather is hot, dry and rainless [70].

The annual average temperature is 21.4 degrees Celsius (70.5 degrees Fahrenheit). Total annual Precipitation averages 26 mm(1 inches), which is equivalent to 26 Liters/m^2(0.64 Gallons/ft^2). On average there are 3451 hours of sunshine per year [11].

1.9.3. Demographics

Imbaba is one of Cairo's largest districts that grew in an informal pattern [1]. In 2010, It was expected to be the home for approximately 1 million inhabitants [65]. Imbaba –as many other informal settlements in Cairo – hosts various layers of the society including middle class educated families , public sector employees ,artisans, workshop owners, doctors and lawyers [27] [15].

Souq el Bouhi , Imbaba , Cairo



Chapter 2

DEPTH ANALYSIS

2. DEPTH ANALYSIS

This chapter presents a detailed analysis for the different urban patterns of Imbaba. The parameters of this analysis includes building typology, the available water resources as well as the socioeconomic potential. The quantity and quality of green and open space existing in Imbaba is also analyzed and presented in this chapter.

2.1. URBAN MORPHOLOGY

As previously explained, Imbaba passed different urban morphological phases during its formation. Agriculture land fragmentation was one of the main reasons that enforced the growth of Imbaba [65]. Like most informal settlements, Imbaba has began its land transformation by substandard commercial subdivision with small dimensional plots, building on the overall area without leaving minimumconstruction setbacks [26]. Nowadays, horizontal expansion is saturated and vertical growth have reached its limits in the old part of Imbaba [65].The urban fabric is very compact ,The small surface areas of the plots result in a tight living spaces that usually contradict the number of inhabitants per family [26]. New nearby agricultural lands are sold to local contractors and traditionally built to meet up with the increasing demand for housing opportunities [65].

2.1.1. Building Typology

Although Imbaba is considered an unplanned area, an analysis presented by the Egyptian General Organization for Physical Planning (GOPP) concluded that 98 % of the constructed buildings in Imbaba are concrete structures(Refer to appendix 1). This construction consists of light weight reinforced concrete frame and local red bricks for the construction of walls [73] [28]. In some areas, older houses were constructed using the walls bearing system [73]. A study investigating the different types of construction of a specific parcel in Imbaba concluded that wall bearing houses represents 58 % of this parcel while skeleton structures represents the other 42 % [18]. This study also shows that 83 % of these houses are in an intermediate structural conditions [18].

Buildings in Imbaba usually has only 1 free facade when normally the other three are attached to neighboring houses [26]. There is 100% plot coverage except for small air shafts or light wells [73]. The majority of the building's free facades are rarely finished or plastered [18].

All the old buildings in Imbaba consists of 4 or less storeys, while some of the new constructions in the last 40 years may reach up to10 levels [18]. Incremental construction is the norm, where houses are not build as an overall structure, but built room by room or floor by floor based on the existing needs [73], [27].

–There is a misconception held by many Egyptian professionals, especially engineers, that informal housing is haphazardly constructed and liable to collapse. Since informal housing is overwhelmingly owner–built without use of formal contractors, it is in the owner's own best interest to ensure that care is taken in construction. –

Noheir El Gendy –The parallel City

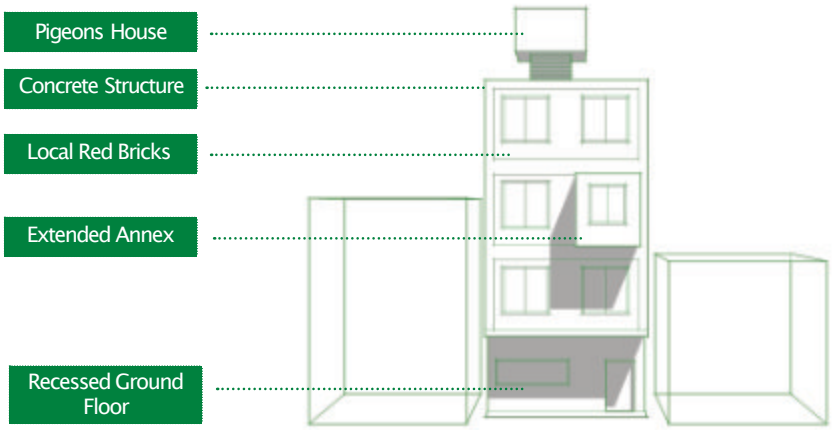


Figure 12: Components of a Typical house unit in Imbaba

Authors Presentation Based on the data derived from "Imbaba Analysis" by studioBasel [65]

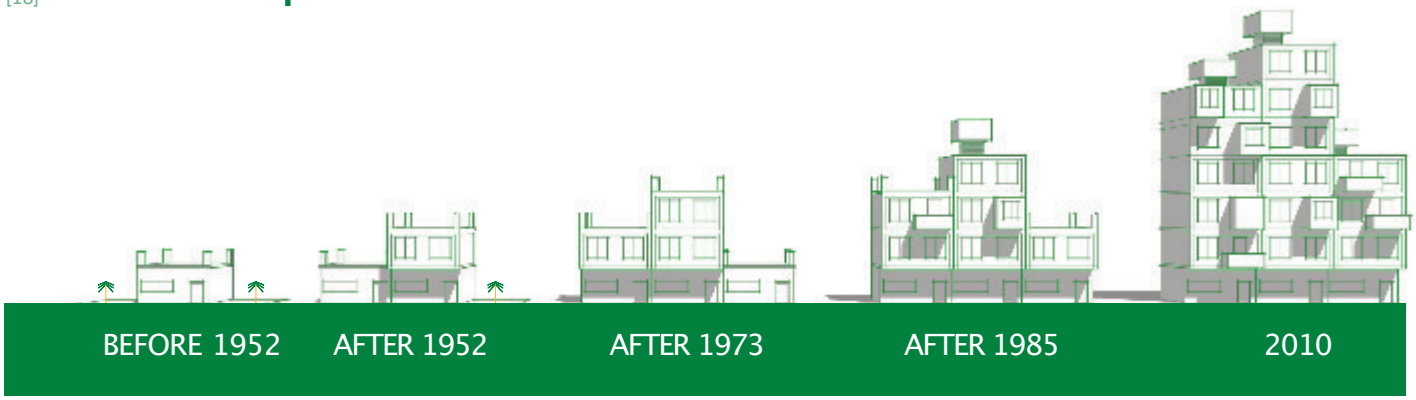
The predominant land use in Imbaba is either pure residential or a residential –commercial mix (refer to Appendix 1). The pure residential type is more concentrated in the inner parcels which is served by narrow streets[18]. In the case of mixed use –which is concentrated in wider streets –the ground floor is usually used as a supermarket, workshop, garment store or a cafeteria.

Rooftops in Imbaba are usually useless spaces. Sometimes tenants use it as a storage facility for their old/unused stuffwhile others throw garbage on top of it. Consequently, those spaces provide a shelter for harmful rodents and insects that could transfer harmful diseases to the living tenants. Some houses tend to raise pigeons on the rooftop by building a tall wooden vertical structurethat can be used as a shelter for pigeons. The existence of a pigeon house on a rooftop presents a sign of wealth of the house owner, as this habit is in many cases perceived as a hobby and not always referred to as a profitable investment[74]. Roofs in Imbaba were previously used in raising poultry and rabbits. However, the spread of Evian flu in the past decade diminished this kind of activity through time. Roofs in Imbaba are basically unused space either owned by the tenant living in the last floor or by the owner of the building. The TV satellite dishes and water tanks in some cases might be the only beneficial use for the roofs.

The common trend of densification of areas overtime created a serious phenomenon of building overcrowding in Imbaba [73]. With the continuous growth of families, it became harder for new families to afford new units, thus the available apartments and rooms become more dense [73]. The inhabitants can only try to extend their living circumstances through small outer annexes [65].

Figure 13: The Incremental Building transformation through time in Imbaba

Author's presentation based on the data derived from "Imbaba Analysis" By Studio Basel & "Ecocitizen World Map Report" [18]



2.1.2. Water Resources

The lack of supply infrastructurelike water and sewage is a major problem facing Imbaba [65]. The rapid increase in population resulted in the overload of existing infrastructurewhich have not been maintained for a longtime [65]. Only formal constructionare legally connected to the water network. In the case of informal areas, the water supply is the responsibility of the owner with the exception of schools and mosques which are often supplied by the government [65].

Due to the poor supply, buildings that are 4 floors and more usually depend on water tanks installed on the rooftops [65]. In mostcases the tenants do not maintain or clean those tanks which resulted in the deterioration of the water quality [18].

The consumptionrates of water in informal areas always depend on the corresponding activities. A study that audited different water uses of a specific parcel in Imbaba concluded that the average water consumption in some householdsreached (and sometimesexceeded) 300 l/inh.*day [18]. The consumptionrate is usually this high because of the added commercial activities to the ground floor, which consume large amounts of water in its daily routine [1]. Adding to that the leakages in the supply water pipes, which contributesto significant water losses [1]. The activities of the ground floor includes washing the entrances of shops, cleaning motorcycles and auto rickshaws (toktoks)as well as daily cleaning of the street and water spraying infront of the shops to reduce the air temperature in hot summerdays.

The previously mentioned study audited the water uses of 15 different residential unitsinside the selected area. it was found out that 75 % of the water flow in all the buildings are consumed in the kitchens and toilets [18].The charts below illustrates the different uses of water for 3 selected houses in the study area.

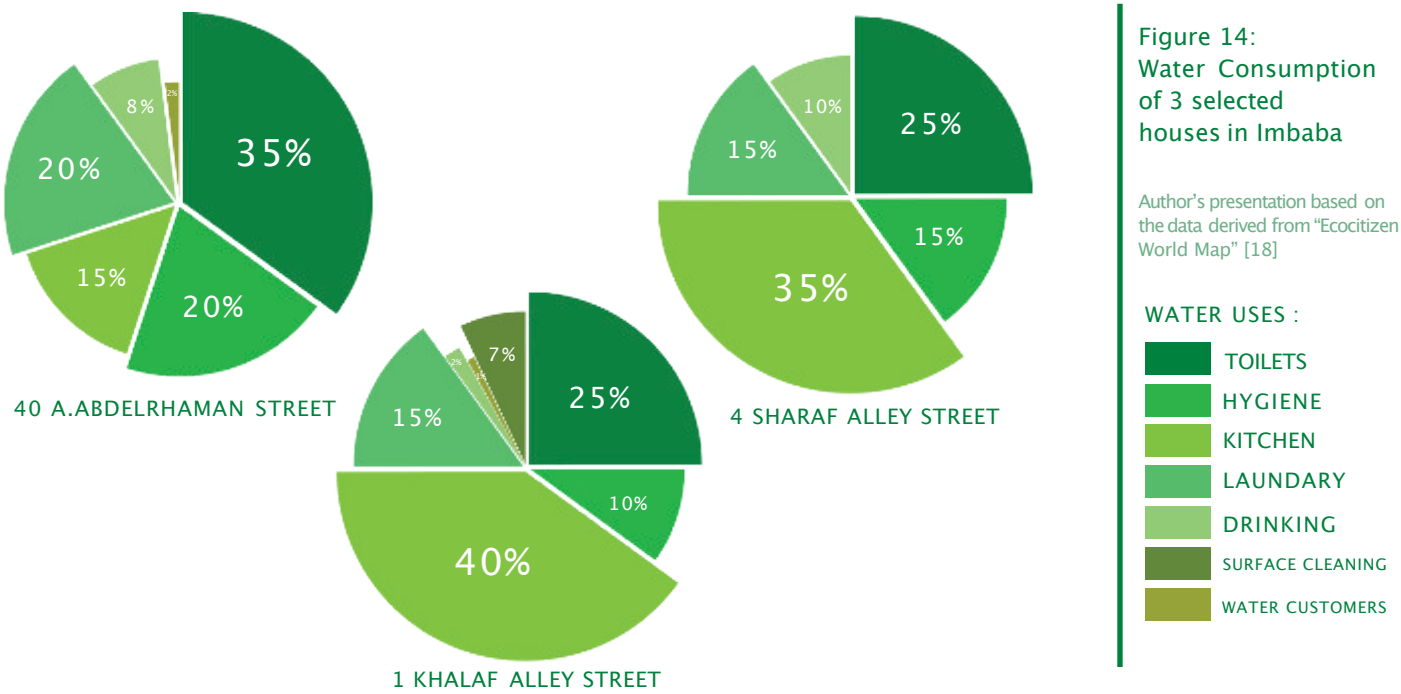


Figure 14: Water Consumption of 3 selected houses in Imbaba

Author's presentation based on the data derived from "Ecocitizen World Map" [18]

This study also investigated the conditions of the existing water systems. It was found out that the old concrete water pipes –which cannot tolerate higher water pressure –were not replaced with plastic ones since the 70s [18]. The low water pressure necessitates the dependence on electric water pumps, which contributes to higher electric bills [1]. In some cases, houses of 3 and more floors suffered from the absence of water pumps which resulted in a poor water flow in the upper floors [18].

Concerning the quality of tap water, tests were done on the samples collected from the units to determine the PH values, as well as the levels of Copper , Phosphate and Iron. It was concluded that ratios of copper were higher than the normal rates due to the usage of old piping systems as well as the deterioration of the cleaning standards of the storage tanks [18]. It was also concluded that the levels of phosphate were higher than normal standards [18] which is a result of building on previous agricultural land that used phosphate as a fertilizer [1]. Moreover, the levels of iron were observed exceeding the WHO limits due to leakages in potable water pipes and its mix with the soil [18].

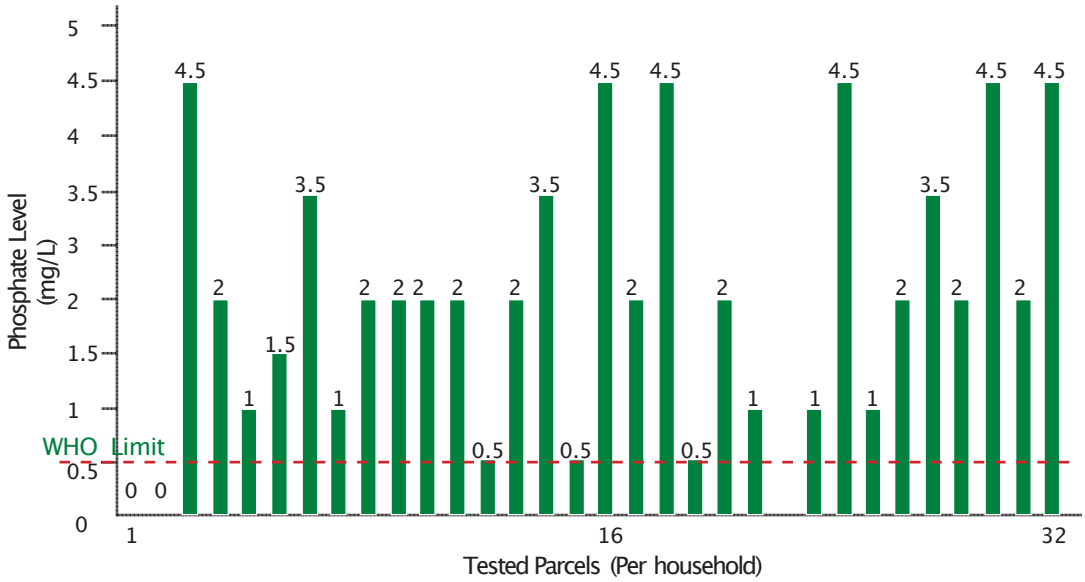
High rate of bacteria coliforms were detected in the samples as a result of leakages that led to the mixing of sewage with potable water, as well as garbage disposal in some of the canals which affected the quality of water [18].

Samples from the water facility and the Nile intake into the station were tested to determine the source of contamination. It was concluded that this sample was of a good quality, which indicates that the water contaminations in Imbaba were caused by the low standard of local piping systems and the high infiltration of both sewage water and contaminated underground water [1].

Although a separation of black and grey water exists in Imbaba, no previous attempts were recorded for the treatment or reuse of grey water. There is no accurate data stating the amount of grey water per household produced in Imbaba. Furthermore, there are no existing legal conditions for the collection, treatment or the reuse of greywater in Cairo.

Figure 15: Phosphate levels in water samples of the tested parcels in Imbaba

Author's presentation based on the data derived from "Ecocitizen World Map" [18]



2.1.3. Socioeconomic Potential

As in many other informal settlements, Imbaba is ruled by Social networks and cultural norms, which are the organizational bases that dictate those rules and the means through which they are enforced.

Imbaba has a heterogeneous demographic profile. It is the home for middle and low economic class and diversified layers of social groups. There is no predominant job field that distinguish the area. The residents could be doctors ,lawyers ,engineers ,judges ,street vendors, shops or kiosk owners, toktok drivers, governmental workers [27] [17] [26].

Regarding economic infrastructure, Imbaba as many other informal settlements is almost self dependent and have a strong internal economic structure although it was build informally or illegally. This is not only in terms of their hidden market investment, but also in terms of their use value for residents by living in such areas [17]. The residents appreciate the fact that the products within a suitable walking distance from their homes and perceive them positively as a source of income for the area residents [27]. Due to the relatively low price of products and services, the Imbaba market attracts other formal neighborhood customers searching for decent prices [27]. In addition, some street vendors searching for higher daily profit use vehicles as a mobile shop to present their products in different locations based on the flow of the targeted pedestrians.

–Informal areas are not a burden. How could this be the case when, in 1997, informal housing was valued at 73 billion dollars? –

"Dina K. Shehayeb –Cairo's Informal areas between Urban Challenges and Hidden Potential"

The rapid increase in housing demand and the continuous encroachments on agricultural land resulted in a lack of basic agricultural knowledge in a wide spectrum of imbaba residents. Agriculture knowledge is limited to the elderly who gained their knowledge either through previous agricultural practices or through there parents and grandparents who used to be farmers. Most of the youth and the new generation have less agricultural knowledge due to the lack of connection to agricultural land and the rapid growth of residential areas, which transformed Imbaba from a productive agricultural center long time ago into a densely populated urban concentration nowadays.

Imbaba is facing lots of challenges regarding health and education. The deterioration of infrastructure especially waste disposal has a strong negative impact on the resident's health [65]. Due to the absence of a governmental waste management plan for some areas, garbage is accumulated for a longtime, transmitting lots of diseases [65]. Quality of water is effected by garbage disposal in water canals [18]. It is also affected by waste water leakage and its mixing with tap water which contributed to an increasing rates of water–based diseases [18].

The number of schools in Imbaba does not match the rapid increase in population [65]. The compact residential areas prevents the establishment of new schools, which result in the overcrowding of existing ones [65]. The area lack other public entities like community centers or sports facilities [65].

2.2. OPEN/GREEN SPACES

Imbaba was built on previous agriculture land. The agricultural basin subdivision of this land formed the regular shapes of the existing housing blocks [45]. The problem is that informal sector usually minimizes the public space in each plot to provide maximumland utilization [14]. As a result, buildings are stacked together from 3 sides with no minimumsetbacks.

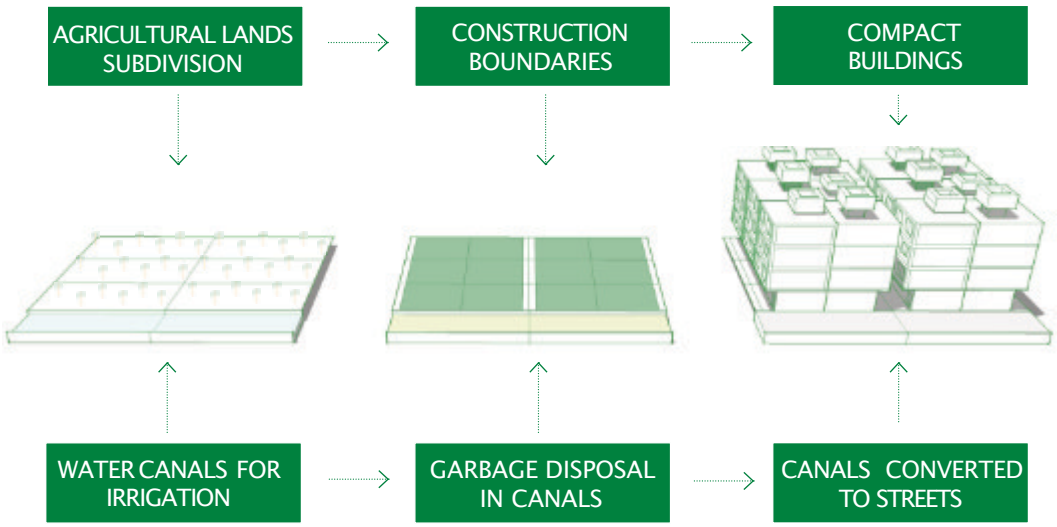


Figure 16: Agricutural land transformation in Imbaba

Author's presentation based on the data derived from "Ecocitizen World Map" [18]

Open spaces in imbaba are limited to streetswith minimumpedestrian walkways as well as the markets(Souq) which are usually created in the collective nodes found in main streets, following the daily pedestrians routes in and out of Imbaba.

A vacant land located west of Imbaba was previously used as a training airport covering an area of 173 acres. This airport was demolished by the Ministry of Housing & Development and planned as a social housing complex overlooking a semi public park [65]. This project is strategically aiming to transformImbaba gradually into a planned district and compensate the lack of open space in its unplanned areas. The official voice of this project is saying that this project's aim is to relocate the underprivileged families living in the dense areas of Imbaba and take over their old houses to be demolished and properly planned. However, until today it is not clear who are the real beneficiaries of this complex and what are the official eligibility criteria that the residents should fulfill in order to benefit from this project [65].

Public space concept for leisure is not one of the strong demands of the residents. They always view parks and green areas as a luxurysetting. Workers city ,which is a planned area in Imbaba, contains adequate open/green spaces which is usually misused or transformed into parking lots and in some cases an extension for houses [65].

2.2.1. Streets Heirarchy

Streets in Imbaba have an irregular pattern. They represent the former irrigation network that used to irrigate the previous agricultural lands [65]. due to the lack of waste facilities, the former locals used to throw their garbage in those canals, forcing the government to fill the polluted ones with sand. It was then converted into a flat open space which by time was transformed in to a homogeneous networks of streets [65].

Based on the excursions that took place in Imbaba, greenery and open spaces are found to be very limited. They are relatively concentrated in wide streets and decreases depending on the width of the street. This means that trees and greenery are almost absent in the inner parcels of Imbaba. Trees and green areas (if existing) are usually maintained by the locals living in that area. Streets in Imbaba are divided into 3 categories narrow streets, typical streets and main streets.

Narrow Streets

Narrow streets ranges from 3 to 6 meters width. The 3 –4 meters ones are usually accessed by pedestrians, bicycles , motorcycles or toktoks but most of them are not easily accessed by cars [65]. Wider access streets ranging from 4 –6 meters allow cars only in 1 direction, which disturb the pedestrian flow especially in dead end streets. This type is the most problematic in terms of open/green space. It is usually dark because of the stacked buildings which prevent the sun from reaching the ground. Consequently, they lack greenery which needs space and light to grow. In terms of social activities, this type is considered a safe street although sometimes street lights are missing. This is because the neighbors almost know everyone around, allowing children to spend time in the street with minimum parental control.

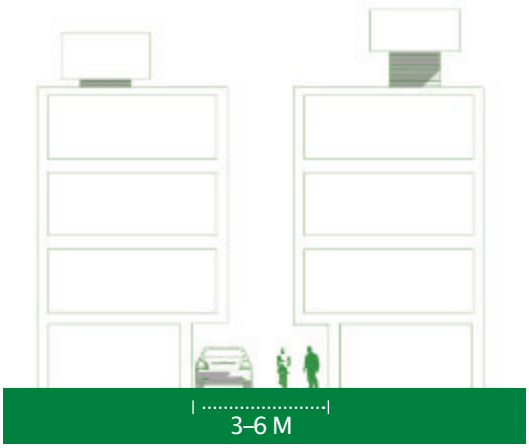


Figure 17: Section through a Narrow street in Imbaba

Author's presentation based on the data derived from "Studio Basel" & site excursions [65]

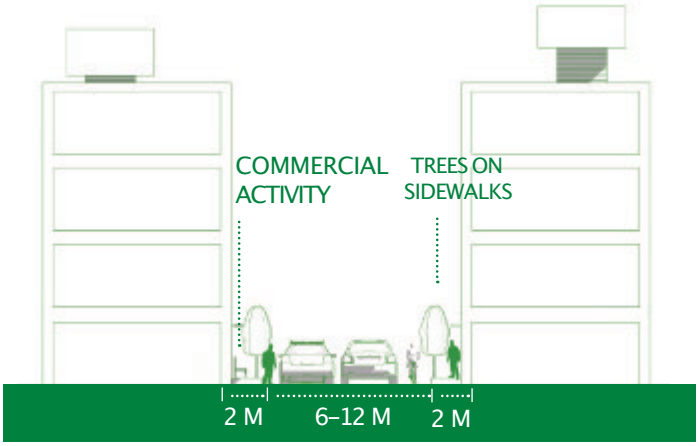
Typical Streets

Typical streets ranges between 6 –12 meters width. They are usually accessed by cars ,toktoks,microbuses and motorcycles. Based on the conditions of the street, sidewalks are usually used as outdoor seating areas for cafes or an extension for garment stores or workshops. This street type usually contains trees on the sidewalks and sometimes planters

or small palm trees. This type serves more pedestrians and vehicles compared to narrow streets. As a result, It is not easy to identify a stranger compared to the narrow streetswhere strangers can be easily identified. In some cases street lights exists based on the location of the street.

Figure 18: Section through a Typical street in Imbaba

Author's presentation based on the data retrieved from "Studio Basel" [65] & site excursions



Main Streets

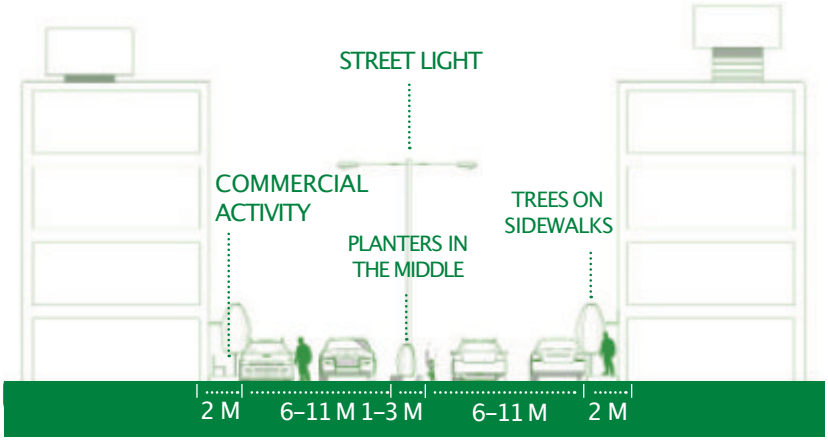
Main streetsranges from 12 to 22 meterswidth. They are accessed by all vehicles including microbuses, buses and mini vans. Some vendors prefer to present their products in popular markets situated in main streets were the flow of people is maximized. This street type usually contains trees on the sidewalks or planters located in the middle isles. Commercial activities situated in this street type usually take over the sidewalks and use it as an extension for their shops. Most of the main streets in Imbaba have proper street lights.

The park executed as a part of the new development project is considered the only decent open/green space in Imbaba. This park contains considerable amount of green areas, water features as well as catering services for food and snacks. However, this park is gated and could only be accessed throughpurchasing a 20 EGP entrance ticket per person. Although this park is a promising project in terms of green/ open spaces, the relatively high entrance fees is a burden on low income families struggling to maintain their basic needs.

Generally, streetsof Imbaba need more development. The lack of open spaces especially in narrow streetsis a challenge that need to be addressed.

Figure 19: Section through a Main street in Imbaba

Author's presentation based on the data derived from "Studio Basel" [65] & site excursions



GREEN SPACE
OPEN SPACE

Figure 20:
A Narrow (3-4m) street in Imbaba

Image & Editing are Courtest of the Author. The infograph is a visual representation of the authors analysis for the visited streets. it does not reflect specific percentages

- No greenery
- Pedestrians , bikes , toktoks & motorcycles
- No street lights

GREEN SPACE
OPEN SPACE

Figure 21:
A Narrow (4-6m) street in Imbaba

Image & Editing are Courtest of the Author. The infograph is a visual representation of the authors analysis for the visited streets. it does not reflect specific percentages

- Rare greenery
- Pedestrians, bikes,Toktoks ,Motorcycles & cars
- Improvised street lights

Figure 22:
A typical street
(6-8 m) in Imbaba

Image & Editing are Courtest of the Author. The infograph is a visual representation of the authors analysis for the visited streets. it does not reflect specific percentages

- Trees on sidewalks
- Sidewalks used by commerical activities
- No street lights

GREEN SPACE
OPEN SPACE

Figure 23:
A typical street
(8-12m) in Imbaba

Image & Editing are Courtest of the Author. The infograph is a visual representation of the authors analysis for the visited streets. it does not reflect specific percentages

- Trees on sidewalks
- Sidewalks used for commerical activities
- Pedestrians, bikes,Toktoks ,Motorcycles & cars
- Street lights

GREEN SPACE
OPEN SPACE

Figure 24:
A main street
(12-22m) in Imbaba

Image & Editing are Courtest of the Author. The infograph is a visual representation of the authors analysis for the visited streets. it does not reflect specific percentages

•Trees& planters on sidewalks & in the middle

• Pedestrians, bikes,Toktoks ,Motorcycles, cars, buses, minivans

• Street lights

• Sidewalks used for commerical activities

GREEN SPACE

OPEN SPACE

Figure 25:
A main street
(12-22m) in Imbaba

Image & Editing are Courtest of the Author. The infograph is a visual representation of the authors analysis for the visited streets. it does not reflect specific percentages

• Trees& planters on sidewalks & in the middle

• Pedestrians, bikes,Toktoks ,Motorcycles, cars, buses, minivans

• Street lights

• Sidewalks used for commerical activities

GREEN SPACE

OPEN SPACE

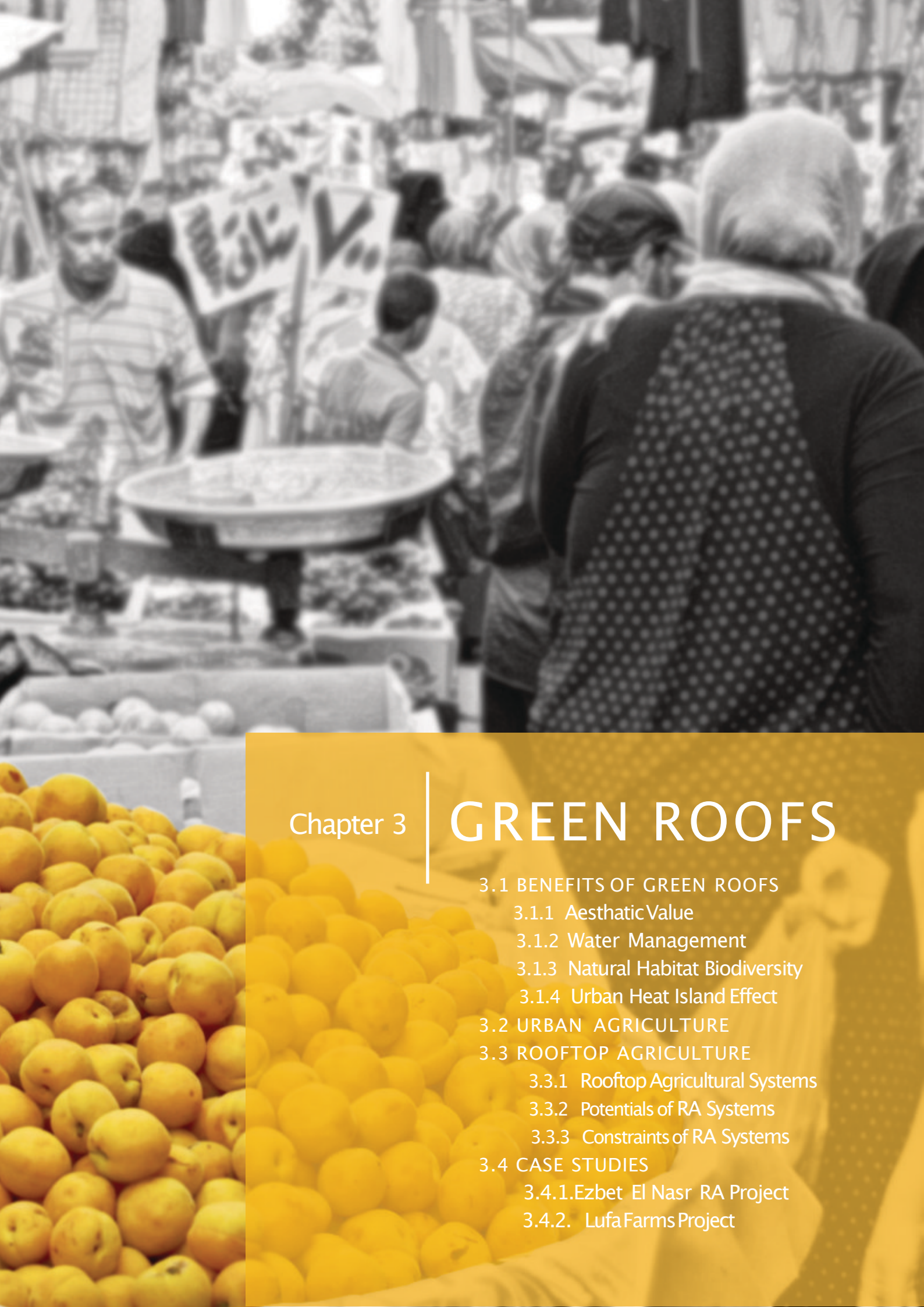
Figure 26:
Giza Park in Imbaba:
a project excuted
on a part of the
previous airport land

Image & Editing are Courtest of the Author. The infograph is a visual representation of the authors analysis for the visited streets. it does not reflect specific percentages

- Gated & entrance fees
- Water features
- Services facilities

GREEN SPACE
OPEN SPACE

Souq el Bouhi , Imbaba , Cairo



Chapter 3

GREEN ROOFS

3. GREEN ROOFS

A green roof, i.e., a roof with a vegetative cover, is a passive technique that can be used to address environmental issues in an urban setting [47]. The word 'roof' refers to any continuous surface designed for the protection of inhabitants whether open or closed from the sides [77]. Rooftops are one of the most underutilized spaces in modern cities which make up between 15 to 35% of an urban footprint[69]. Green roofs are considered a useful alternative that provides other greening solutions within a cost perspective of how to optimize land utilization as a response to rapid urbanization and increasing building densities in cities [48].

3.1. BENEFITS OF GREEN ROOFS

Green Roofs represents opportunities for significant social, economic and environmental benefits, particularly in cities [5]. Research has shown that green roofs can be used to mitigate problems associated with stormwater runoff, Urban Heat Island effect, wildlife habitat, urban food security, air & water quality [5] [91] [47] [50] [59]. Green roofs also have the potential to improve the thermal performance of buildings through shading, insulation, evapotranspiration and thermal mass, thus reducing the energy demand for space conditioning [49]. In the majority of cities around the world, rooftops covers thousands of acres of unused spaces. These unused spaces could be transformedinto resourceful areas. Moreover, they can be used to alter the visual and spatial quality of urban, commercial and industrial landscapes [29].

> Green Roof technologies not only provide the owners of buildings with a proven return on investment, but also represent opportunities for significant social, economic and environmental benefits, particularly in cities.
>
> sabinah Frueh –IGRA Public Relations

3.1.1. Aesthetic Value

Green roofs provide a very pleasant view for overlooking buildings especially in densely urban areas where the roof view is often grey concrete slabs combined with mechanical equipments[77]. A well designed green roof can grant a favorable view, which have a positive direct effect on health. Green roofs creates a pleasing space out of an area which is usually neglected or misused.

3.1.2. Water Management

Water management is a very significant benefit of green roofs. Roofs account for up to 50% of the impermeable surfaces in many urban areas [77]. A well designed green roof can reduce water run–offby50 –90% [91]. Stormwater retention achieved with permeable surfaces and vegetation result in a gradual run–offwhich eventually decrease strains on sewers and reduce downstream flood risks[59]. Green roofs also decreases stormwater contamination as a result of the less direct runoff and the absorption of pollutants by vegetation [77].

3.1.3. Natural Habitat Biodiversity

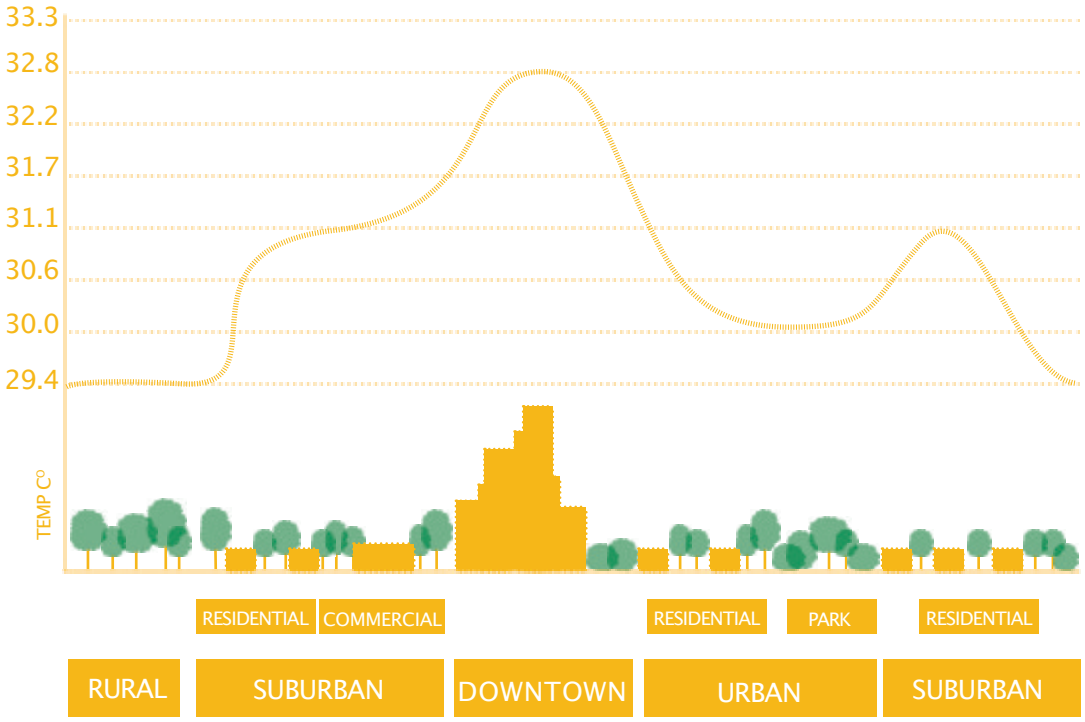
Green roofs provides a natural habitat for wildlife which brings nature back into the cities. The level of biodiversity usually depends on the type of vegetation used [77]. Natural vegetation provides a habitat for resident and migratory birds and insects [77].

3.1.4. Reduce Urban Heat Island effect

Urban heat Island effect (UHI) is described as the difference in temperature between densely populated cities and the surrounding countryside. Cities are generally hotter than the countryside because of the lack of vegetated areas, the large number of builtup structures with heat production properties and the insufficient natural cooling resulting from high buildings that usually block the wind [77]. Vegetation –whether on ground or roof–can have a cooling effect by decreasing some of the city heat through the process of evapotranspiration, were plant materials absorb heat and produce oxygen, resulting in lower ambient temperatures [59].

Figure 27:
Urban Heat Island Effect

Authors presentation based on the image retrieved from "Rooftop Agriculutre Policy" by Lucy Price [62]



Green roofs could enhance acoustical properties of the buildings through sound absorption. They could reduce reflective sound by up to 3 dB and improve sound insulation by up to 8 dB [91]. They could also extend the roof life through the protection of the roof layers. This will eventually save heating/cooling energy costs and increase the economic value of the building [77]. Green roofs provide another benefit of food production through rooftop agriculture, which will be elaborated in the next sections.

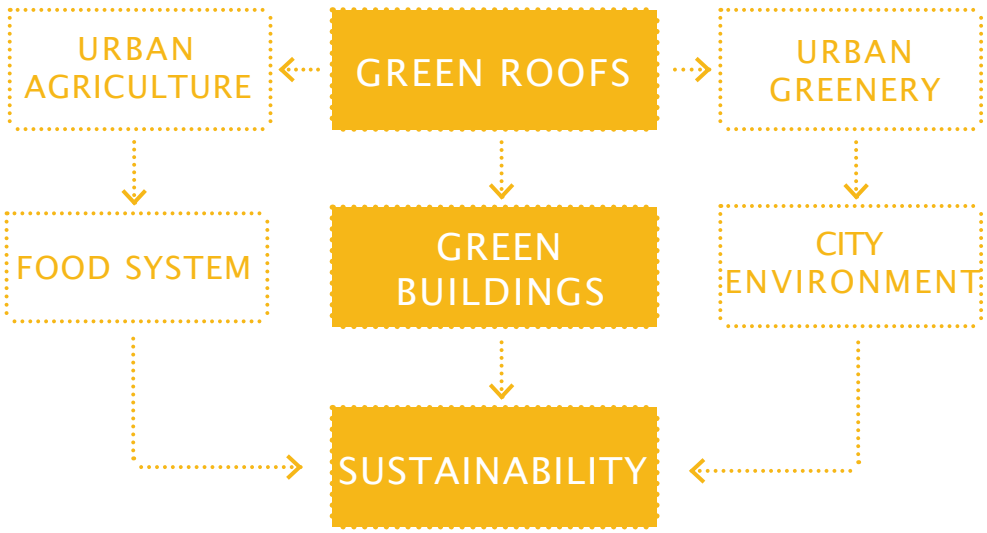


Figure 28: Contribution of Green Roofs to the sustainability of the urban environment

Authors presentation based on the diagram retrieved from "Greenroof urban farming" by Sam Hui [37]

Although Green roofs technologies seems very promising, there are some barriers and challenges facing it. The problems are presented in the following figure.

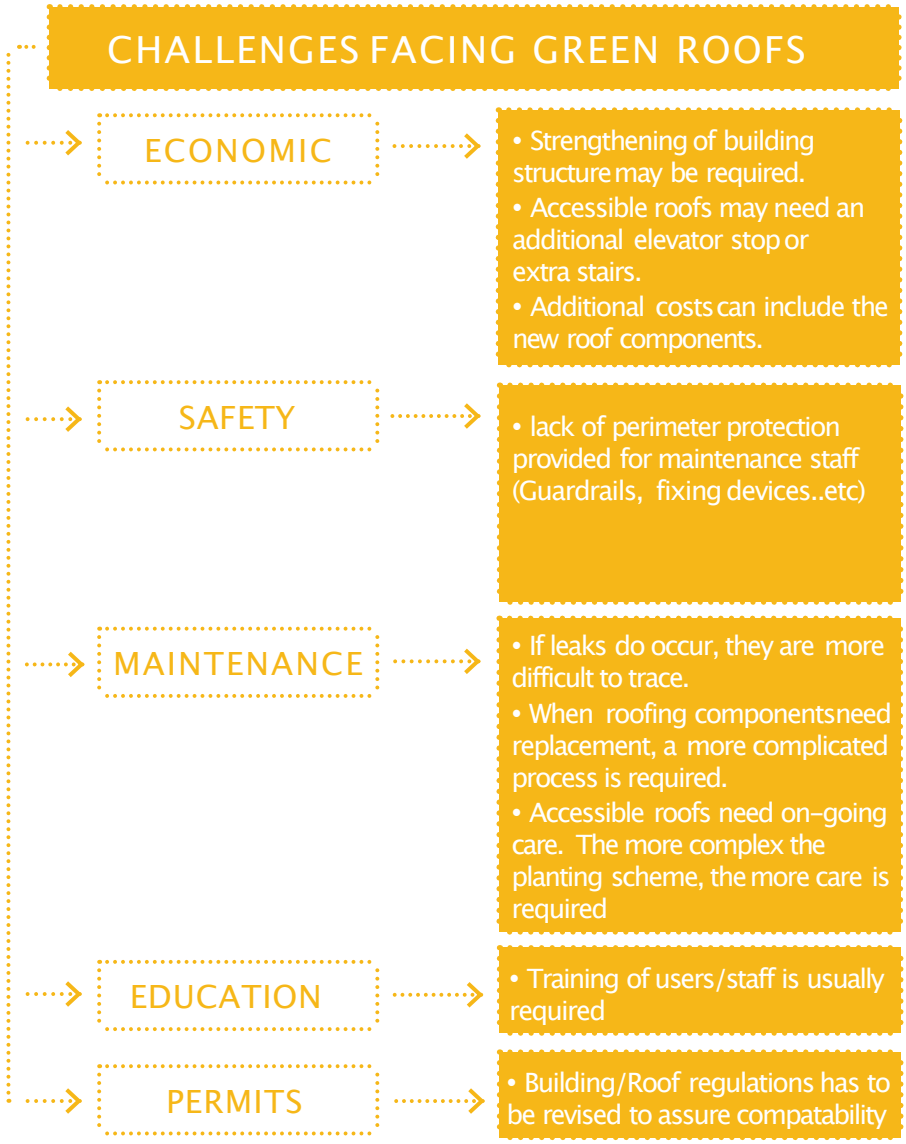


Figure 29: Challenges facing Green Roofs

Authors presentation based on the data retrieved from "Manual for Greening Roofs" by Cornelia Oberlander [59]

3.2. URBAN AGRICULTURE

Nowadays, cities in the world are facing problems of Urban Heat Island (UHI), the lack of green spaces and food insecurity [37]. Many cities has almost driven out agricultural practices from their boundaries [57]. Food has to drive hundreds of kilometers from field to table, consuming lots of energy in transportation, which usually result in a non fresh produce treated with unknown types and percentages of pesticides and preservatives that diminish its health value [33] [57]. Studies shows that a 5 –10 days transportation & storage lag between production and consumption leads to losses of 30 –50% of some of the food's nutritional constituents [7].

As cities are growing in a fast rate, new approaches that aim to deliver healthy, fresh and local food are evolved. Attention to urban agriculture practices has increased internationally in the last couple of decades.

–To grow your own food gives you a sort of power and it gives you dignity. You know exactly what you're eating because you grew it. It's good, it's nourishing and you did this for yourself, your family and your community–

" Karen Washington –Growing Food in Cities "

Urban agriculture (UA) refers to growing edible plants and/or raising of animals for food within and around cities and towns [51] [84]. One major challenge that faces the viability of urban agriculture is land availability and access [75]. In some cities open space and land is not a limiting factor but for many other densely populated areas space could be a challenge. However, no–space or low–space technologies offer tremendous opportunities for space–confined cities [63] [75]. There is undeniable potential for the use of urban spaces like industrial and residential rooftops, undeveloped private and public lots and commercial properties for local food production [54].

UA main foundation is based on the contribution to food security and healthy nutrition [84]. Growing food in cities can have a positive effect on local economies by bringing the production closer to consumption, which saves lots of money and energy [75]. In addition, UA encourages the development of microenterprises for the production of necessary agricultural inputs, the processing, packaging and marketing of products, which contributes to flourishing of the local economies and the creation of positive opportunities in the job markets [69] [84]. Moreover, UA plays an important role in building communities by integrating the layers of society into the urban network through shared agricultural practices [84].

Some studies presented possible health risks of UA due to crops contamination with traffic emissions ,industrial effluents and heavy metals.Soils in some urban areas could contain Polycyclic Aromatic Hydrocarbons (PAHs), a known carcinogen which is formed as a result of incomplete combustion of fuel in vehicles from adjacent roads or railways [7]. However, proper preventive measure could be taken in to consideration to overcome such risks [84]. In addition, using raised bed, container gardens or hydroponic systems could provide solutions to some of these contamination problems [7].

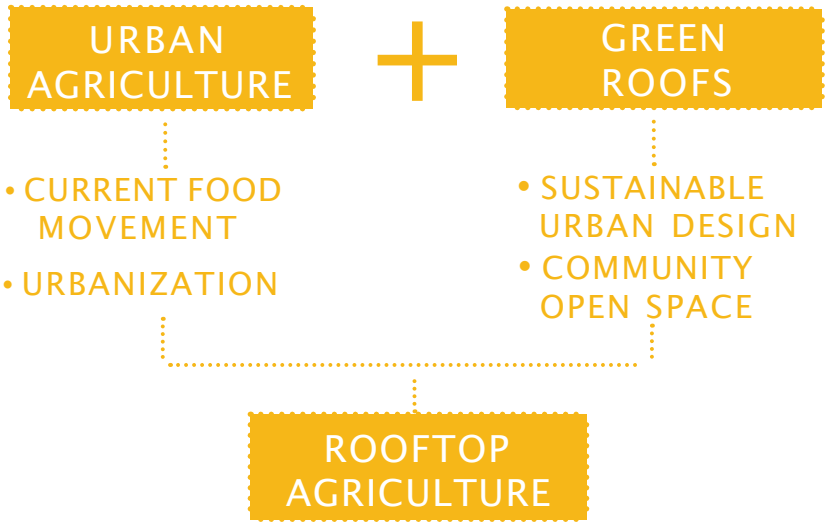


Figure 30: Integration of Urban Agriculture and Green Roofs

Authors presentation based on the image retrieved from "Rooftop to tabletop" by Benjamin Engelhard [19]

3.3. ROOFTOP AGRICULTURE

Rooftop agriculture is the production of fresh vegetables, fruits, edible flowers and herbs on buildings' roofs for the local consumption [69]. Rooftop agriculture is a strategy connecting urban agriculture to the green roofs technologies. When compared to conventional green roofs , rooftop agriculture has other benefits, different design requirements and implementation considerations [89]. Agricultural green roofs are designed for the purposes of food production, active recreation, reusing waste (water or compost) and educational opportunities [37]. Rooftop agriculture have major environmental, social and economic benefits presented in the following figure.

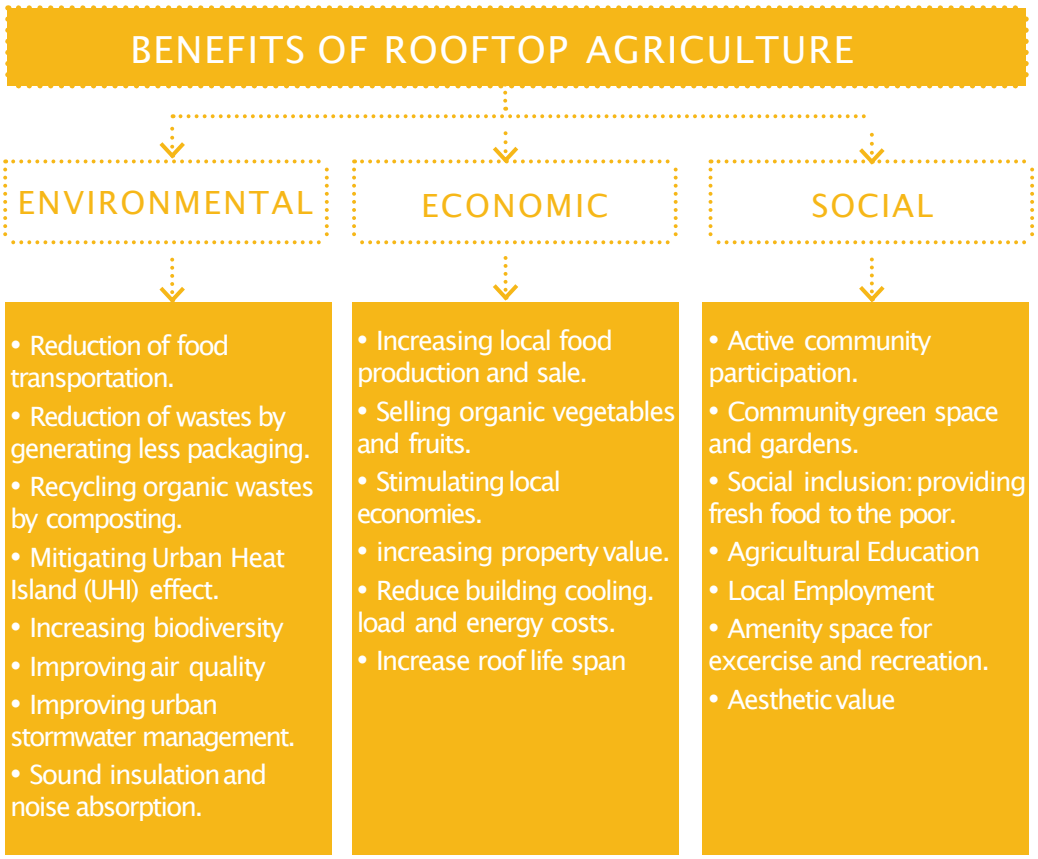


Figure 31: Benefits of Rooftop Agriculture

Authors presentation based on the data retrieved from "Greenroof urban farming" by Sam Hui [37]

3.3.1. Rooftop Agriculture systems

Rooftop agriculture systems are found under 3 main categories; Agricultural Green Roofs, Rooftop Containers, and Rooftop Hydroponic systems.

Agricultural Green Roofs

Agricultural Green Roof (AGR) provides crops planted in a soil based medium which is partially or fully covering the roof surface area [69]. AGR system consists normally of 6 main elements:

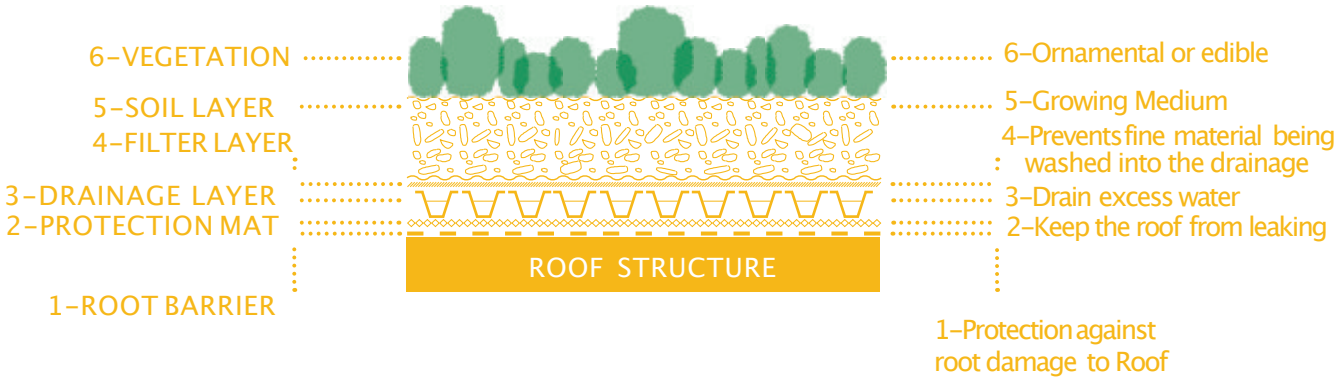
The first is the root barrier which is a polyethylene sheet or copper compounds in membrane installed to stop the roots from penetrating the roof structure. It must be installed as the first layer after the roof slab if the protection mat is not root resistant [8] [62] [91]. The second is a protection mat that protects the roof from leaking. It could be applied as a liquid monolithic layer, Modified bitumen or in plastic sheets, which are seamed or lapped depending on the experience with a product, roof conditions, budget, and ease of repair [62] [59]. If not installed properly the water proofing layer can jeopardise the integrity of the green roof, affecting the building and its occupants [9].

The third layer is the drainage layer which is used to drain excess water out of the system. All the new drainage technologies consider prefabricated drainage mat systems [91]. This mat is usually light weight , long lasting and is designed to properly direct water. The fourth layer existing on top of the drainage mat is a nonwoven filter fabric used to keep fine soil from clogging the layers below [59].

The fifth layer is the substrate layer which is the medium used for growing the vegetation. This medium could be of natural, artificial or waste minerals. Lava (scoria) & pumice, perlite, vermiculite, light expanded clay aggregate (LECA), rockwool, diatomaceous earth (DE) and numerous other materials [9]. Substrate is usually case specific depending on various factors, including load bearing capacity, slope of roof, climate, drainage and plant species [9]. The depth of the substrate defines 2 subcategories of the AGR, which are either extensive or intensive.

Figure 32: Basic elements of an Agricultural Green Roof (AGR)

Authors presentation based on the data retrieved from "Greenroof urban farming" by Sam Hui [37]



Extensive green roofs is a lightweight system used for light vegetation or crops using a shallow layer of substrate [91] [62] [77].They weight normally 50 –150 kg/m^2 [91] [77].Substrate depth varies from 5 to 15 cm [69] [91]. They require low maintenance which is usually 1–2 times per year while their supply of water and nutrientsis usually by natural processes [62] [91]. Extensive green roofs are sometimes used for small scale agricultural practices [69]. However, in most cases and studies extensive green roofs are used for non agricultural practice since most of agricultural activities needs deeper substrate, ongoing maintenance and regular followup [91].

Intensive green roofs consists of a 15+ cm depth of substrate, with a weight exceeding 150 kg/m^2 [91] [77] [69]. They are a suitable system for agricultural practices on well designed rooftops that can tolerate overweights [62]. Intensive green roofs requires regular maintenance which includes constant mowing, fertilizing, watering, weeding etc.[91].The depth of substrate provides diverse options of plants species [62]. Additionally, it provides a longer life span for roof membranes as well as more levels of water retention and higher quality of roof insulation [62].

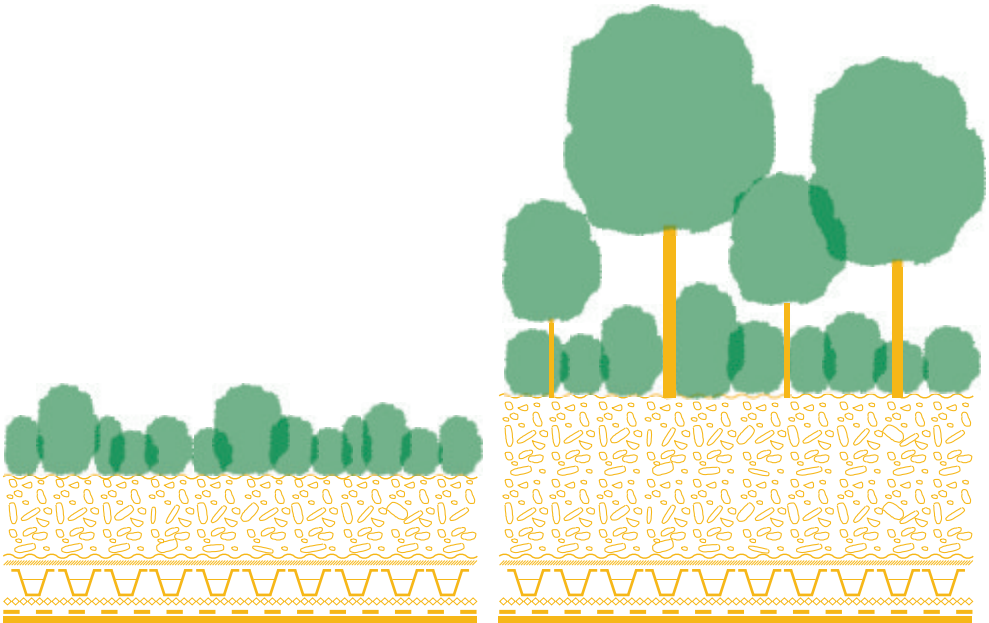


Figure 33:
Extensive and Intensive Green Roofs Systems

Authors presentation based on the data retrieved from "Green Roof systems" by Zinco [91].

EXTENSIVE	INTENSIVE
Substrate Depth : 5–15 cm	Substrate Depth : More than 15 cm
Weight : 50 –150 Kg / m^2	Weight : More than150 Kg / m^2
Properties: • Low weight • Low capital cost • Low plant diversity • Low maintenance requirements	Properties: • Deeper soil and more weight • Higher capital costs • Increased plant diversity • More maintenance requirements

Rooftop Containers

Containers is the system of planting in pots or raised beds which contains soil based growing medium[69]. Containers require a basic depth, but beyond that have few design limits, lending themselves to the upcycling and recycling of materials [62]. Containers may be made of wood, clay, fiber or plastic. However, Buckets, trash cans, crates, and milk cartons are some of the many items found around the home that can be used as a planting container [57] [10]. Containers are dynamic solution for planting in a limited space [62]. They also have the ability to fit on rooftops of limited structural capacity and they can easily adapt to different design settings[62]. When placed on a roof, they can always be relocated if any maintenance need to take place [57].

Whatever kind of container used, drainage is a crucial issue and could cause the failure of the rooftop garden if not properly handled [10]. Containers drainage is as simple as holes in the bottom or the sides of the container [10]. If located in the bottom, elevating the container slightly off the ground is a must, to allow excess water to drain off the container [10].

Since containers are usually elevated from the ground, they provide a decent depth for soil and roots compared to extensive roofs [57]. It is better to use lightweight, porous growing medium like peatmoss, vermiculite or perlite [10]. These materials are more preferable than garden soil which is usually too dense to provide adequate aeration and drainage [10]. Containers are a good option for users who cannot or do not want to make changes or upgrades for their actual roof structure[57].

Rooftop containers can host diverse species of plants depending on the size of the container. It is a highly flexible form of gardening that is effective for urban settings especially low cost housing developments, where the surrounding soil is nutritionally damaged and not used due to construction processes [29].

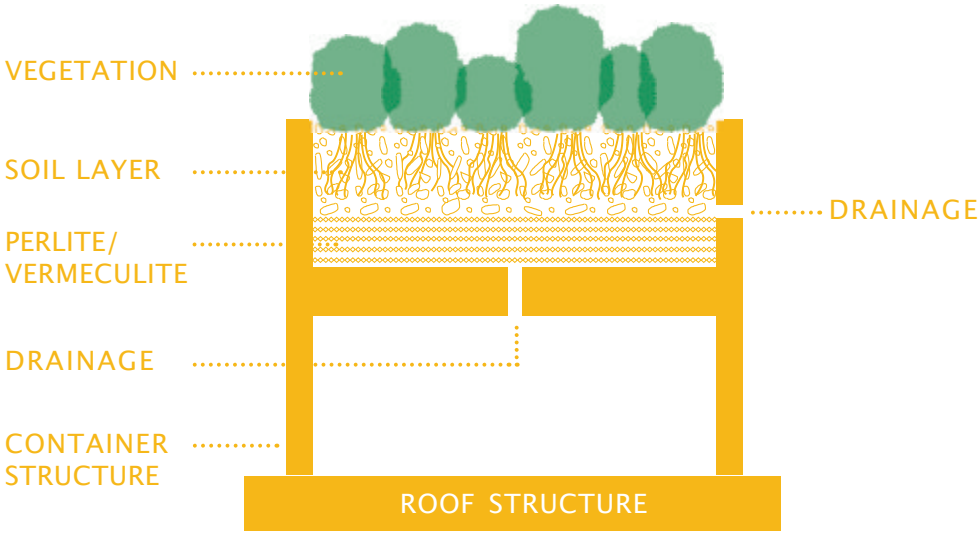


Figure 34: Containers Green Roofs System

Authors presentation based on the data retrieved from "Green Roof systems" by Zinco [91].

Rooftop hydroponic Systems

hydroponic is a technique that grows plants without a layer of soil [62]. The plant is usually supported by a thin layer of substrate, while the plant's roots are immersed in a water–based nutrient solution [57] [69].

Hydroponic is a lightweight ,water efficient, mobile system offering a superior aeration of plant roots compared to soil based systems [62]. The fact that bieng soil less eradicates soilborne diseases and contaminants [62]. There are lots of benefits of growing hydroponically. Plants may grow 2–4 times faster as they have a ready access to nutrients and water, using only 10 % of the water required in soil based systems [57] [62]. The plants normally soak up the solution, putting their energy into growing leaves, fruits, and stems instead of roots [57].

Hydroponics could be classified into passive and active systems. Passive bieng the cheapest, requires a container with drainage ,a tray that holds liquid and a growing medium [57]. Passive technique requires constant followup were plants should be hand watered with the nutrient solution [57]. Other active systems could flood the plant tray with nutrient solution using a nutrient pump and allow the excess water to drain back into a holding reservoir for furtheruse [57] [62] . Hydroponics are subcategroized into open and closed systems. Open systems are "run to waste" systems, allowing nutrient solution to drain out of the tray, while closed systems recover and recycle a surplus of the nutrient solution [62].

Wick system is a simple passive form of hydroponics. It does not contain any moving parts and in most cases it does not need electricity [38]. However, some users prefer installing an air pump to aerate the water reservoir. The system simply works by drawing up the nutrients from the reservoir through the wick to the growing medium by the means of capilary action [57]. The main disadvatnage of a hydroponic wick system is that it does not really work well for larger plants that need to drink up more water [38]. Moreover , they are less efficient at delivering nutrients to the plants. Wick hydroponics are an optimum system for small plants (herbs, lettuce) growing in places where electricity is unreliable or cannot be used [38].

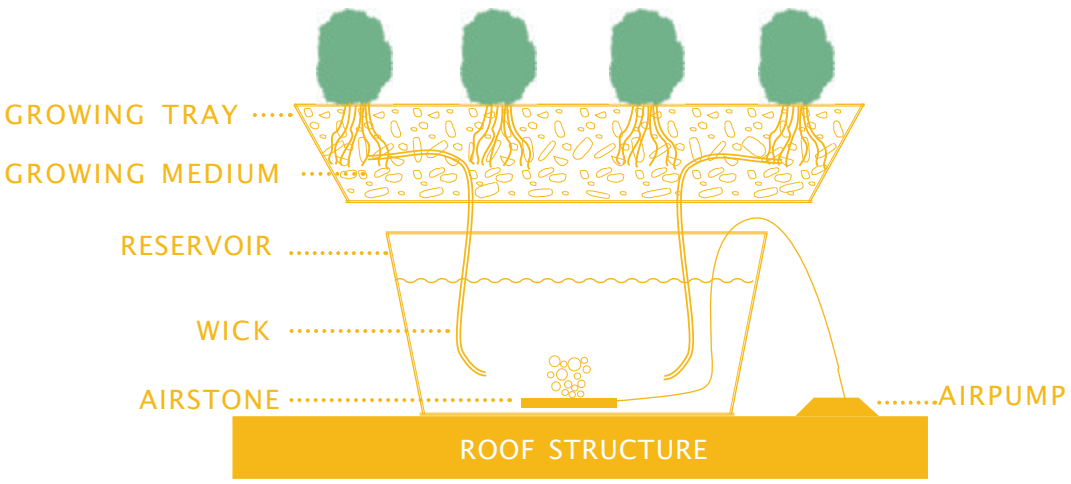


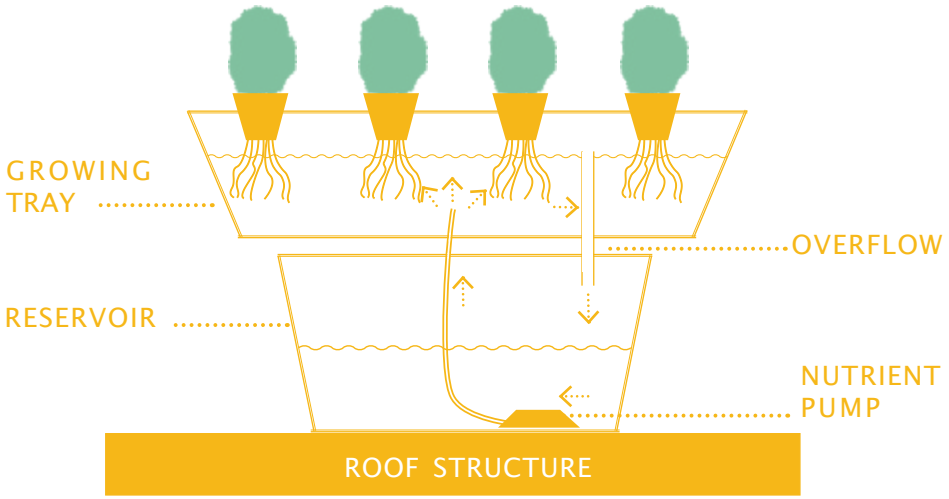
Figure 35: Hydroponic Wick System (Passive)

Authors presentation based on the image retrieved from "Rofotop Agriculture Policy" by Lucy Price.[62]

Flood and Drain or "Ebb & flow" is a hydroponic system that uses a simple technique of flooding and draining the growing tray periodically with nutrient solution [57]. Nutrient solution is pumped through tubing from the reservoir up into the growing tray using a submerged pump, which is operated manually or using a timer. The nutrient solution continues to fill (flood) the growing tray until it reaches the height of the preset overflow tube so that it soaks the plants roots [38]. When the water filling/flooding the system reaches the overflow tube height, it drains back down to the reservoir where it recirculates back through the system [38]. An advantage of this system is the ability to grow all sizes of plants with a simple and inexpensive technique.

Figure 36: Hydroponic Ebb & Flow system

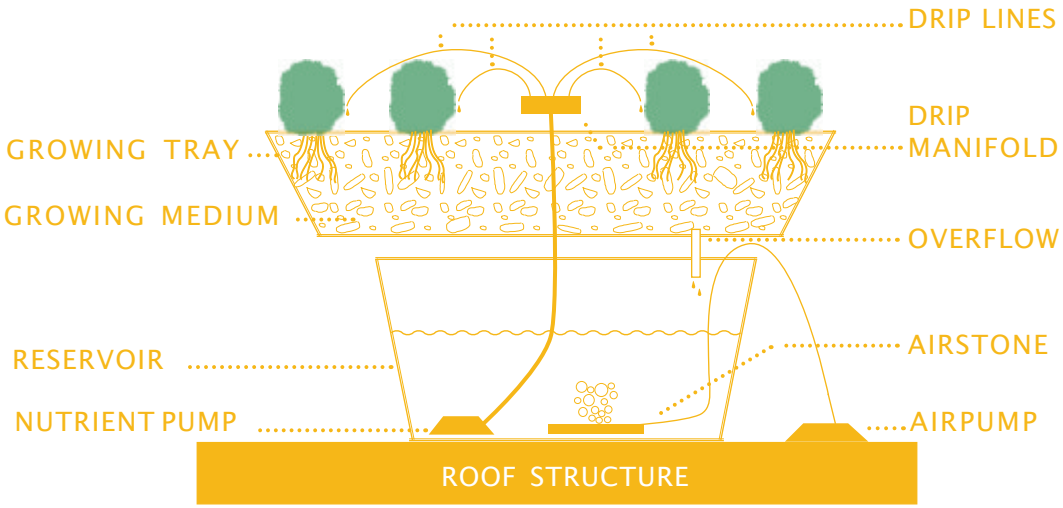
Authors presentation based on the image retrieved from "Rofotop Agriculture Policy" by Lucy Price.[62]



Dripping is another common and versatile type of hydroponic systems. It uses a drip system that dispenses nutrients at a very slow rate through nozzles that trickle the water down through the growing medium and the roots to keep them moist [38].This system provides more aeration for the roots compared to the previous one, as the roots are not totally submerged in the nutrient solution [62]. Dripping system is useful for large plants, since dripping lines can run over longer spaces [38]. Drip hydroponics can be found as a closed or opened system. The excess nutrient solution could be drained off the tray or recirculated and recovered for contineous use [38].

Figure 37: Hydroponic Dripping system

Authors presentation based on the image retrieved from "Rofotop Agriculture Policy" by Lucy Price.[62]



Nutrient film technique (NFT) is a popular hydroponic system which is simple, easy to install and highly productive [62]. Nutrient solution is pumped up from the reservoir to a tilted growing tray creating a thin layer (film) of the nutrient solution running contineously through the roots of the plants [38]. The excess nutrient solution can be drained downwards through the overflow back to the reservoir. The recommended slope for a NFT growing tray can range from 1:30 to 1:40 ratio [62] [38].While the plant roots are getting bigger, it is better to adjust the slope to avoid the obstruction of the water flow [38]. The recommended flow rate of nutrients is 1–2 Litres/minute which should be cut in half when the plants are still seedlings to avoid possible nutrient dificiencies [62] [38]. The flow rate could be gradually increased as the plants continue to grow [38]. NFT are best suited for growing "quick–growing" plants like lettuce, baby greens and herbs [38].

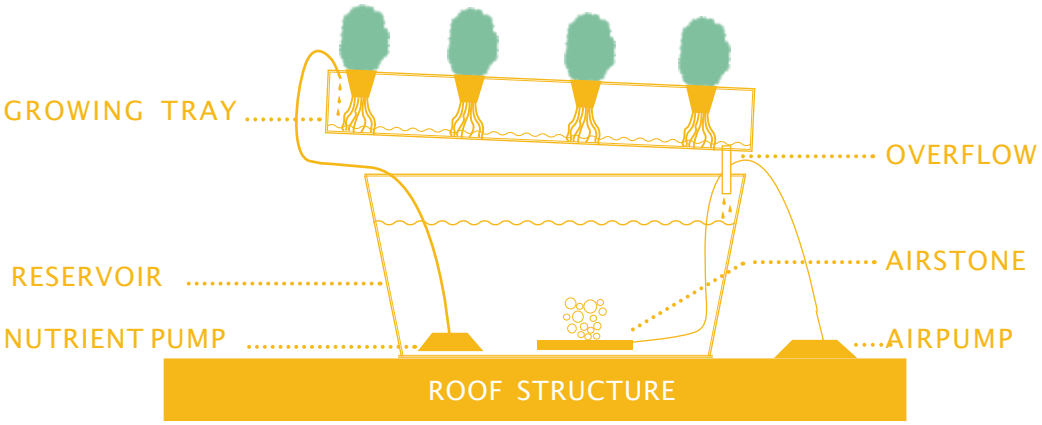


Figure 38: Hydroponic Nutrient Film Technique (N.F. T)

Authors presentation based on the image retrieved from "Rofotop Agriculture Policy" by Lucy Price.[62]

Aeroponics & Aquaponics

Aeroponics and Aquaponics are the offsprings of hydroponic systems [62].Those systems are not commonly used, however, technology and developmental research is growing.

Aeroponics is an application of closed system hydroponics. Plants are grown in holes in vertical panels of expanded polystyrene or other material [43]. The roots are suspended in the air and the root surface is misted periodically with high pressure sprayers [62]. The system is normally turned on for only a few seconds every 2–3 minutes which is sufficient to keep roots moist and the nutrient solution aerated [43].

Aquaponic is a hybrid system of growing fish in the water used for irrigating plants. Fish and plants have a mutual benefit as microbes and worms of fish waste acts as plant nutrients, which is eventually filtered by the plants and returned to the water in an integrated system [62]. Aquaponics requires attention for several factors including feeding rate ratio, water quality, water tanks aeration, smell and insects control [64]. Aquaponic system sometimes contains mechanical systems for biological filtration and aeration of the tanks that needs regular followup and ongoing maintenance [64].

3.3.2. Potentials of Rooftop Agriculture Systems

Rooftop agriculture help mitigates various environmental problems. It decreases UHI effect as well as retaining and utilizing rainwater [57] [69]. The availability of various rooftop agriculture systems provides adaptable solutions for different water circumstances [62]. Rooftop agriculture contributes to the reduction of GHG associated with food transportation. In addition, it could promote biodiversity through supporting a diverse range of edible and ornamental plants which attract a wide variety of habitats [69].

Rooftop agriculture provides various social benefits, including community integration through sharing agricultural practices and techniques [37]. It provides physical and mental health benefits through presenting highly nutritious fresh food and an attractive aesthetic value that positively affect the users [7]. Rooftop agriculture also supports local economies through growing and marketing local food while increasing the economic value of buildings by developing various underutilized opportunities [69].

–This innovative use of rooftops has been shown to create green jobs, increase local food production, and provide substantial ecological benefits by expanding available areas for food production in a world where this is a growing sustainability concern –

" Aaron Quesnel –Solution From Above"

The three presented rooftop agricultural systems provide different environmental, social and economic potentials when compared to each other. Despite many gaps in research that could assure the superiority of one system over another, certain types are more effective in tackling urban challenges compared to others.

The three types offer high potential for Urban Heat Island (UHI) reduction. AGRs may have the highest potential due to the roof surface area coverage. However, some literature state that hydroponics or containers with high Leaf Area Index (LAI) could produce comparable results depending on the shading effect and plant density [62], while others question the ability of hydroponics in making use of evapotranspiration to achieve a high cooling effect [69]. The exact data that could build a fair opinion of hydroponics' impact on UHI effect is still unavailable.

AGRs have a high potential to mitigate stormwater runoff, taking into consideration the depth of the soil and the plant type, which play a role in the amount of water retained [69]. Containers offer a good potential based on the variability in coverage area and size of containers [62]. Hydroponics offer lower potential for stormwater management as a result of being constructed with impervious materials like plastic or glass [69]. It is however possible for hydroponics to properly manage stormwater if a capture system is integrated in the design [50].

AGRs are considered less efficient in utilizing water compared to hydroponics and containers. However, this efficiency could be enhanced through improved irrigation techniques [62]. Hydroponics are highly efficient in water usage especially closed circuit systems that continuously recycle excess water [69].

AGRs have high potential to increase biodiversity, as intensive rooftop systemscould be ideal for supporting a diverse range of plants which subsequentlyattract a wide variety of organisms [69] [62]. Containers have a less potential to increase biodiversity compared to AGR as a resultof the less provided surface area of soil. Hydroponics , being a soilless technical systemhas a lower potential to increase biodiversity, however, exposed systemscould still provide habitat for some species due to the presence of living vegetation [69] [62].

The three rooftop agricultural types offer a good potential for community development. The concept of rooftop agriculture by any means could improve social bonds and increase communityinteraction. However, AGR and containers in some cases could provide higher potential compared to hydroponics, as the technical nature of hydroponic systemswhile intriguing may intimidate some community members [69].

AGR and containers systemscould present a very good potential when addressing food security. The increased depth of soil for those two types presentsan opportunityto grow greater variety of plants [69]. However, hydroponics offer a higher potential, since they are characterized by their high yielding capabilities compared to soil based systems[62] [69]. This high yielding property has been noted as the main reason for bringing hydroponic food production systemsinto cities [69].

AGR and containers could provide a high potential for nature connectivity. Deep substratesin intensive AGR and containers could support diverse range of plants and trees, which provide a strong visual impact within an artificial urban area, offering aesthetic benefits to city residents [62]. Hydroponics have a less potential compared to AGR and containers due to its technical nature. They do not provide a significant impact on connecting citizens with the natural ecosystem, especially systemdesigned for mass production [69]. However, including landscape features in the design of a hydroponic farm could provide a pleasant view and reinforce the citizen's connection to nature.

The three rooftop agricultural type offer a promising potential when addressing public health. Generally, rooftop agriculture provides an opportunity to abandon the use of chemical fertilizers and harmful pesticides, that usually have a negative impact on human health [69]. Moreover, better diets that include more nutritiousfood could play a vital role in improving health and reducing the rates of malnutritiondiseases[62].

AGR offers a high potential in building's energy savings. Deep soils of intensive AGR provides improved insulation to the building ,decreasing the energy demands for mechanical ventilation [49]. Hydroponics also provides a high potential throughutilizing passive cooling and heating techniques [62]. Hydroponic greenhouses can heat the top floor of a building during winter throughtrapping solar gains and harnessing evaporative cooling during the summerwhich eventually contribute to heating/cooling energy savings [62]. Containers have a less potential of

energy savings compared to AGR and hydroponics as a result of the less provided surface area of soil [69].

The three rooftop agricultural types provides a high potential for addressing economic development opportunities [69] [62]. AGR could improve building efficiency through energy reduction [62]. It could also offer different employment chances, which create a market value for building tenants [62]. Containers are known by their practicality and ease of application, which could offer dynamic solutions and opportunities for different building circumstances [69]. Hydroponics which are characterized by the light weight and the high yielding rate could also provide a significant economic value for building owners and tenants [69].

The potential levels presented are adopted from the previously stated references. They represent the literature conception of the different rooftop agricultural types. Rating each type in relation to mitigation ability proved to be an extremely difficult task which is complemented by the lack of supporting literature. The comparisons produced may not be fairly accurate and requires further research.

Figure 39: Environmental, Social and Economic Potentials of Green Roofs systems

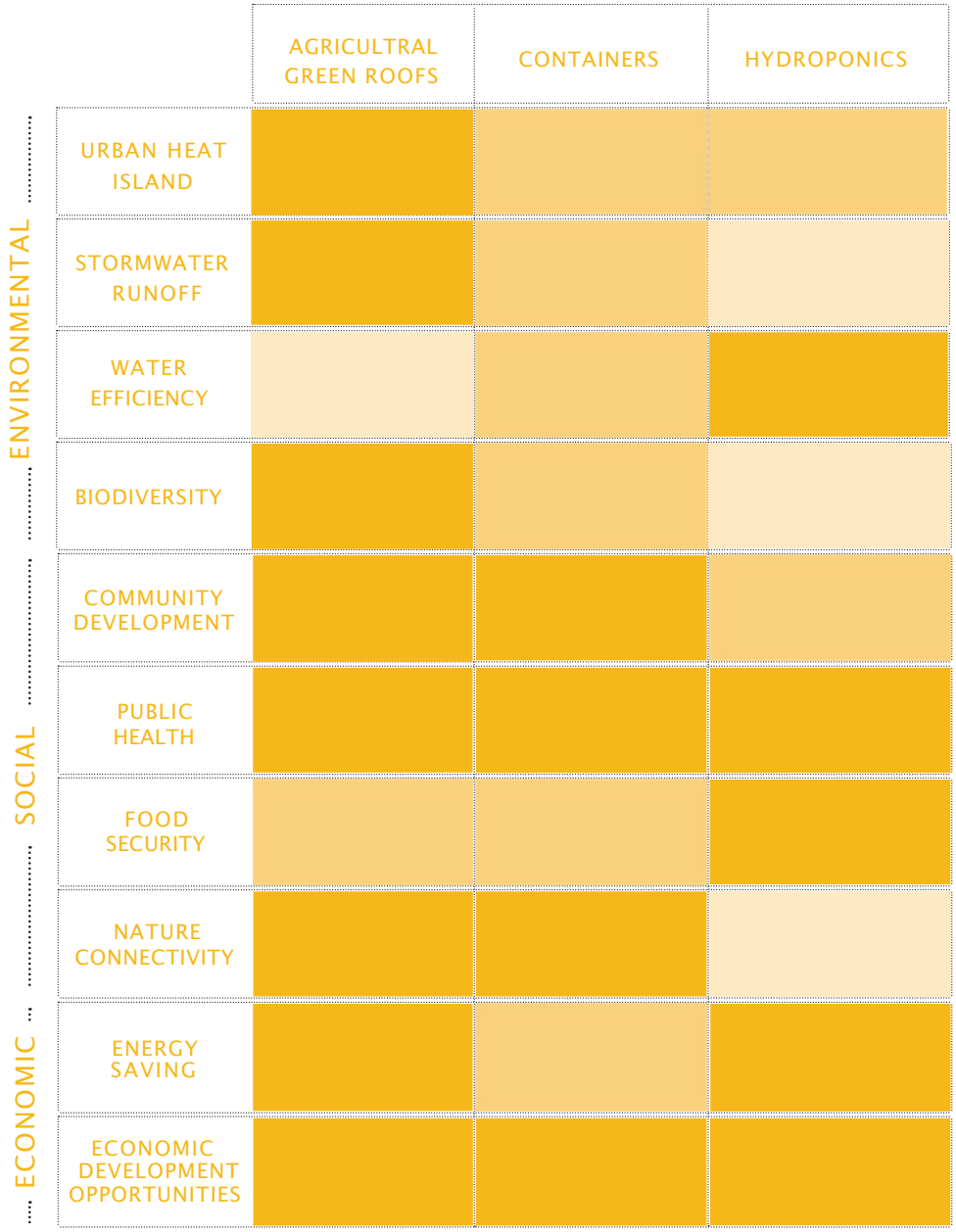
Authors presentation based on the date retrieved from "Rofotop Agriculture Policy" by Lucy Price [62] & "Solutions from Above" by Aaron Quensel [69]

POTENTIAL LEVEL :

HIGH

MEDIUM

LOW



3.3.3. Constraints of Rooftop Agriculture

Although rooftop agriculture offers many benefits, they face clear challenges to their widespread application.

Technical Challenges

Load bearing of roof structure is a significant issue for the success of a rooftop agriculture project. AGRs especially intensive system has a weight exceeding 150 kg/m^2 [91]. It requires a sufficiently strong roof that could bare the load. Alternatives for low load bearing roofs could be either containers systems or Hydroponics [62]. Structural calculations for the roof load bearing is a prerequisite before applying a rooftop farming theme [59].

–How often it is, in the various fields of design, that negative factors can with study be turned to advantages –

" Jhon O. Simonds"

Water leakage is a big challenge that faces AGRs. If the roof is not root and water proofed, water could leak and plant roots could penetrate the roof surface causing its damage [59]. If leakage occurs, it is always not easy to trace [77]. As a result, It is very important to properly insulate the roof surface before installing the AGR layers.

For intensive AGR, soil composition and plant nutrient absorption is an important aspect for growing fresh and healthy produce. While most garden plants can tolerate a soil pH between 5.2 and 7.8, plant growth is best supported in soils with a slightly acid PH range between 6.0 and 7.0 [46].

Pest control should be regularly provided to assure clean and healthy products. biological controls are more favored than chemical pesticides to avoid harmful effect on human health and the environment [59].

Climate

It is important to take into consideration the climatic conditions when developing a rooftop agricultural system. Studies proved that significant changes in microclimatic factors occur as the altitude increases, leading to constraints in design requirements and opportunities [77]. Plants located at higher levels above ground are influenced by stronger wind and extreme temperatures which could cause plant burning and dehydration [59] [62]. Additionally, growing food on rooftops where wind and sun are generally stronger than at ground level requires the use of more potable water for irrigation, adding stress to many cities' shortages of water [69]. Intensive AGRs are recommended in areas with moderate temperatures while hydroponic systems –which are vulnerable to cold weather– could tolerate higher ones [62] . Studying sun angles and daylight hours for each season is important to provide sufficient sunlight for the plants [59] [62].

Cost

There is a lack of understanding of direct and long–termeconomic benefits of rooftop agriculture. This uncertainty may mean that costs are thought to be higher than they actually are. However, implementinga rooftop agricultural system needs higher upfront capital cost when compared to normal roofing [69] . While this investmentmay increase the building's value and benefit the community, those outcomes may not be recognized by financing organizations, making it more difficult to attract investors [69]. Intensive AGR can be up to three times the cost of extensive ones [62]. Although some rooftop agricultural systemsare relatively expensive, other low cost systemscould be achieved. Some hydroponics and containers systemsare built of local materials with usually low maintenance cost and high quality produce [62] [69] [37].

Awareness & Policies

Rooftop agriculture is considered a new concept among the public, the professionals and policy makers [77] [69] [37]. Rooftop agriculture lack proper support because of the fears of bieng an unreliable strategy [69]. Rooftop agriculture is slowly spreading, particularly in the developing world, where rooftop food production may have a significant impact on food security and income [57]. For existingAGRs, awareness is always needed for proper safety measures. Guardrails and fixing devices should be used while working on the roof especially in buildings with low parapets [91].

Adequate policies have the capabilities of achieving the benefits of rooftop agriculture and overcoming the challenges facing it [62]. Regional policies which do not include urban agriculture provisions and sale of food is one of the challenges facing cities in the process of developing rooftop agriculture projects [69]. Developing countries –were rooftop agriculture is not popular –lack the policies and guidelines that regulates this practice. Consequently, it leads to losing valuable opportunities and potentials that could have positively effect different aspects if proper policies and regulations were developed.

Research

All existing rooftop agriculture literature are calling for more support to academic and technical research at educational institutes, governments research centers and non profit research facilities [62] [69] [37] [57]. Rooftop agriculture existing research opportunities is still narrow and relatively inconsistent. The rapid development of different rooftop agricultural techniques and the increasing need for fresh produce in urban areas drive research in this field to expand and to be given more attention.

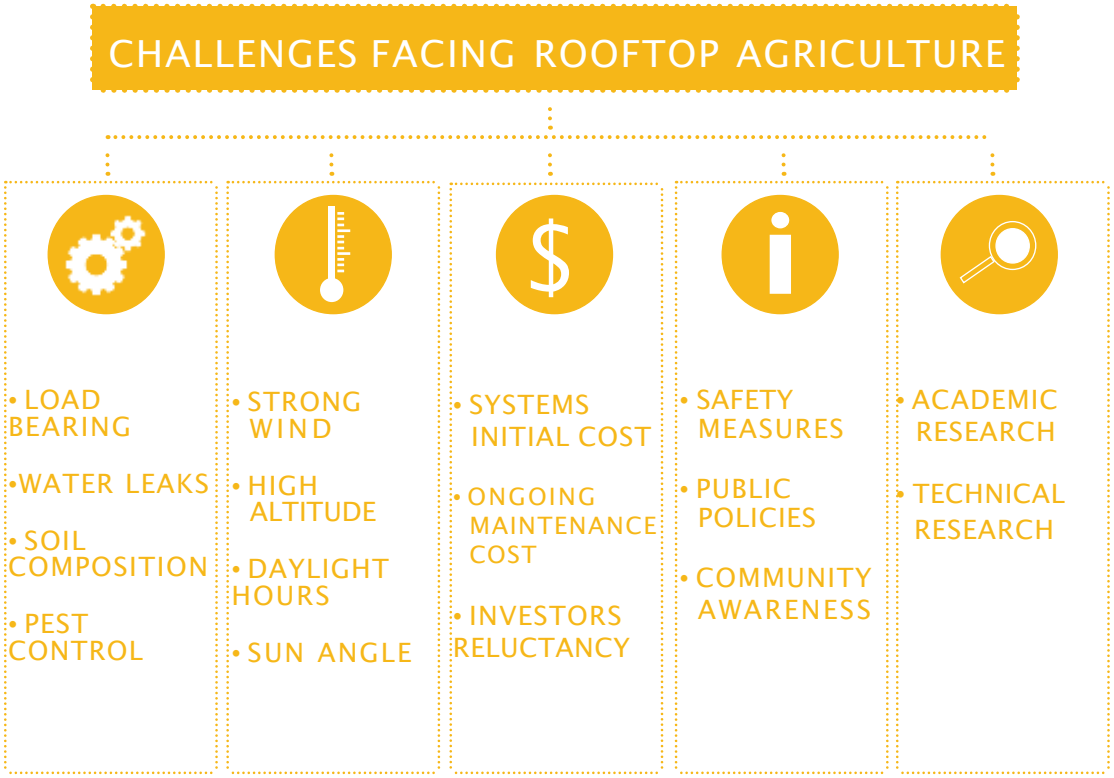


Figure 40: Summary of the Challenges facing Rooftop Agriculture

Authors presentation based on the date retrieved from "Rofotop Agriculture Policy" by Lucy Price [62] & "Solutions from Above" by Aaron Quensel [69]

3.4. CASE STUDIES

Reviewing practical case studies is important to fully understand how rooftop agriculture systems are designed ,implemented and managed. Two different projects were studied to highlight various approaches and techniques used in the development of rooftop agricultural themes. An Egyptian pilot project in informal settlements of Cairo is presented followed by an international commercial scale project in Montreal , Canada.

3.4.1. Ezbet El Nasr Rooftop Agricultural Project

Ezbet El Nasr is an informal settlement located in Basateen District South of Cairo Governorate. It is situated 4 km East of Nile River and 8 km south of Cairo's historic center. It covers around 135 acres of state owned land of which the informal fabric covers 75 acres [78]. Housing standards differ remarkably in the area due to its proximity to formal residential areas (Maadi in the south)[78]. Basic supply of infrastructure are relatively well, however, The area has weaknesses regarding street lighting, construction waste, sanitation services, noise and pollution from nearby workshops as well as the lack of open/green spaces [78].

Ezbet El Nasr is an area of focus for the GIZ (gesellschaft für internationale zusammenarbeit), The German international cooperation in Egypt. The GIZ is currently working on a Participatory Development Program (PDP), an Egyptian–German development project implemented by the Egyptian Ministry of Urban Renewal and Informal Settlements (MURIS)

with financial assistance of the German Federal Ministry for Economic Cooperation and Development(BMZ) [61].

The main objective of this program is developing urban informal areas. A specific component (C2) focuses on promoting resilient communities, supporting their efforts to adapt to the impact of climate change. It also works on increasing awareness and information levels among public administration and civil society on climate change consequences in urban areas [60].

The pilot rooftop farming project was executed in Ezbet El Nasr as a part of the PDP C2 to serve multiple objectives.

Objectives

The main objective of this project is to create knowledge, raise awareness and encourage concrete actions that mitigate the strong impacts of climate change on informal settlements[31]. The project aimed specifically to improve the socioeconomic situation of the residents through providing financial support and job opportunities. Additionally, this project intended to gain references on the micro–climatic effects of rooftop farming in informal settlements[31]. Furthermore, this project aimed to investigate technical and social feasibility of urban rooftop farming in informal areas, and document the lesson learnt for possible future small–scale projects (and funding) within the PDP [31].

Figure 41: Location of Ezbet El Nasr in Cairo's Informal Map

Authors presentation based on the maps retrieved from "The Parallel City" by Noheir El Gendy [15]

Methodology

Local NGOs in informal areas usually have connections and links to the residents of the area where they are situated. This project used a method of communicating with the local NGOs of Basateen district through the district's Urban Upgrading Unit (UUU) to facilitate the selection process of the potential participants [31]. They also collaborated with "Schaduf", a growing Egyptian social business dedicated to rooftop farming to work on delivering and managing the desired model [31]. Schaduf is known for using proven practices to streamline and simplify rooftop farming, in an attempt to create the maximum impact in low income communities [12] [13].

Description

Six houses were chosen as the pilot of this project. PDP has set an eligibility criteria for the selection of the beneficiaries. This criteria included owning at least free 12 m^2 roof space for the project implementation [32]. In addition, the selected residents must attend 4 training sessions conducted by Schaduf to get the basic information needed for the project [32]. The residents must also have the ability to co–finance 10% of the equipment costs in order to guarantee their commitment and assure their ownership (150–300 EGP, depending on the plot size) [32]. In case of the applicant's inability to pay this amount, 5% have to be paid to Schaduf before implementing the system and the other 5% can be returned in the form of produce during the first 3 months of farming [32]. Moreover, the residents must show strong interest in rooftop farming and agricultural knowledge .This is to ensure that they will allocate sufficient time for farming practices on their rooftops [32].

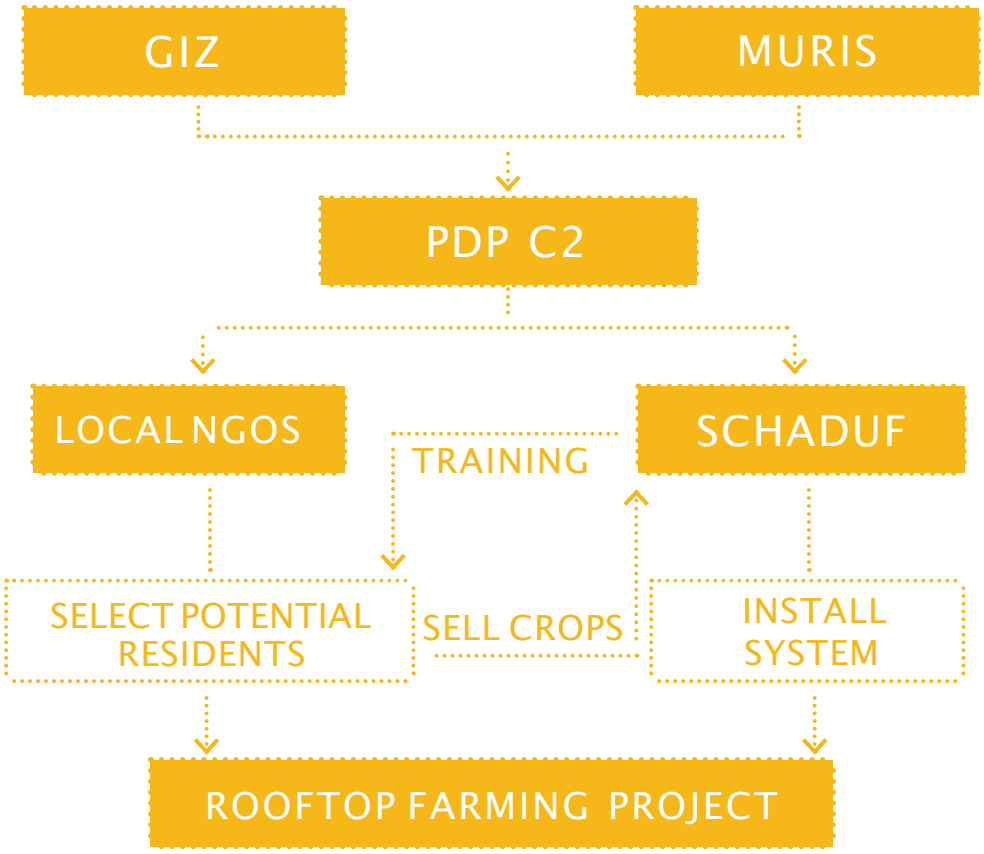


Figure 42: Structure of Ezbet El Nasr Rooftop Farming Project

Authors presentation based on the Data retrieved from GIZ reports "Improving Informal Areas in Cairo–Ezbet el Nasr" [28] & "Rooftop Farming in Ezbet el Nasr" By GIZ,2013 [31]

The selected residents utilized 10 m^2 of their rooftop farms to plant Arugula, Mint, Jawmellow and spinach [31]. They are selling their harvest to Schaduf, who is locally marketing the produce in a farmers market in Maadi, one of Cairo's affluent residential districts.

The project adopted a low tech passive hydroponic system called "Deep Water culture" [20]. It consists of a growing tray made out of light wood which in some cases is raised from the ground to trace possible leaking areas and to easily carry the tray if relocation is required.

A protection layer of light foam is fixed on the wooden tray complemented with a thin layer of polyethylene which together acts as a proofing layer, insulating the growing tray and the roof structure from water leaks and root penetrations [20].

The tray is then filled manually with a mixture of water and nutrients. This water basin allows the next layer which is a light layer of perforated foam holding the plant pots or the saplings to float on the water surface and the roots of the plants to feed. The plant pots are usually made of light plastic and contains light growing medium like peatmoss, perlite or vermiculite covered by a thin layer of compost [20]. An air pump is installed to allow for the continuous aeration of the nutrient solution [20]. The whole system is covered by a mesh blanket to prevent birds and pests from reaching the plants.

The residents are responsible for day to day operation of the system, while Schaduf is designated to guidance and supervision, in case of technical difficulties [32].

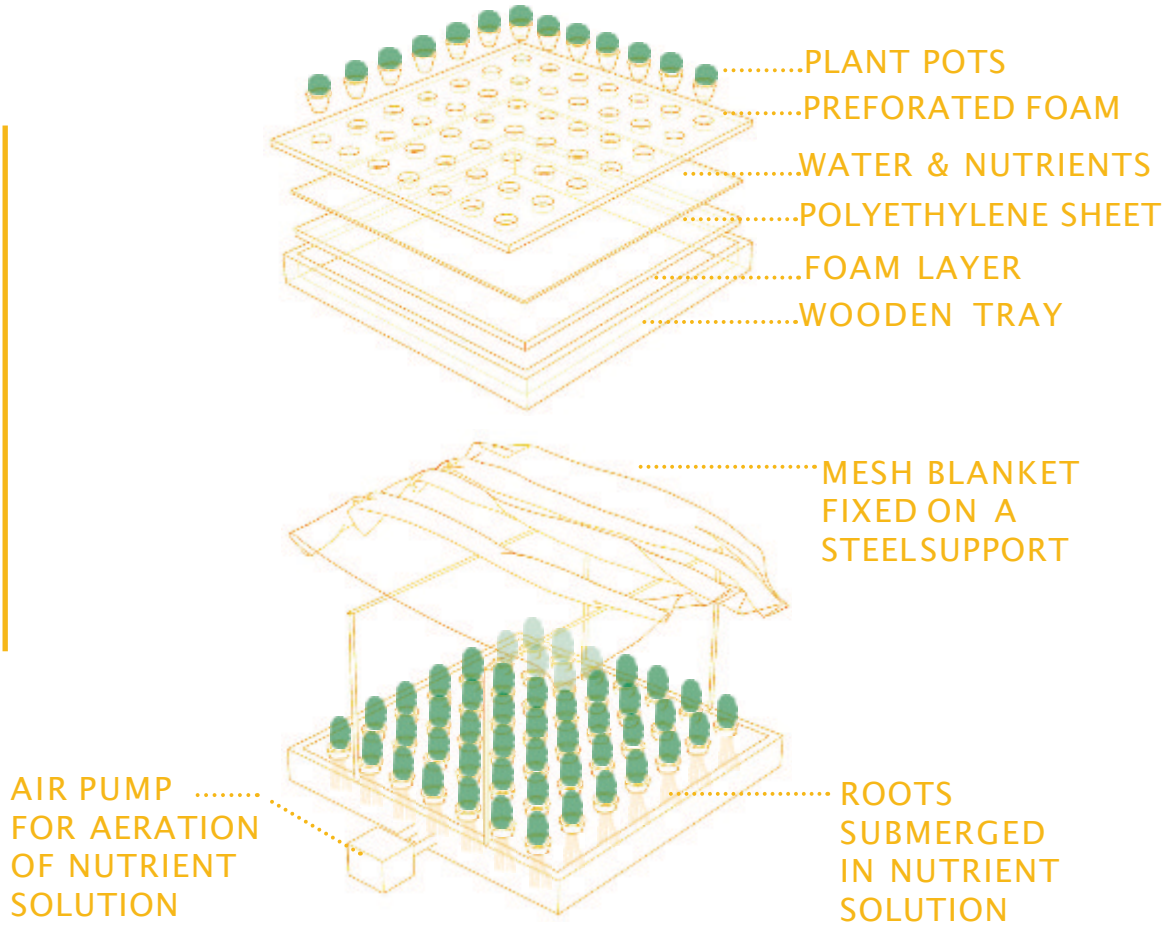


Figure 43: Components of Deep Water Hydroponic system implemented in Ezbet El Nasr Rooftop Farming Project

Authors presentation based on the Data retrieved from GIZ reports "Improving Informal Areas in Cairo-Ezbet el Nasr" [28] & "Rooftop Farming in Ezbet el Nasr" By GIZ,2013 [31]

Impact

This project had multiple impacts on the residents of Ezbet el Nasr. It provided a reasonable potential for income generation among the residents living in poverty through selling their produce. It also decreased their food expenditures ,saving a suitable amount of money regularly paid on their basic needs of some fruits and vegetables.

The project also established greenery and open spaces on rooftops for residents living in narrow streets that usually lack open/green spaces. It also provided a venue were neighbors could meet regularly and exchange different agricultural knowledge and techniques, promoting social integration and increasing community bonds.

The project also contributed in raising awareness of environmental issues among local population, especially on adaptation to climate change and the role of rooftop farming in mitigating such issues.

Including local authorities from the respective districts as well as involving the residents in decision making and problem solving was the key aspect of success for this pilot project.

Figure 44:
Ezbet El Nasr Rooftop Farming produce

Authors editing , Image Courtesy of GIZ, retrieved from "Rooftop Farming in Ezbet el Nasr" By GIZ,2013 [31]

3.4.2. Lufa Farms Project

Lufa farms is a commercial greenhouse agriculture project, found in Montreal, Canada in 2010. The idea came up to the founderswhile wondering about the lack of fresh and high quality food in Montreal [50].

They concluded that the fundamental problem in getting fresh food is that produce is often grown far away from where it's eaten. This means that food is handled, packed, travelled thousands of kilometers, stored and/or refrigerated before bieng served, which eventually lead to a less fresh, less nutritious and less tasty produce [87].

Objectives

The main objective of the project is "Farming for a Better Future" [50]. By practicing sustainable rooftop agriculture, high quality produce could be provided with less impact on the environment. The project aimed to support and promote local food systems through sourcing from partner farms and food makers who share the values of providing fresh and local products to urban populations [50].

Description

The prototype farm is a 2900 m^2 hydroponic greenhouse, built on top of an office building in the north side of the city. Hydroponic systems are not eligible for organic certification in Canada because of their intensive use of mined nutrient salts which are non–renewable [87]. However, the founders decided to focus on a closed circuit hydroponic system. This system re–circulate 100% of irrigation water and cuts down on an estimated 90% of nutrient usage [87]. The system uses between 50% to 90% less water than a comparable farm not practicing water recirculation [87]. The farm also has a rain water capture system which decrease the stress on the municipal water supply [50].

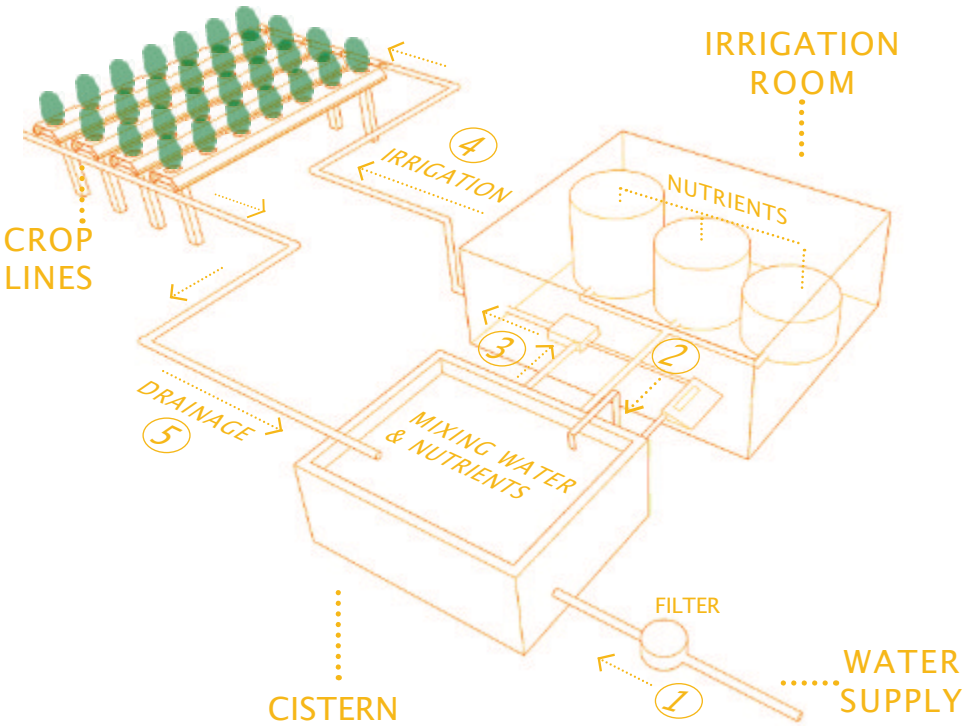


Figure 45: Basic Components of a Greenhouse Closed Circuit Hydroponic system

Authors presentation, inspired by the image retrieved from New Growing Systems website, NGsystem.com.

The greenhouse also provides multiple growing climates for the diversity of cultivated vegetables. With over 25 varieties of vegetables being grown, it relies on hot zones for some vegetables, cool zones for others, and several "micro–climates"within each zone [87]. The facility is also designed to absorb as much natural heat from the sun and the building before supplementingwith heating boilers [87].

The farm used natural gas in heating the greenhouse on cold days. However, they offset their consumption through not refrigerating the produce, as they deliver it fresh to consumers living within the same urban area [87]. Additionally, the city's own atmosphereacts as a supporting factor in crop production through lowering the energy of the farm. Since the farm is located in an inner city where temperaturesare often higher at the core than at the periphery, resulting in less heat consumption by the greenhouse [8].

Moreover the farm employs semi–transparentenergy curtains which are automatically deployed on cold evenings. It helps insulating the greenhouse and reduce heat loss at night, resultingas well in a significant energy use reduction [87].

The farm provides a sub system for on–sitecomposting of organic waste, using an in–vesselrotating drum located in the basement of the building [87]. The finished compost is used for potted herbs and sold for customers in compostable bags [87].

The farm practices sustainable agriculture throughpreventing the use of syntheticpesticides, herbicides, or fungicides [50]. They use biological methods(controlling pests using other living organisms), were beneficial insects like lady bugs and others are released into the greenhouse to combat crop–harmingpests [50]. The farm also uses weed–free growing media and rigid protocols to maintain a clean, productive and problem–free area [50].

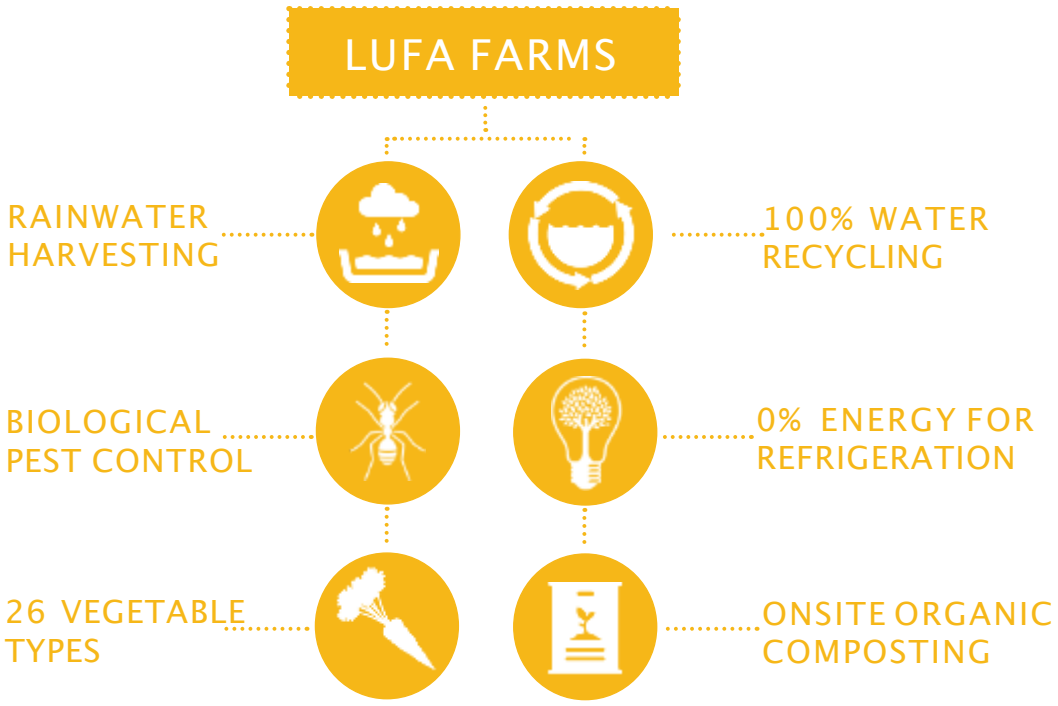


Figure 46: Lufa Farms project benefits

Author's presentation based on the data retrieved from Lufa Farms [50]

Impacts

Lufa farms is a successful grass–root rooftop agriculture initiative that addresses food security and quality issues in formal urban areas. It is now an expanding project feeding more than 1300 customers weekly, producing around 250,000 pounds of produce annually [53] [87]. They already launched a second rooftop farm in Montreal covering an area of 4000 m^2 [50] . The company announced securing $4.5 million in financing to begin expanding to additional rooftops in other cities of Canada [50]. The company is also looking at opportunities to enter the U.S. market, hoping to increase their customers to 5000 [87].

Lufa farms provides fresh vegetable baskets which can either be picked from the farm or from specific drop off locations in the city on weekly basis [50]. Recently, they included a home delivery system to serve seniors and disabled [50]. They also launched an online marketplace were different crops could be easily browsed, customized in a basket and ordered [50]. They are also organizing daily guided tours for people interested to visit the farm to gain more knowledge about the farm and the agricultural techniques used in it [50].

Figure 47:
Lufa Farms
Greenhouse Produce

Author's presentation, Image courtesy of Lufa Farms [50]

Souq el Bouhi , Imbaba , Cairo
Image & Edit © 2015 Abdallah Tawfic

Chapter 4

THE RETROFIT

4. THE RETROFIT

The first two chapters of this research studied informal settlements in Cairo and selected Imbaba as an area of focus. The study explored the morphological conditions of Imbaba in terms of street hierarchy, open space availability and building typology. It concluded the lack of open/ green spaces especially in narrow streetswhich is facing challenges as a result of compact & informal construction. Moreover, the study covered the socioeconomic status of the residents, concluding high rates of unemployment, health problems and low levels of education.

The last chapter provided a detailed research of green roofs technologies, covering their different uses, general benefits as well as their limitations and challenges. Rooftop Agriculture was the selected potential from the different benefits provided by green roofs. Various agricultural techniques and systemswere presented, complemented by two different approaches of rooftop agriculture projects in Cairo and Montreal.

This chapter represents an integration of the previously described topics, exploring the application of rooftop agricultural systems in the urban setting of Imbaba. These two topics are developed and retrofitted in the form of a fictional model called "Imbaba Farms". The parameters of design of this project as well as the expected impacts are presented in this chapter.

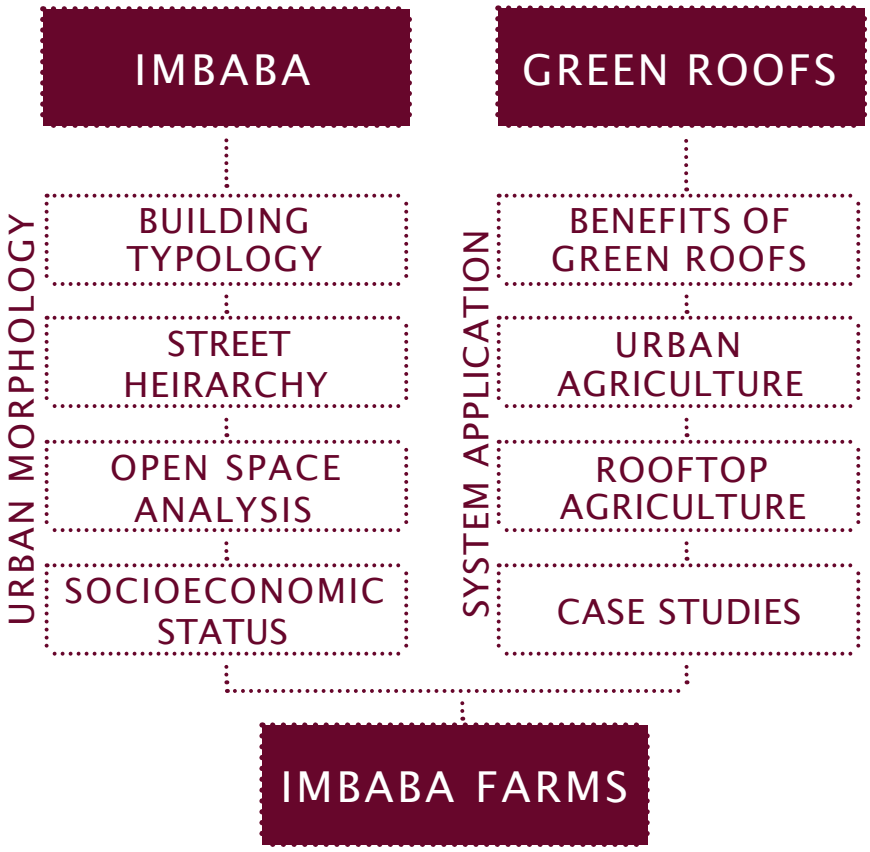


Figure 48:
The integration of the urban morphology of Imbaba and the Green Roofs systems forming Imbaba Farms model

Courtesy of the Author

4.1. SYSTEM APPLICATION IN IMBABA

Each rooftop agriculture project may be designed to accomplish different goals and operate under varying environmental conditions. The application potential of rooftop agricultural systems differs from one project to another based on several factors.

Roof conditions is an important criteria for the selection of the rooftop agricultural system. The load bearing of the roof is a critical aspect that mustbe taken precisely before installing a rooftop agriculture theme. Intensive AGRs requires a high roof load bearing capacity [91]. On the contrary, Containers and Hydroponics respectively requires less load bearing as less or no growing medium is required.

In Imbaba most of the roofs are constructed using reinforced concrete. However, the unconsidered structural calculations do not encourage the implementation of an intensive AGR. Containers and hydroponics –being more light in weight –could be a more suitable alternative that fits with the conditions of the existing rooftops.

System Selection Criteria

Construction conditions, types of crops, and the economic feasibility are important criterias for the selection of rooftop agriculture systems

Types of crops is another criteria that identifies the choice of the rooftop agriculture system. Intensive AGR provides a wide variety of crops as a result of the deep substrate layer which increases the flexibility of planting [69]. Containers and simple Hydroponics are less flexible, However, complex hydroponic systems can provide a wider variety of crops but it requires high technology systems and high energy input [50].

Light weight crops are more encouraged for the context of Imbaba. Hydroponics are considered an optimum system for light weight, Leafy vegetables and Herbs which requires constant water & nutrients flow compared to other types.

Economic feasibility is another important criteria for the selection of the rooftop agricultural system. Start up costs of developing the infrastructure required for rooftop agricultural systems proved to be a significant challenge [62] .Intensive AGR requires a high startup cost compared to Containers and Hydroponics which provide more flexibility, as local materials and simple low tech solutions could be efficiently utilized to reduce the startup cost of the system [69].

Simple Hydroponics and Containers are economically feasible for the context of Imbaba. Hydroponics proved to be a successful system for stimulating local economies as they have the ability to produce higher amount of crops [69]. However, it is logical to state the difference in production between the simple and complex systems. Although the quantity may not be comparable, simple hydroponics provide adequate solutions for low income groups planning to initiate a rooftop agriculture project with a low startup cost.

4.2. FRAMEWORK FOR STRATEGIC SUSTAINABLE DEVELOPMENT

The framework for Strategic Sustainable Development (FSSD) is used as a guiding tool for this project. As briefly explained in the first chapter, FSSD will help answering the research questions related to retrofitting rooftop farming systems to the urban morphology of informal settlements generally and Imbaba specifically in compliance with the four sustainability principles.

Research Question 1

Which green roof technologies can be the mostbeneficial and fits–in terms of technical aspects–in the context of Imbaba to achieve a sustainable development?

It was expected that hydroponics and containers would be the most suitable systems for the context of informal settlements and Imbaba. Hydroponics have a very high potential in addressing food security issues as they are developed to maximize agricultural yields. The diversity in hydroponics technologies provides more flexibility in choosing an adequate system that fits with the social, economic and environmental conditions of Imbaba.

Facing a problem of water scarcity in Egypt, a system that uses water efficiently would be desired. Additionally, the absence of growing medium would result in a light weight system that would fit for the low load bearing roofs of Imbaba. Moreover, the potential for using local materials and reusing existing ones would decrease the initial cost of the designed system.

Framework for Strategic Sustainable Development

FSSD helps answering the research questions based on the previously studied topics

Hydroponics are not usually designed to address environmental issues. Simple hydroponics could have a limited effect in decreasing UHI & biodiversity loss. They could utilize transpiration from plants until harvest time to achieve minimal cooling. However, it could provide a suitable opportunity for communities like Imbaba lacking the availability of open/ green spaces.

Research Question 3

How would Imbaba residents react to the concept of rooftop farming? Is agricultural background an important aspect for acceptance of such concept? Is financial profit from selling the crops the main stimulating element for the success of this concept? what are other stimulating elements that could drive the locals to work for the success of this concept?

Rooftop agriculture is a new concept that is still developing worldwide. It is expected that Imbaba residents would not fully accept the concept before including them in decision making and explaining all the project components and benefits. It is also expected that the lack of agricultural

knowledge among the residents would affect the sustainability of the project. Providing suitable theoretical and practical training sessions would be an important aspect for the success and continuation of the project.

Imbaba hosts mainly the middle to low income strata. It is logical to state that the lower income communities are driven by their basic needs. Almost all of the low income families are searching for an extra source of income to improve their living conditions. It was expected that financial profit would be the main stimulating element that drives this project to success. Other elements could be the need for community venues for social gatherings ,the relatively limited connection to nature through creating green spaces and the health benefits from providing clean, nutritious and well managed produce.

4.2.1. The Generic 5 levels Framework

The FSSD helped identifying how rooftop agriculture can strategically move informal settlements generally and Imbaba specifically towards a sustainable future. This section will consider the project through the generic five levels of the FSSD to help structure and organize the results.

System

Informal settlements are covering more than half of Cairo's urban area [26]. Almost 12 million inhabitants which represents 70 % of Cairo's population live in informal areas [27]. The failure of the government to provide suitable , affordable and viable housing opportunities for middle–low income strata is the substantial reason behind this phenomenon to spread , resulting in an illegal or semi illegal housing systems built on private or public land.

Imbaba is the system of study being included in informal settlements of the urban areas of Cairo, which all reside in the biosphere. The current conditions of Imbaba is affected by the informality which is leading to major socio–ecological problems. The effect of climate change and insufficient open spaces in poorly designed areas, as well as the deterioration of basic infrastructure like water & sewage and the lack of waste disposal facilities compromise the ability of life to be sustained into the future. The increasing rates of poverty and food insecurity as a result of unemployment and low education levels provide a threat and undermine people's capacity to meet their own needs.

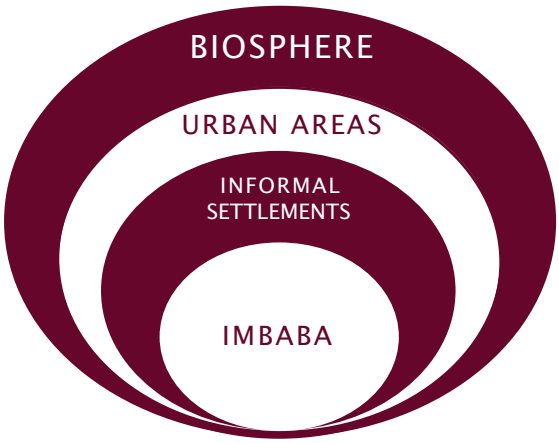


Figure 49: Relationship of Imbaba within its corresponding systems

Author's presentation, inspired by the system diagram retrieved from "Solutions From Above" by Aaron Quensel [69]

Success

Informal settlements generally and Imbaba specifically are very complex entities which requires dynamic interventions to approach a sustainable future. For this specific project to succeed, it should not contribute to violations of the sustainability principles described in the first chapter, which aim to use resources efficiently. The general success goal of this project is to provide resilient solutions that lead to better living conditions for the residents of Imbaba.

A successful rooftop agriculture project in Imbaba utilizes the unused roof spaces to generate decent income for families, in an attempt to improve their living conditions. Introducing rooftop agriculture to Imbaba could create various job opportunities for the locals, as it drives demand for venues like farmers markets or Community Supported Agriculture (CSA) programs. It could also provide food locally and develop healthy populations through fresh and nutritious food. In addition, it could decrease the vendors' long daily trips to distant markets, thus decreasing the dependence on fossil fuels needed for food transportation. A successful rooftop agriculture project also redefines open/green spaces for communities lacking green areas and gathering venues .It also contributes to building strong community bonds through residents' social integration and knowledge exchange.

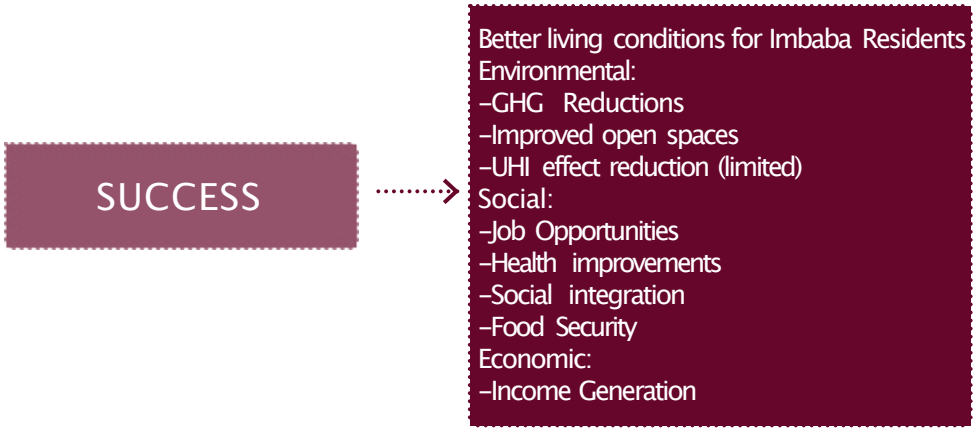


Figure 50:
The Success level applied to the Project

Courtesy of the Author

Strategic Guidelines

The main guidelines that could drive this project towards success requires backcasting from a vision compliant with the sustainability principles. When applying strategic actions to this project, the role they may play can be analyzed by asking the following questions:

1. Does this project help Imbaba taking a step towards compliance with the Sustainability Principles?

2. Does this project provide a flexible platform for future development of Imbaba?

3. Is this project likely to produce a sufficient return on investment (environmental, social, economic) to support Imbaba moving towards a sustainable future?

Those questions are the guidelines that would help identifying the values that this project could bring to Imbaba. They will be discussed after presenting the parameters of design of the project.

Actions

This project requires specific actions in order to move the system (Imbaba) which follows specific strategic guidelines towards success (better living conditions).

Involving the local CBOs in the different project stages as well as including the locals in decision making are important actions that have to be considered. Those actions will ensure the fitting of the designed model with the social and economic conditions of the residents. Regular monitoring and evaluation of the system as well as transparent communication between the stakeholders are also required to ensure the sustainability of the project.

Encouraging locals to increase their income and generate jobs through rooftop agriculture practices is the prime action that could push the project towards success. Moreover, it is important to change the locals' mindset into realizing the potential of their discarded roof spaces if properly utilized for farming practices. This could be achieved through presenting a visual image of the future scenery as well as the expected financial return that the project could establish. It is also important to spread the awareness of the high nutritional values of fresh food and its positive effect on health as another motivator for the success of the project.

Those actions would produce multiple solutions (social ,economic, environmental) which could help moving the project towards success. However, one action may positively affect one dimension while at the same time neglecting certain aspects of another. It is important to integrate the proposed actions to provide a holistic view of the expected results.

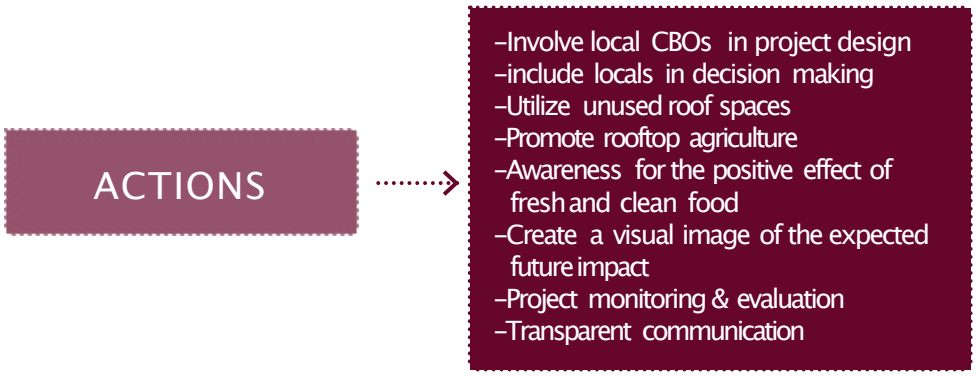


Figure 51:
The Actions needed for the Success of the Project

Courtesy of the Author

Tools

Different tools are needed to achieve the stated actions that will help moving the project towards compliance with the stated goals. The local CommunityBased Organizations (CBOs) in Imbaba is a strong tool that could provide a link between the residents and the project experts. Including the local communityin decision making could be achieved throughperiodical meetings, workshops and questionnaires. Walking and analyzing the streetsof Imbaba and visiting existing rooftops as well as direct communication with the locals are important tools that help properly analyze and present the existing conditions which reflects on the future creditability and success of the project.

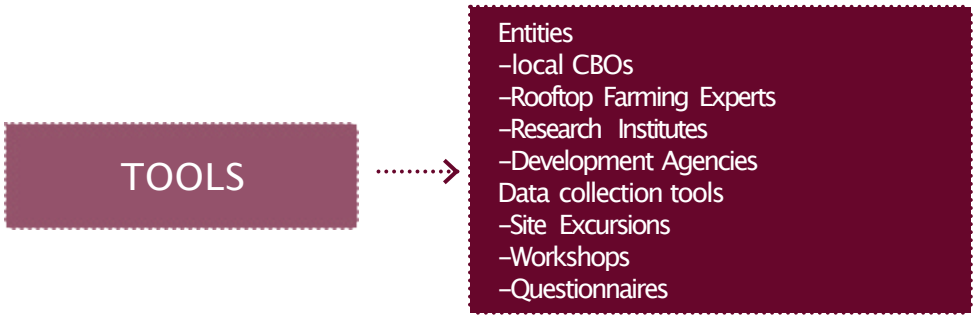


Figure 52:
The Tools needed to achieve the actions that drives the system to success

Courtesy of the Author

The framework described will be used to assist the project. Considerations will be made to the 5 Level Framework throughoutthe design of the project, developing a deeper and more structuredunderstanding of the systemdesigned from a sustainability perspective.

4.3. PARAMETERS OF DESIGN

Taking the information gleaned from the case studies as well as the authors better understanding of the technicalities of the previously described systems, This project moves into implementation. The project is entitled "Imbaba Farms" and is initially planned as a pilot phase on a houshold and a neighborhood levels.

4.3.1. Strategic Location

The area selected for the project piloting is located in the South West section of Imbaba, on the boarders of "Bashtil" informal settlement. Bashtil is a less densely populated informal settlementwere agricultural lands are still existing. As explained by a representative of one of Imbaba's CBOs, mostfamilies living on the outskirtsof Imbaba are previous Bashtil residents or their offsprings who usually sell their agricultural land and move out to nearby urban agglomerations. The probability of finding families with an agricultural background or 'hands still in the mud' as described increases at the Imbaba–Bashtil borderlines.

This location could help increasing the rates of success of this pilot project as the existing basic agricultural knowledge of the resident would facilitate the operation of the installed system and accelerates the creditability of the project incase of further dissemination.

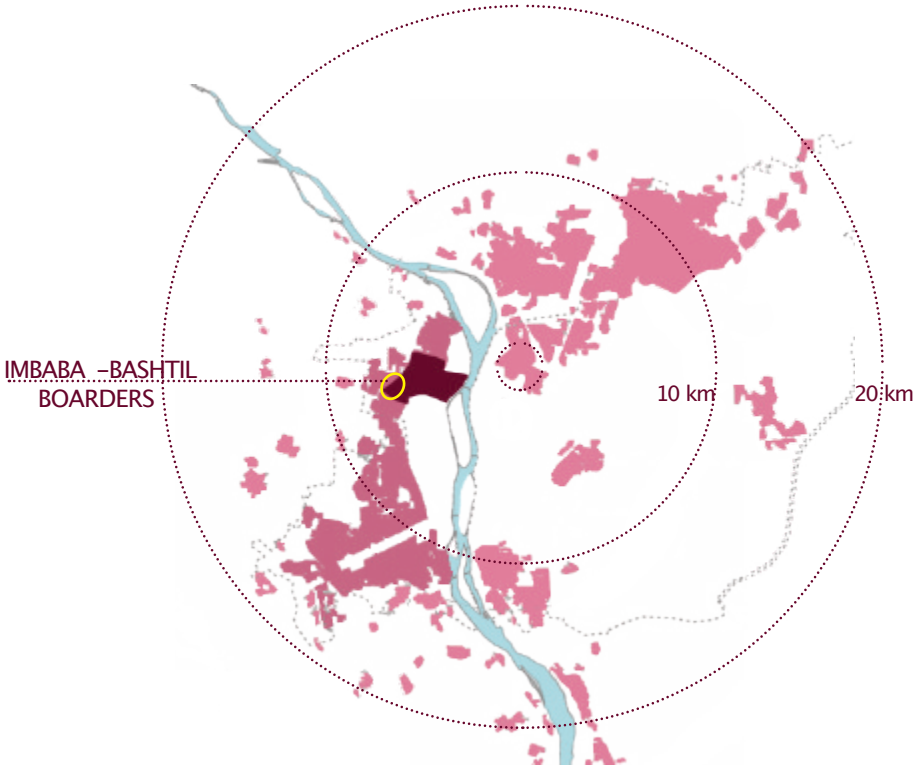


Figure 53:
The potential area selected in Imbaba for the pilot project

Author's presentation Based on maps retrieved from "The Parallel City" by Noheir El Gendy [15]

4.3.2. Selection Criteria

In order to reach out properly, a more detailed study is done for the social and economic status of the families of this area, to come up with the selection criteria of the candidates. This set of criteria are inspired by the previously described case study in Ezbet El Nasr. This criteria set priorities for widows/divorced with children, unemployed adults and housewives. It must be fulfilled by the selected candidates to grant the possibility of being a part of the project. the selection criteria states that:

The selected resident must own an accessible rooftop with minimum of 10 m^2 vacant space for farming. An area less than 10 m^2 would be less beneficial in terms of system design and produce quantity.

The selected residents must be willing to co–finance 10 % of their installed system to guarantee commitment to the project and to assure ownership of the installed system. The 90 % remaining cost is paid through interested national and international development agencies, research funding institutes planning to examine a pilot project in the field of urban agriculture, and/or community services organizations working on the development of informal settlements.

The selected resident must pass a basic agricultural evaluation test in order to be granted a "Rooftop Farmer" title. Residents can choose between

taking the test directly if they think that they have the required knowledge or they could attend a free organized compact course before taking the test.

The selected resident mustalso allocate at least 1 hour per day for the rooftop farm to assure the ongoing operation and maintenance of the installed system.

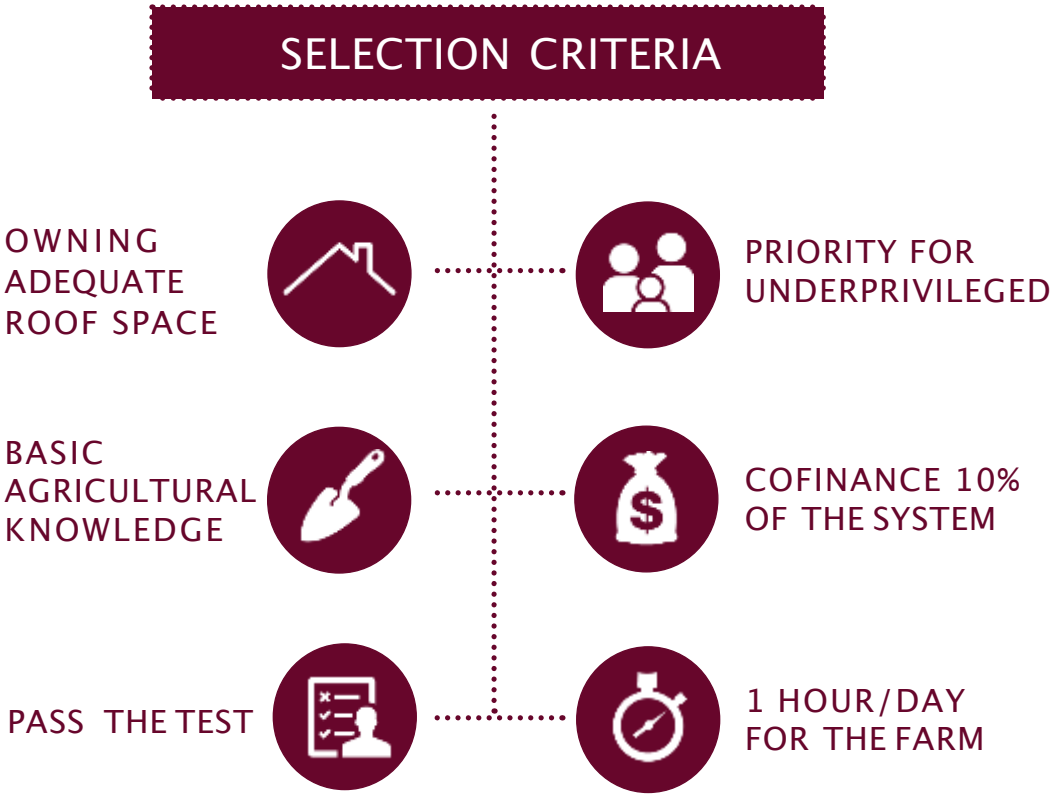


Figure 54: Selection Criteria of the project beneficiaries

Courtesy of the Author

Setting a selection criteria could increase the rates of success of the project .The residents who are qualified for this set of criteria would have a suitable start up potential to operate the agricultural producing systems installed on their rooftops. Following this criteria would ensure that this system reaches the suitable calibers, which eventually contribute to the success and sustainability of the project.

4.3.3. Project Structure

The project is managed through collaboration of different stakeholders. Imbaba's CBOs represent the connection between the project entities (Rooftop farms technicians, development agencies, research institutesand the residents).

The local CBOs under the supervision of the research institutesand the funding agencies is responsible for the selection of the residents that might have the potential to fit in the previously presented set of criteria. The local CBOs also plays an importantrole in the financial systemof the project. A special financial unit is created for the project under the CBOs' management inorder to organize the profit of the rooftop farmers and regulate the prices of crops sold in the farmers markets. The CBOs also

manage the local venues where "Imbaba Farms" produce are presented and sold. In addition, it examines the opportunities of selling the produce to nearby supermarkets in formal areas.

The local CBOs cooperates with the development agencies, research institutes and the funding NGOs to hire the rooftop farming technicial firms, to work on the implementation of the rooftop farming systems. The technical firms are required to carry out the training sessions as well as organizing the technicial and theoratical exams needed by the residents. The technicial firms also cooperates with the CBOs in organizing the types of crops planted in the different blocks of the neighborhood.

The residents role in the project is defined and straight forward. After fitting for the selection criteria, the residents are obliged to manage and maintain their farms on daily bases. Any technical malfunction of the system in the first year after the project implementation will be managed and maintained by the technical firm. The residents are committed to harvest the crops after ripeness and deliver it directly to their corresponding farmers market were they get paid through the financial units of the CBOs.

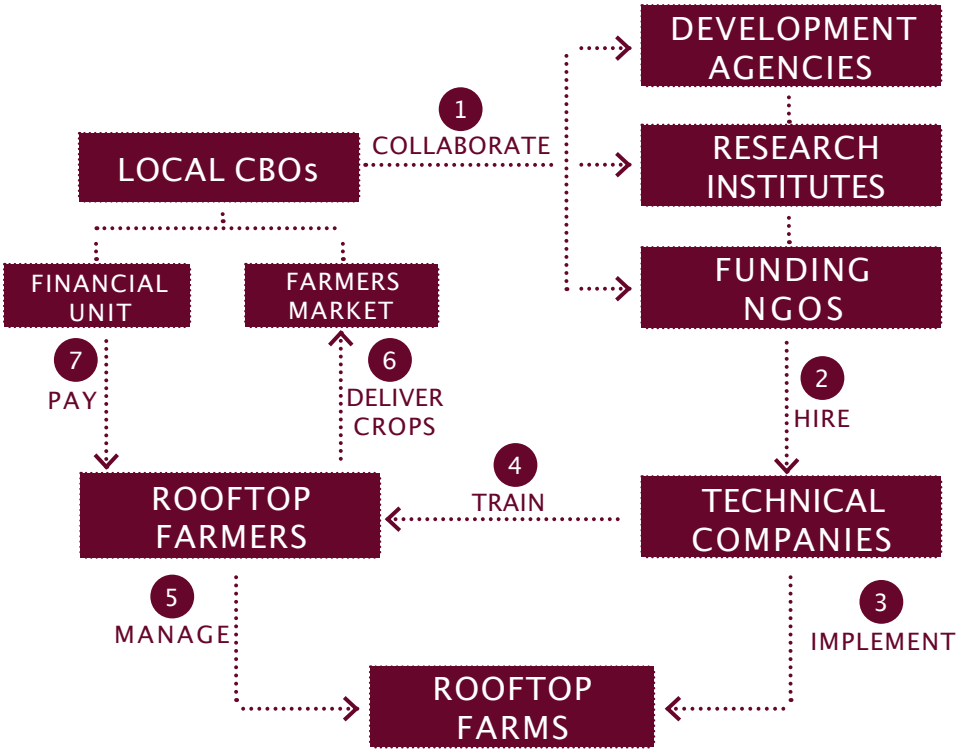


Figure 55: The preliminary Structure of the pilot project

Courtesy of the Author

In the project's second phase, the structure is planned to transform. The future plan is to create a local autonomous entity that fully control the designed structure. After gaining enough experience through participating in the design, implementation and maintenance of the early phases of the project, this entity should be qualified to gradually overtake the duties of the development agencies , research institutes and funding entities. A project management unit would be created by the CBOs to manage the existing phase as well as planning the future expansion phases of

the project. The role of the development agencies , research institutes and funding NGOs would be limited to periodical supervision of the progress and offering advice when needed. A technical unit is planned to be designed under the supervision of the project management unit. The local technical unit could overtake the duties of the technicial companies who implemented the pilot phase of the project. The technical companies role would also be limited to periodical supervision, to ensure the proper technical management of this unit. In addition, this unit would help creating a local microbusiness opportunity for rooftop farming systems as well as training seminars for the future rooftop farmers.

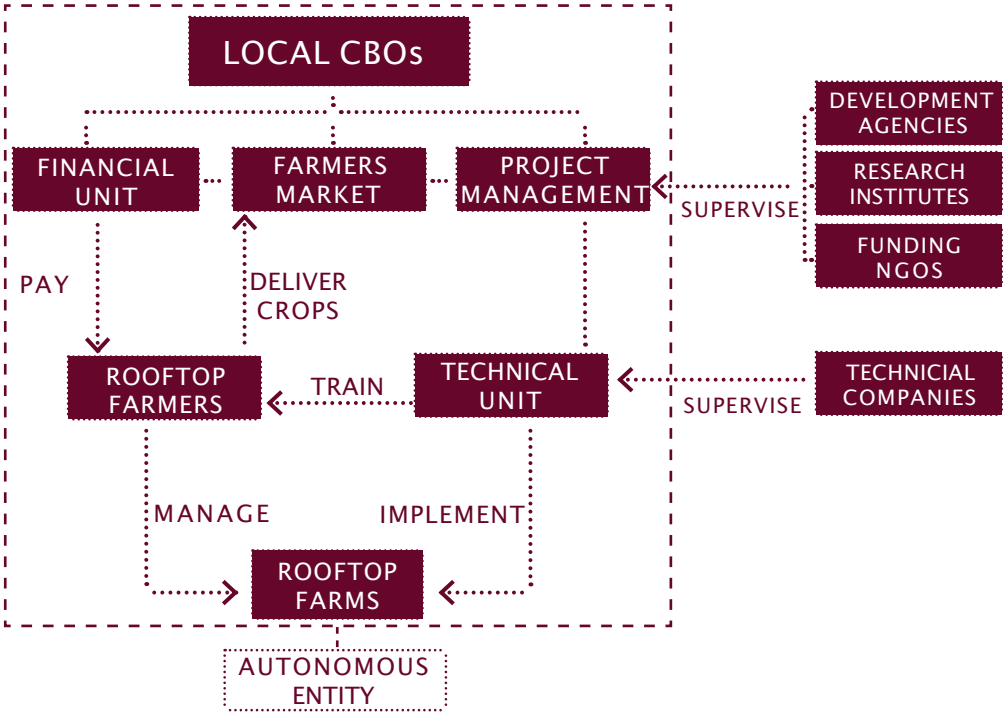


Figure 56: The Project future Structure transformation

Courtesy of the Author

4.3.4. Household Scale

The rooftop agricultural system implemented is "Deep Water" hydroponic system. As previously explained, hydroponics represents a fit for the context of Imbaba. The system is light weight, relatively cheap, water efficient and does not require high technology components.

The base of the system consists of locally constructed wooden basins. To avoid purchasing new materials, the project could utilize a lower cost opportunities, like buying planks leftovers from furniture factories or purchasing the unused wooden pallets in exportation activities of existing companies. With minimum effort the wood could be unassembled, treated and reused to construct the simple basin. Plastic basins could be an alternative incase of difficulties in acquiring wood. Plastic basins are also cheap and locally available. The dimensions of the basin are flexible depending on the surface area of the roof. However, for the effectiveness of the system it was assumed that the minimum surface area of a basin should not be less than 2 m^2 to ensure effective productivity.

The basin is covered by a layer of white foam sheets acting as an insulator for the wood. The white foam is a low cost material that could be found locally. To decrease the system cost accompanied by purchasing new foam sheets, the project could target corporate social responsibility (CSR) programs of local foam companies that might donate unutilized leftovers. Moreover, the project could benefit from the unused foam that resulted from unpacking electronic machines, tv sets, printers,etc.. which could be donated or purchased from companies, office buildings or individuals.

The foam is then covered by a thin layer of polyethylene that seals the wooden basin and protect it from water and root penetrations. Polyethylene is an available cheap insulator that is easily installed and is less problematic compared to other low cost insulating materials.

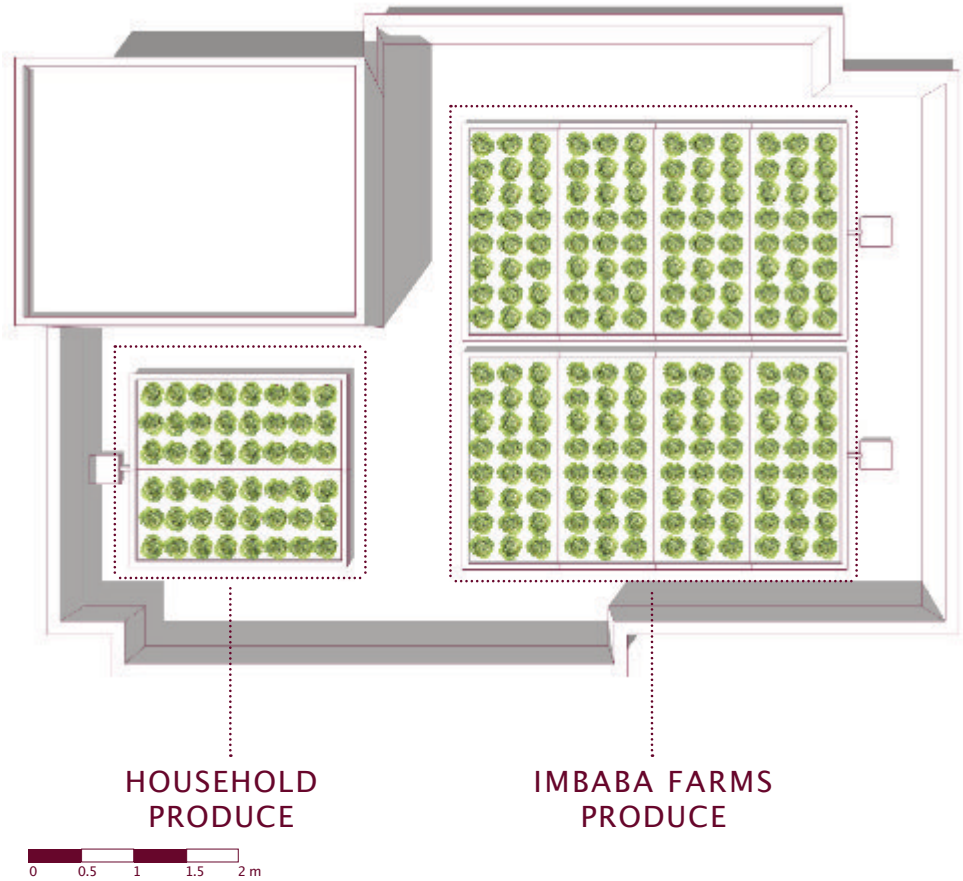


Figure 57:
A plan of a prototype Rooftop farm of 55 m²

Courtesy of the Author

The basin is then filled up with a mixture of water and nutrients. Nutrient solution can typically last 14–21 days, but it all depends on the size of the plants, the climatic conditions and the volume of the basin [40]. After this period the basin could be refilled with half-strength nutrient solution rather than making up an entire fresh batch, which eventually leads to less water consumption [40]. PH values and color of nutrient solutions should be inspected by the rooftop farmer to ensure that the system is properly functioning.

As previously explained, air pump is an important component for most hydroponic systems. The nutrient solution has to be constantly aerated to ensure proper plant respiration and to provide enough levels of Dissolved Oxygen (DO). DO is vital for the health and strength of the root system as well as being necessary for nutrient uptake [38].

The last layer is the perforated foam which is carved to fit the width of the pot or the saplings. The pot filled with peatmoss or perlite, is fixed inside the foam layer and left to float on the surface of the water. A bird mesh could be further used for protection of the plants. The seeds or saplings needed for the first year of production are financed through the pilot phase developers within the budget of the project. The seeds of the future cycles could be purchased by the farmers from the Egyptian Institute of Agricultural Research which could cooperate with the project developers to provide low cost seeds and saplings compared to the private market prices.

The household system is subdivided into two sections. The main section is usually the bigger one, were the expected produce would not be the property of the household. However, the residents have to ensure the proper functioning and maintenance of this section. The other smaller section is a property of the household. Farmers are free to plant any desired crops that fit with the installed system. The produce of this section is divided among the project owners for their own consumption.

Efficiently using the available resources could lead to higher rates of success of the project. Reusing existing materials would have a positive impact on the environment and coincide with the sustainability principles. It could prevent pollution caused by the need to harvest new raw materials and would reduce greenhouse gas emissions resulting from materials transportation. Used wood and foam could be purchased and reused with prices lower than new ones, which eventually decreases the cost of the designed system.

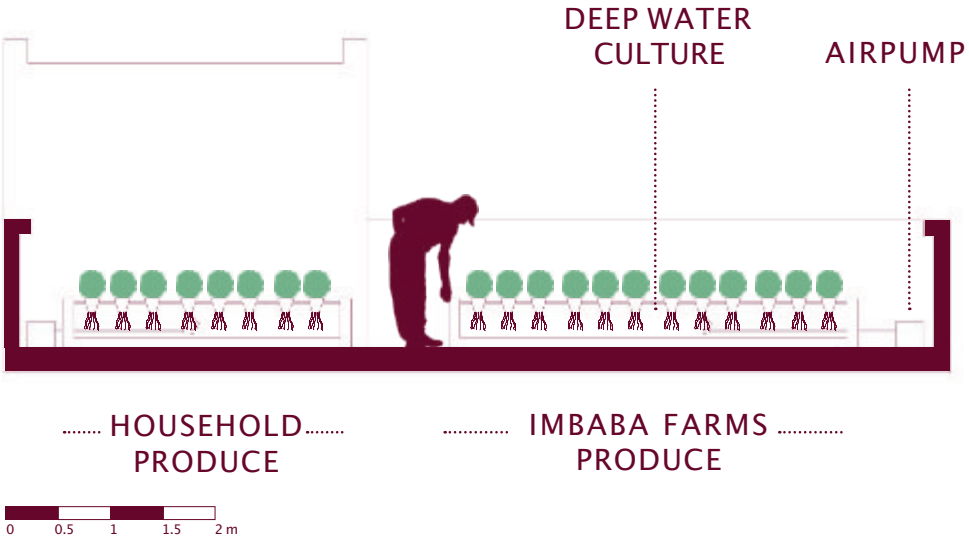


Figure 58:
A section through the rooftop farm

Courtesy of the Author

4.3.5. Neighborhood Scale

Neighborhood Scale

The neighborhood scale provides a more comprehensive approach based on the integration of adjacent blocks

The previously described model provides flexibility in adapting to different patterns of neighborhoods. The neighborhood scale is based on an integrative approach between adjacent blocks inside one neighborhood. The crops selection for each block is based on the studies and recommendations of the rooftop agriculture technical firm integrated with the needs of the targeted neighborhood. Residents should abide to the rules of crops selection in order to direct the designed system to function properly. The project future phases could spread on a wider scale, integrating different neighborhoods together and increasing the variety of crops.

This strategy gives the rooftop farmers of each block an advantage of frequent planting and harvesting specific crops based on the agricultural season. The farmers could improve their agricultural skills and master the techniques and the know–how of managing specific crops through time. Eventually, this will decrease the chances of technical difficulties and reduces training sessions required as a result of lack of knowledge of new crops.

The training sessions carried out for the residents before taking the evaluation test should cover general information about rooftop farming as well as a brief explanation of the structure of the project. The training should provide technical information regarding planting and harvesting , pest and growth problems and means of monitoring the system in cases of malfunction (PH values, Nutrient solution ratios, root cause problems..etc). The training also should provide a session that presents proper packaging and handling techniques of the crops in order to ensure the safety of the final product.

Managing the neighborhood scale in an integrative manner could increase the success rates of the project. The residents would have the chance to cover their own needs of the specific crops planted on their rooftops, as well as making a reasonable amount of money from selling the produce. In addition, they could benefit from the adjacent farms through purchasing their crops from the neighborhood's farmers market. The project also could provide extra job opportunities for the locals in the farmers markets units and the CBOs financial units.

A future plan for the project could integrate rooftop agriculture containers with the existing installed system, to be able to cover other crops that could not be planted in deep water hydroponics. As previously analyzed, containers are raised soil–based systems which are characterized by their high flexibility in size as well as their adaptability to different roofs circumstances [62]. Moreover, it could provide a dynamic solution for crops that need a layer of soil.

NEIGHBOURHOOD SCALE

BLOCK -A-

CABBAGE

BLOCK -B-

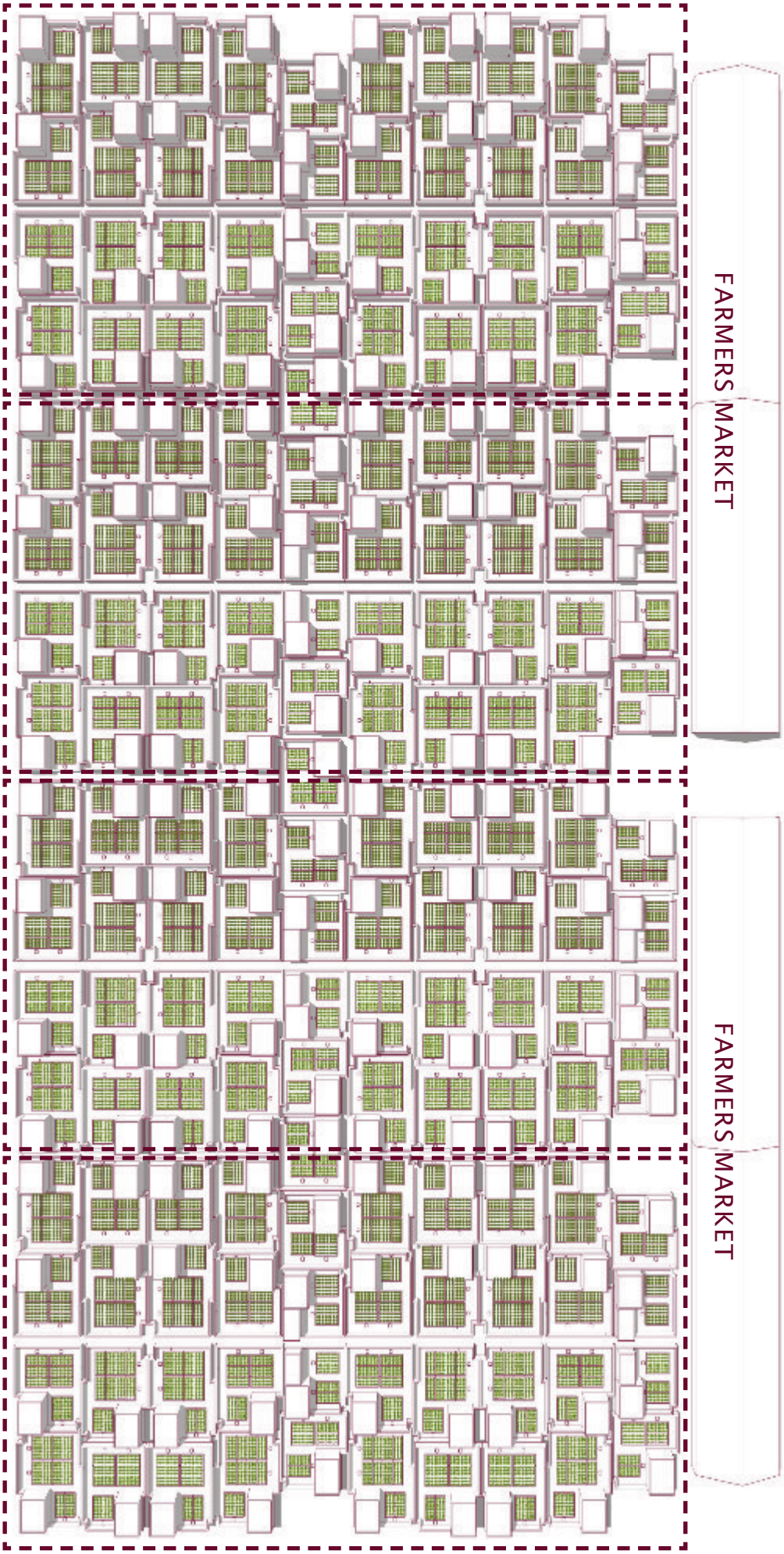
PEAS

BLOCK -C-

LETTUCE

BLOCK -D-

PEPPER



4.4. EXPECTED IMPACTS

Based on the previous analysis of Imbaba and the presented rooftop agricultural types, the project is expected to have disparate environmental, social and economic impacts.

The project is expected to positively impact food security, complemented by using hydroponic systemswhich are generally characterized by their high yielding capabilities. Beside the quantity, the produce is expected to be fresh as a result of not traveling long distances to reach the consumer, as well as being clean for not utilizing any harmful pesticides or chemical fertilizers. Using water based hydroponic system decreases the probability of crops contamination compared to soil based systems, which eventually contribute to a better quality of the produce. Moreover, the system designed should provide reasonable variety of crops recommended by the technical firms, which are suitable for the installed system and are frequently consumed by the residents.

It is expected that the project could be highly influential in stimulating the local economy through creating a new job market. The project could provide a reasonable financial profit and increase the incomes of families affected by continuous rising in prices of basic services. The project could also provide a venue for social gatherings in a community suffering from the lack of open spaces, as a result of compact construction. The project could also improve the agricultural knowledge of the residents through training sessions, evaluation exams and daily practices.

Figure 59:
A layout designed for a neighborhood rooftops, assigning different crops to the proposed blocks (Left)

Courtesy of the Author

As previously explained, hydroponics may have lower environmental impacts compared to other types of rooftop agriculture systems. Drawn from the previous experience of the rooftop agriculture project implemented in Ezbet El Nasr, which concluded that the project had limited improvements in the surrounding microclimatic conditions [31], this project is expected to have a limited impact in mitigating UHI effect. However, this expectation might not be very accurate when taking into consideration the different circumstances with respect to project design, demography, urban density, scale of project and location.

The project is also expected to slightly impact biodiversity loss due to the technical nature of hydroponic systems and the absence of substrate. However, living vegetation could still provide habitat for some species. The degree of impact would vary based on the density of the farms and the types of plants used.

The existing Imbaba vendors usually travel a daily trip of 26.5 km to the outskirts of Cairo to a big market hall (El Oboor Market) that offers varieties of fresh produce [65]. When analyzing the project on a neighborhood scale, the project is expected to have an impact in decreasing this daily commute which could result in GHG reductions related to food transportation.

The project could also have an impact on decreasing the use of raw materials through reusing and recycling wood and foam. It could utilize a future opportunity of using household organic waste after composting, to use it as a fertilizer for the installed system. However, this would require specific interventions and more planning related to composting procedures and techniques.

Most of hydroponic systems uses water efficiently. However, the installed system presents a lower level of efficiency compared to closed circuit types. The water basins only require adding extra amount of water (vary based on the design) to compensate the plant consumption and evaporation losses. The system installed could utilize a future potential for the reuse of treated grey water, which is separated from blackwater in Imbaba but not treated or utilized.

In terms of energy usage, most of hydroponic systems require a constant energy input. The system implemented in this project requires the installation of air pumps in order to ensure the constant aeration of the nutrient solution. However, In case of electricity cut outs or the malfunction of an airpump, the designed system could be manually aerated using a hand pump or an aeration stick. This is one of the advantages of Deep Water culture compared to most hydroponic systems which usually need electricity to pump and deliver nutrient solution to the plant roots.

In terms of green spaces, the project is expected not to completely fulfill the aesthetic objective of green roofs. Hydroponics are not systems that provide a strong connection to nature due to its technical quality and the absence of soil hosting diverse types of aesthatic greenery. However, the roof design could always be guided to integrate the crops planted with other softscape features that could provide an aesthetically pleasant view of the roof.

The previously presented impacts should help Imbaba take a step towards compliance with the previously mentioned sustainability principles. The project could provide a solution for the residents to meet some of their needs through gaining an extra income and consuming healthy and nutritious crops. The project also could efficiently recycle existing materials and cut down the consumption of raw ones. However, the project does not fully comply with the sustainability principles in terms of water efficiency as a result of using a relatively less efficient system.

This project could provide a flexible platform for the future development of Imbaba, developing a new concept that aims to increase the agricultural production through the integration of neighborhoods. This could gradually revive the original function of the Imbaba land, a district emerged longtime ago to be agriculturally productive. The project could also generate new intervention that deals with the lack of open/green spaces in narrow streets.

Expected Impacts

The levels of impact proposed is the author's expectations based on the integration of the previously studied topics and an imaginary backcasting from a success level

This project is likely to produce a sufficient return on investment to support Imbaba moving towards a sustainable future. The project could contribute to an environmental return through decreasing GHG emissions related to food transportation as well as a limited impact in mitigating UHI effect. The project could contribute to a social return through providing job opportunities, fresh and clean produce and gathering venues for residents living in areas that lack adequate open spaces. The project could contribute to an economical return through improving the financial situation of the low income families and stimulate the local economy as a result of internal trading activity.

The expected impacts of this fictional model depends on a qualitative backcasting from an imaginary success level reached in this project. Those impacts were built through integrating the structure of this project and the previously studied topics. The project impacts –in this stage– cannot provide precise figures and numbers that could be taken for granted or used as a marketing strategy.

The project provides a resilient design that could positively impact different sustainability aspects. However, the quantitive impacts of this project are not tangible as a result of not identifying a specific scale or a defined area of focus.

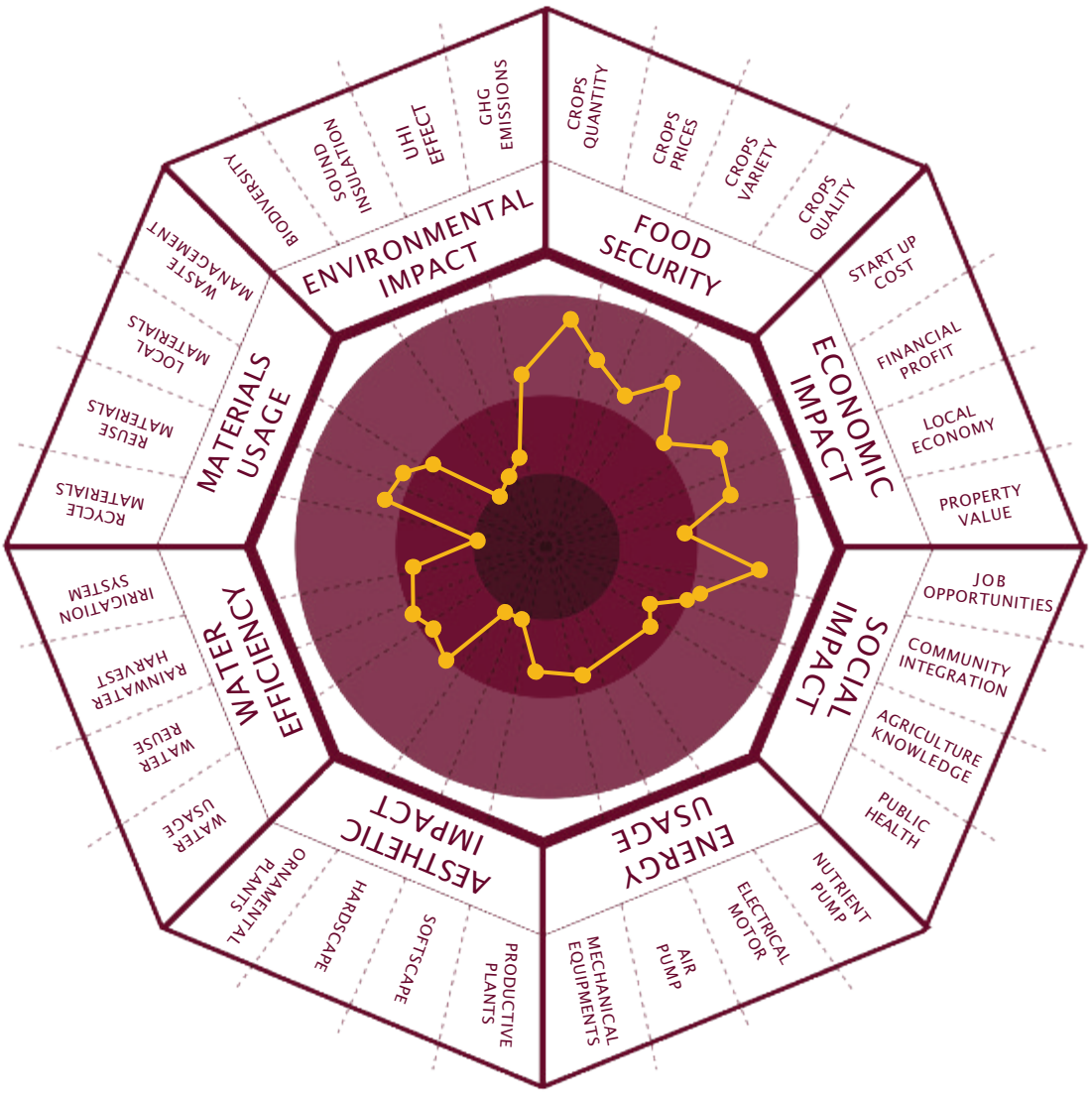


Figure 60:
The project expected qualitative impacts

Courtesy of the Author

IMPACT LEVEL

HIGH

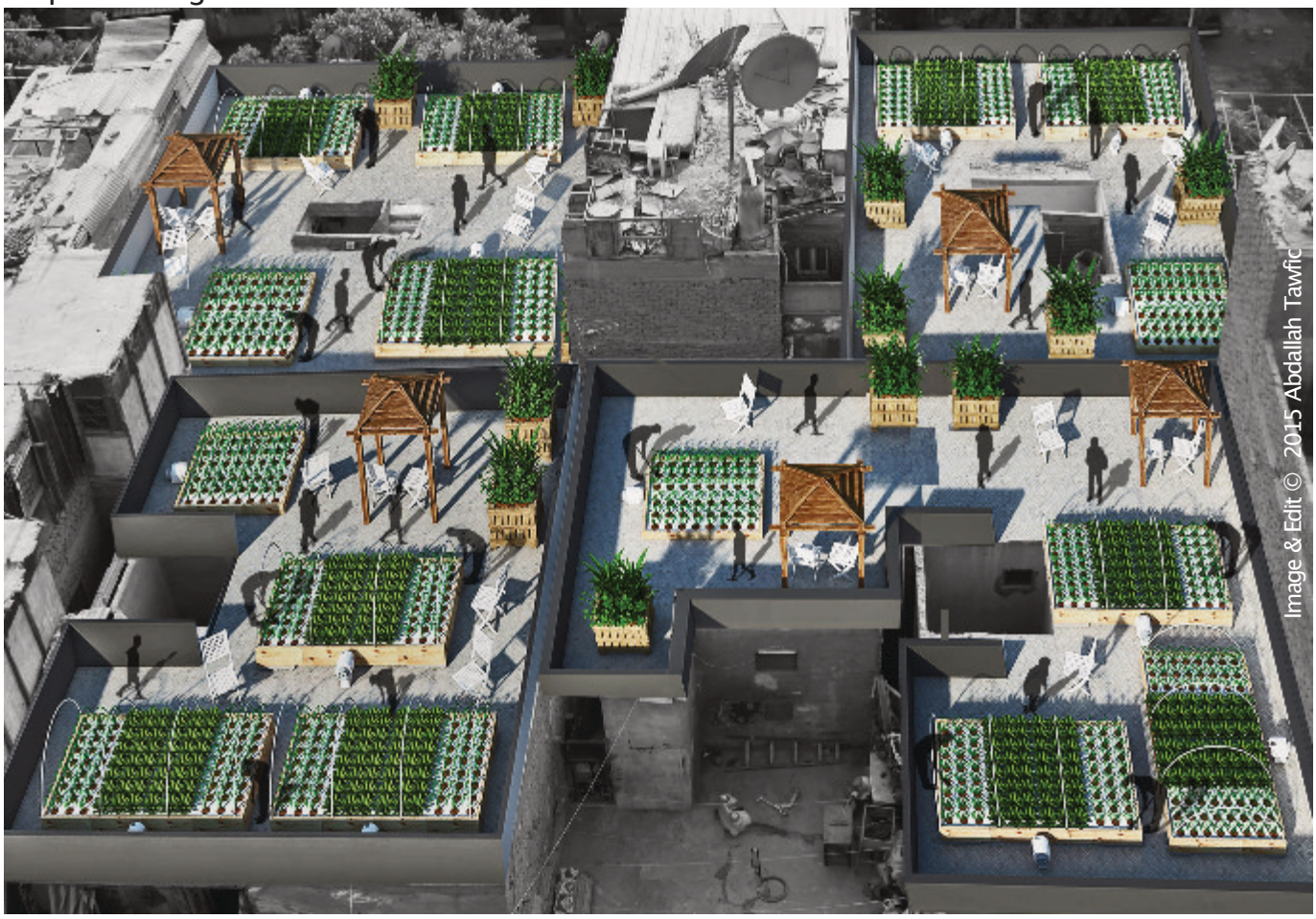
MEDIUM

LOW

the levels of impact proposed is the author's expectations based on the integration of the previously studied topics and an imaginary backcasting from a success level

Current Situation

Proposed Design



Current Situation

Proposed Design

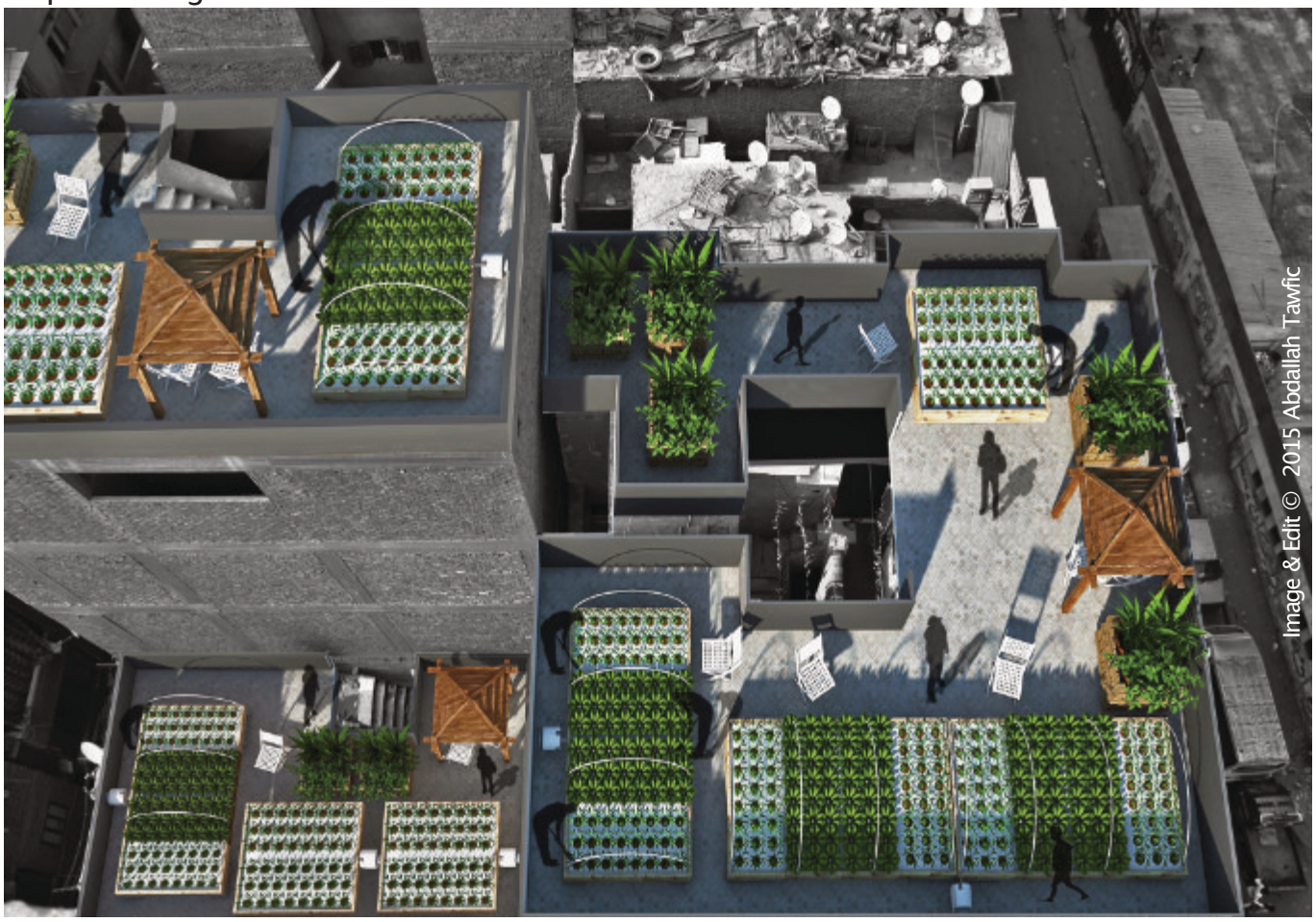



Image & Edit © 2015 Abdallah Tawfic

4.5. CORPORATE IDENTITY

In order to be presented in the market, Imbaba farms would complement its fresh and nutritious produce with an attractive and simple identity. The logo uses all the shades of green color in its designs to reflect the ambitions for a green future and a healthy lifestyle. The logo would be stickered on the packs of vegetables and fruits and printed on bags used in the farmers markets.

The logo is available in both Arabic and English designs, in an attempt to attract international development agencies and urban agriculture investors and developers planning to test the produce or work on developing the project to an advanced level.

Figure 61: Imbaba Farms different designs of the English Logos

Author's presentation
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Figure 62: Imbaba Farms marketing produce

Author's presentation.
Image courtesy of: freegreatpictures.com

The project could launch a campaign that markets "Imbaba Farms" produce to nearby restaurants in the formal areas around Imbaba, as well as supermarkets that are interested in presenting organic roof grown produce.

The future phases of this project could also include an online unit under the supervision of the CBOs management, containing an updated website and a facebook page that works on informing Imbaba Farms' customers in restaurants and formal areas with the available different types of crops for online orders. Fresh vegetables baskets could also be delivered upon request to groups or individuals, creating more fields and job opportunities for the residents of Imbaba.

Figure 63: Imbaba Farms different designs of the Arabic Logos

Author's presentation © Imbaba Farms.All Rights Resereved.

Figure 64: Imbaba Farms vegetable Basket

Author's presentation. Image courtesy of: freegreatpictures.com

4.6. SWOT ANALYSIS

S

- Providing an extra source of income for the underpriviliged.
- Providing diverse job opportunities.
- development of local economy.
- Providing fresh, clean and nutritious food for the residents.
- Increasing the residents' agricultural knowledge
- Providing venues for social gatherings and community bonding.
- decrease the use of raw materials and promoting reusing and recycling.
- improving the function of rooftops which are mainly used for storing old and unused stuff.
- The neighborhood model provides variety of crops.

O

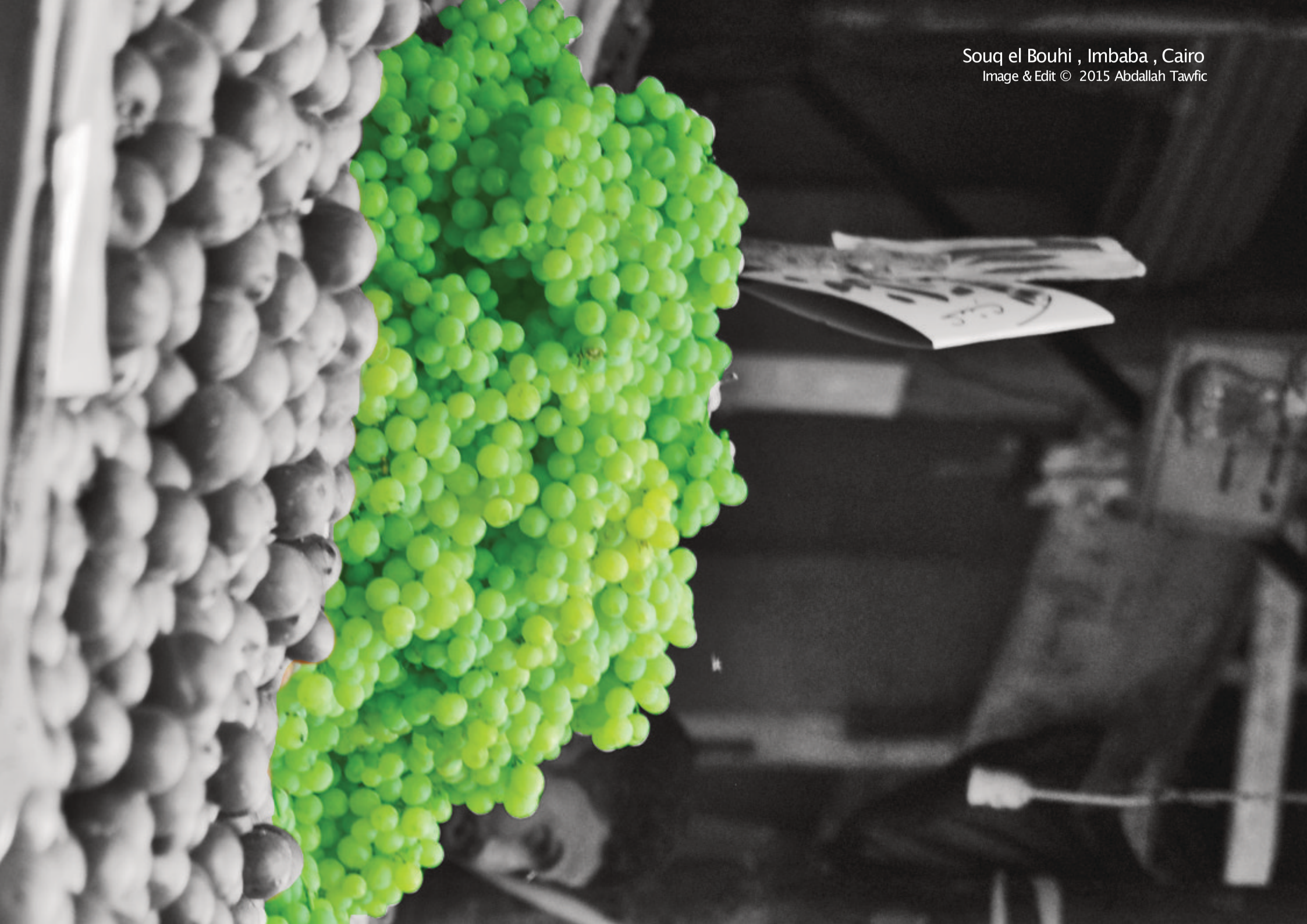
- The project could utilize an opportunity of treatment and reuse of grey water for irrigating the crops.
- The model could be developed and transformed to target formal areas.
- If well managed and marketed , the produce could reach supermarkets of adjacent formal areas.
- Integrating several neighborhoods in the project could provide wider variety of crops.
- In case of future dissemination, the private sector could invest in similar models using more complex systems (inspired by Lufa farms) to increase the quantity and quality of the produce and provide more efficient and well managed crops.

W

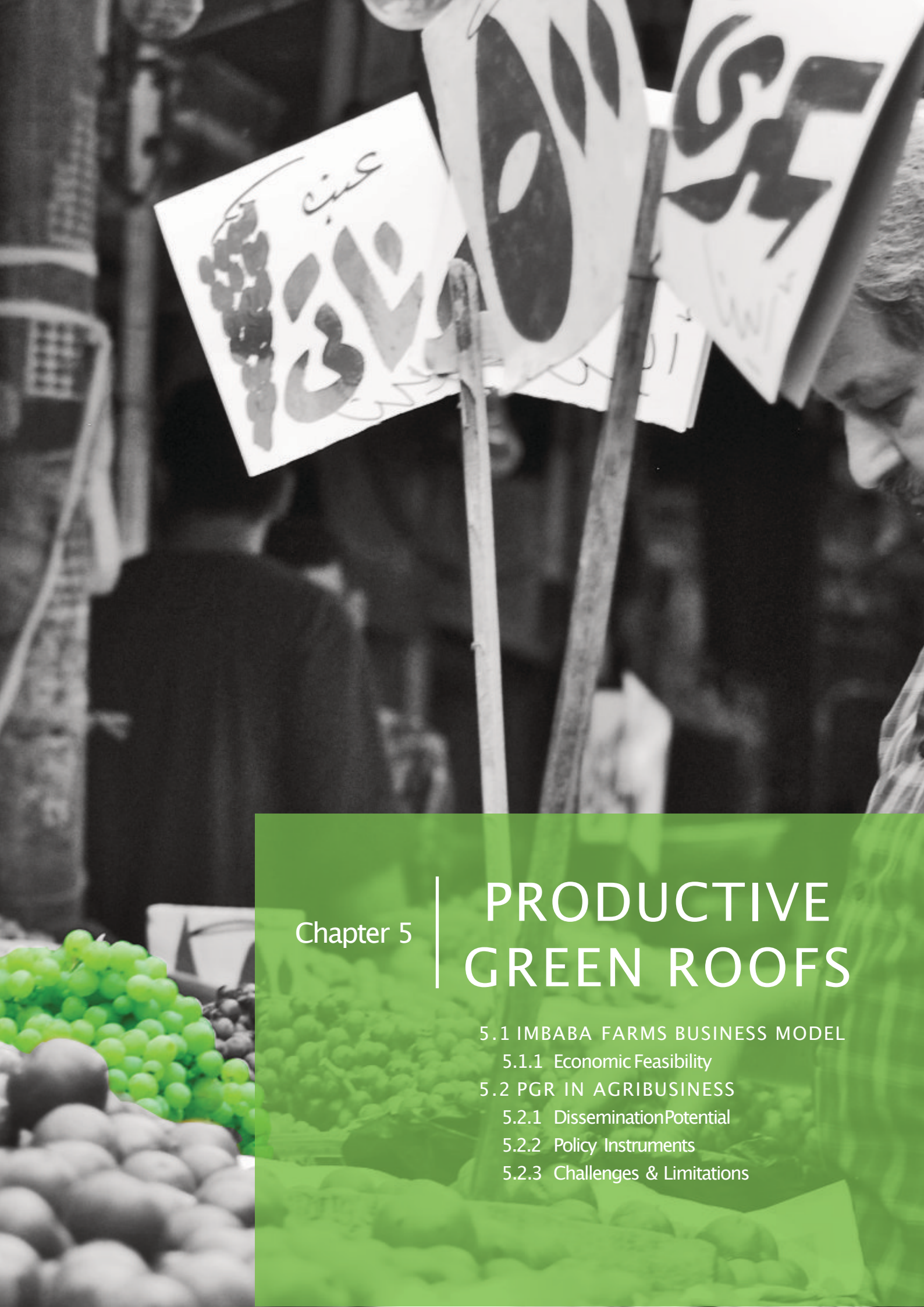
- Crops varies in price in the Egyptian market.This will force farmers to avoid low cost crops, searching for a higher financial profit.
- Although hydroponic systemsare generally water efficient compared to soil based, the installed systemis less efficient
- The need for airpumps which requires a source of electricity add an extra burden on the rooftop farmers.
- satellite dishes– if not relocated– would limit the area used by the rooftop farmers when installing their systems.
- The project would have a limited effect in mitigating UHI effect and biodiversity loss.
- Incase of a non family based house, conflicts between teants could occur when managing profit and crops.

T

- Some farmers seeking a higher financial profit may find other ways to sell the crops individually.
- The fluctuations in prices of fruits and vegetables and the changing behavior of supply and demand in the Egyptian market through time could lead to reluctant decisions regarding the types of crops chosen for the project.
- The failure to control the systemin bad weather conditions could cause the damage of crops.
- Incase of dissemination, a possible conflict could occur between the existing street vendors and the farmers market buyers as a result of competition



Souq el Bouhi , Imbaba , Cairo



Chapter 5

PRODUCTIVE GREEN ROOFS

5. PRODUCTIVE GREEN ROOFS

As previously described, Imbaba Farms provided a promising concept designed for food production and income generation in informal settlements. In order to convince the house owners to invest in a rooftop farming theme, a simple business model of the system expenditures as well as the expected profit should be created. This chapter presents a simple feasibility study of a proposed rooftop farming theme on a household level. This chapter also introduces the concept of productive green roofs for informal settlements and how it can contribute in terms of quantity and quality to the Agriculture business sector. Moreover, this chapter discuses the strategies applied for the dissemination potential of this concept as well as the obstacles, challenges and limitations that can face it.

5.1. IMBABA FARMS BUSINESS MODEL

Imbaba Farms is piloting as a research project on both a household and a neighborhood scale. As previously explained, 90 % of the startup cost of the pilot phase would be covered through donations. Moving on to a post pilot phase, the project should provide an independent business model that could guide future rooftop farmers through the expected return of investment. This model varies based on several factors including surface area of farming, crop type and crop market price.

5.1.1. Economic Feasibility

This model assumes a rooftop surface area of 60 m^2, were 30 m^2 is dedicated to rooftop farming practices. Based on the previous rooftop farming project executed in Ezbet El Nasr, the technical company working on the implementation of the project (Schaduf) defined a price of 140 EGP/m^2 for installing a deep water hydroponic system, including all its components [31].

Based on that, the initial cost of implementation of a 30 m^2 rooftop farm would be : 30 m^2 x 140 EGP = 4200 EGP. In case of the project's pilot phase, the farmers are required to cofinance 10 % of the system to ensure ownership and commitment. In this case each rooftop farmer should be able to pay 420 EGP to own his/her rooftop farm.

The prices of fruits and vegetables in the Egyptian market is variable based on the supply and demand and the location of markets. This model is using the prices of vegetables from El Obour market where almost all Imbaba vendors purchase their produce [65].

This model assumes Lettuce as the chosen crop for this study. The updated price of Lettuce in El Obour market is ranging from 1.5 to 3.5 EGP/kg, depending on the species and without adding the profit bracket of the vendors [21].

Imbaba Farms Business Model

This model presents an overview of the possible system cost and the future return of investment

For the production of lettuce hydroponically, 1 m^2 of a hydroponic system could produce 15 lettuce heads with a 15 –33 cm distance between the lineal centers [39] [52].The weight of a fully ripe lettuce head is ranging between 0.5 –0.8 kg depending on the species [55].

The rooftop farm of 30 m^2 could produce: 30 m^2 x 15 lettuce = 450 lettuce head per cycle. Lettuce is a crop that can grow hydroponically almost all year long in northern latitudes [76]. In the context of Egypt, lettuce is a winter crop that can be planted during the months of October and November [52]. However, other lettuce species could be planted all year around [72]. Lettuce usually need 30 –90 days for harvesting depending on the planted species and the follow up time [88] [56]. The selected household could produce : 450 lettuce head x 0.5 kg = 225 kg of lettuce per cycle. Assuming a 5 % loss in produce, This means that around (225 x 5 /100=) 11 kgs could be lost each cycle. As a conclusion the net lettuce produce could be : 225 kg (yielding capacity) –11 kg (expected loss) = 214 kg.

When sold to the farmers market following El Oboor market price, the net profit of planting lettuce hydroponically in one cycle could be : 214 kg x 3.5 EGP = 749 EGP

this means that in the pilot phase, the farmers planting lettuce could make a profit of (749 –420 EGP (10% cofinance)) 329 EGP starting from the first planting cycle. While the future cycles could provide the whole 749 EGP, if no maintenance or seeding costs are required.

When looking at the opportunity of self financing the project on a household level, the rooftop farm investor in this case would need : 4200 EGP(total cost of system)/ 749 EGP(profit per cycle) = 5.5 cycles. if the planting cycle is averaging on 60 days that means that the rooftop investor would need (60 days (2 months)x 5.5 cycles = 11 months to break even and start making a profit. Adding a risk factor for natural hazards, the running cost and possible maintenance cost , the project could roughly start making profit after 13 months.

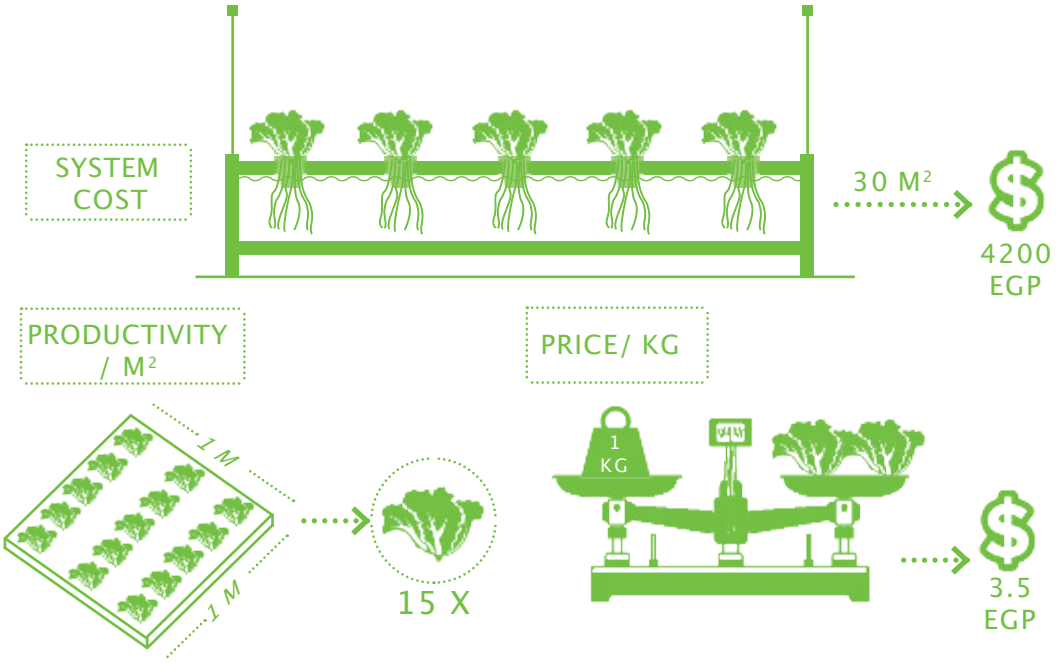


Figure 65: Lettuce production in a 30 m^2 hydroponic rooftop farm

Courtesy of the Author

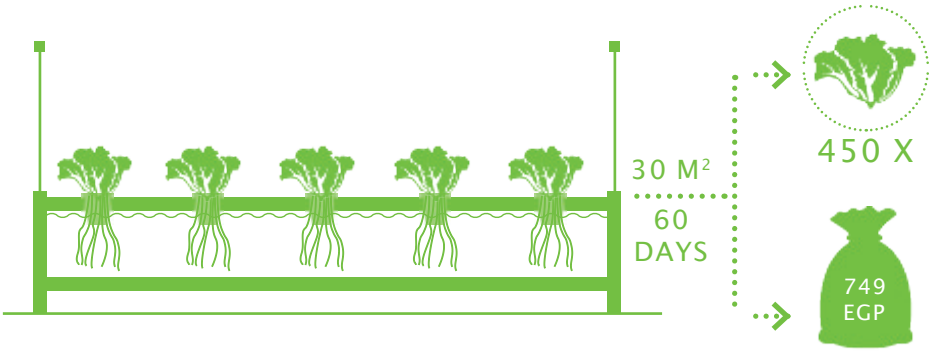


Figure 66:
Expected yielding and profit of hydroponically planted Lettuce per cycle

Courtesy of the Author

Utilizing the same rooftop farm but testing a different crop like Green Beans, it was found that the price in El Oboor Market ranges from 12 – 18 EGP /kg [21]. For its production, 1 m^2 could produce an average of 4–6 kg depending on the seeding distances and the vertical limits of the growth [81]. The harvesting cycle of Green Beans ranges between 5 –12 weeks depending on the planted species [3]. Green beans is a crop that can be planted all year in Egypt [25] . This means that the rooftop farm of 30 m^2 could roughly produce : 30 x 4 = 120 kg/cycle. Assuming a 5 % loss of produce per cycle (5 x 120/100= 6 kg). When sold based on the market price , the expected profit could be : 114 (net kgs of peas) x 15 (Price/kg) = 1710 EGP/cycle.

This means that in the pilot phase, the farmers planting Green Beans could make a profit of 1710 –420 = 1290 EGP starting from the first planting cycle. The future cycles could provide the whole sum of profit if no maintenance or seeding costs are required.

When looking at the opportunity of self financing the project on a household level, the rooftop farm investor in this case would need : 4200 EGP(total cost of system)/ 1710 EGP(profit per cycle) = 2.5 cycles. if the planting cycle is 90 days, that means that the rooftop investor would need (90 days (3 months)x 2.5 cycles = 7.5 months to break even and start making a profit. Adding a risk factor, the running cost and possible maintenance cost , the project could roughly start making a profit after 12 months.

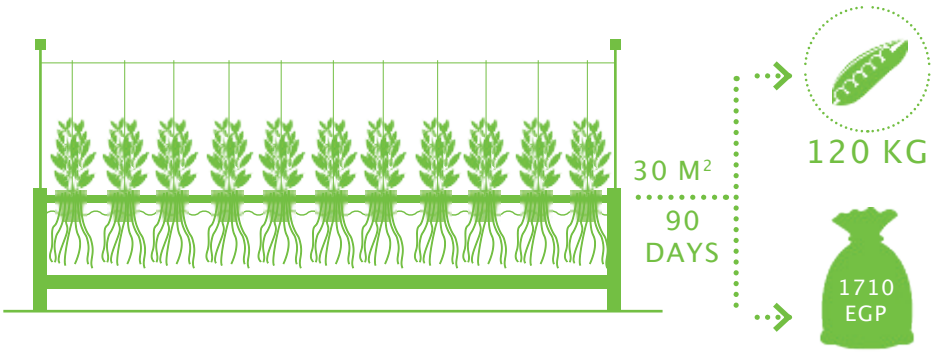


Figure 67:
Expected yielding and profit of hydroponically planted Green Beans per cycle

Courtesy of the Author

All types of crops varies in planting seasons, production cost, operation & maintenance time and effort ,shelf life, market supply and demand which leads to a wide variety of prices based on their different circumstances. This model could be presented to the project beneficiaries to analyze various types of crops, providing approximate figures of the startup cost of their systems as well as the expected profit.

5.2. PRODUCTIVE GREEN ROOFS

Rooftops in our urban centers represent a strong potential of currently underused space. The transformation of these urban rooftops into an environmental, ecological resource through an increased implementation of green roof technology is becoming a normal practice in many cities throughout the world [68]. As a result of the growing interest in urban agriculture practices, a new type of green roofs is emerging [68].

It is no longer a question of whether or not green roofs should be implemented, but rather how their impact can be maximized beyond their recognized environmental values. Green roofs usually target densely populated cities and urban agglomerations that lack open/green spaces. This is exactly where the presence of agricultural lands is rare, and the proximity to fresh and nutritious produce is diminishing. The development of Productive Green Roofs (PGR) could transform conventional green roofs into business–driven systems.

Lufa Farms project in Montreal, Canada is an excellent example of utilizing underused roof spaces in creating a multidimensional agriculture business opportunity. This project created a trend that could one day impact the regional agricultural market in Canada if properly disseminated. Lufa farms provided a successful attempt to integrate rooftop agriculture practices in urban areas and solely develop through an independent business model.

The fact that Lufa farms is a sophisticated green house system that used high technology components does not overlook the potential of low tech rooftop farming systems, if the proven agricultural measures are followed. However, It is logical to state the difference in capabilities between simple and complex agricultural techniques.

Nowadays most of rooftop agriculture projects in developing countries is planned on a small/household/pilot scale. Most of the larger scale rooftop farms exists in the developed world especially North America, where in most cases the produce is meant for private use rather than for the market, or is processed, cooked and/or sold to another business in the same building (a restaurant with a kitchen garden) [79]. Some rooftop farms cooperate with regional farmers to increase product variety and use common marketing and distribution channels. The commercial farmers in developed countries compete on the basis of quality rather than price [79].

It is important to state the difference in market demand between developed and developing countries. Large scale PGRs planned for informal settlements in Egypt would have a different design approach marketing techniques and selling strategies when compared to PGRs in Canada ,The United States or Europe.

5.2.1. Dissemination Potential

A new approach should be developed in the informal settlementsof Cairo when discussing an attempt to disseminate the concept of PGRs. To provide a realistic model that could fit within the context of Cairo's informality, this new approach should follow adequate design parameters and operation guidelines in order to reach out properly.

Building upon existing models or blindly following successful PGRs in developed countries would lead to a misfit. This new approach could be developed through studying rooftop agriculture policy instruments created by the cities in the developed world and transforming it to fit with the environmental, social and economic context of Cairo's informal settlements.

There are several factors that could affect the dissemination of PGRs in informal settlements. One of the main features of informal housing construction is its reasonable structural quality [15]. Structural Conditions in most of the roofs are relatively acceptable and has proven –through the presented case study – to support light weight hydroponic systems. However, in case of a larger scale project that works on mass production, it is important to consult civil engineers to examine the proposed systems' weights, to ensure the safety of the roofs.

Community acceptance is an important factor that should be taken into consideration. PGRs and Rooftop farming practices are new concepts to most of the developed world. Spreading this concept in informal settlementsof a developing country might not be an easy task and could be overwhelming to the community members. Awareness campaigns could take place to ensure the understanding of the concept and the benefits of its dissemination.

Food affordability is another factor that could affect the dissemination of PGRs in informal settlements. The unpredictable price fluctuations of some crops in the Egyptian market could affect its affordability. The low income strata living in informal areas are the most affected layer of the society, resulting in the exclusion of some crops from their daily food diets as a result of unaffordability. The production of agricultural crops away from the formal market could be utilized as a dissemination marketing strategy. In addition, PGRs could create smaller parallel markets that could one day affect the monopoly of some agricultural suppliers to certain crops, which is one of the reasons for the price fluctuations [44].

The Economic return of PGRs is an important factor that could lead to its future spread. The need for new job opportunities that generate extra sources of income could be a strong stimulating element. The Project economic business model could be presented to the locals to encourage the dissemination of the concept.

The presence of policies ,guidelines and regulations that could manage and operate rooftop farming themes as well as subsidies and incentives that could encourage the implementation are factors that could help foster the dissemination of PGRs.

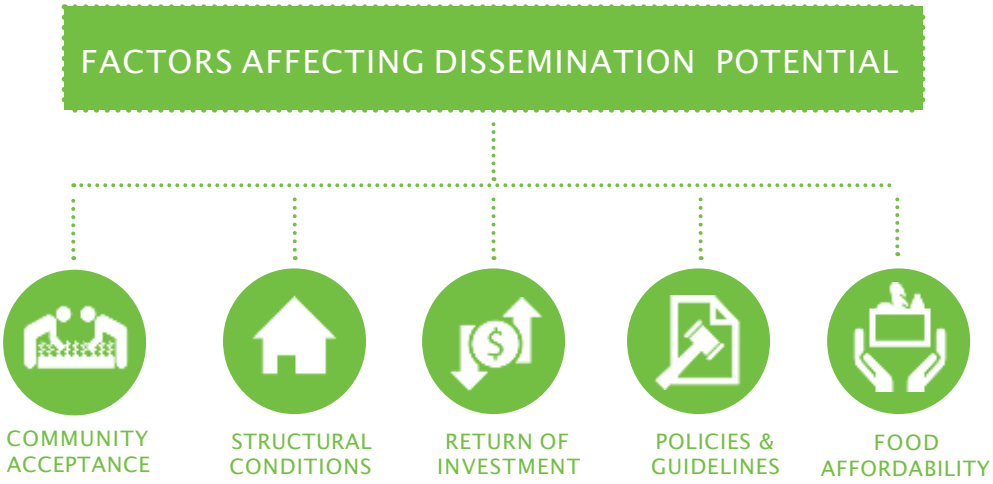


Figure 68: Factors affecting PGRs dissemenation potential

Courtesy of the Author

5.2.2. Policy Instruments

Rooftop agriculture practices are controlled in the developed world by sets of policies that regulates the design, implementation and operation. These Policies are encouraged through 3 different instrumentsincluding regulations or "command and control" (i.e. prohibiting or limiting certain actions, with penalties for non–compliance),Direct or indirect economic incentives such as taxes and subsidies (Market Based Instruments)and persuasive measures such as education, awareness and advertising [24].

Regulations are official rules designed to control the conduct of those to whom it applies [42]. Regulations or "Command & control" mechanisms involves mandatory policies which influence the behavior change through laws, rules and codes [62].

From the perspective of most urban agriculture advocates, regulations are perceived as an important tool to promote rooftop agriculture practices [62]. Regulations –in terms of where it is implemented –affect rooftop agriculture through zoning and land use designations, what farmers may sell via permits, as well as how certain systems are implemented via specific standards [62].

Informal settlements are built following certain norms and circumstances which are not usually certified by the local authorities. It is illogical to setup certain regulations that control and facilitate rooftop agricultural practices in areas lacking basic land use, construction, land subdivision laws. Adding to that the absence of legal framework that regulates the implementation and operation of conventional green roofs in Egypt.

Market Based Instruments(MBIs) are instrumentsof environmental policies in which a change in technology, behavior or products is encouraged throughfinancial incentives (either subsidies, taxes, price differentiation or marketcreation) [30].

Market Based Instruments(MBIs) could foster the implementation of rooftop agriculture projects driven by economic profit [62].The strengthof MBIs is their hidden resilience, often filling voids in urban policies which exceeded the reach of regulations, as in areas where regulations may not apply such as existing areas in need of roof retrofits [62].

Market Based Instrumentsare subcategorized into Direct and Indirect incentives. Direct incentives could be financial assistance, subsidies or grants, while indirect incentives could be any strategy that provide an indirect cost effective impact (i.e. split Stormwater Fees) [62].

Informal settlementscould benefit from MBIs through smart direct and indirect incentives. Direct incentives could include startup loans for the implementation of rooftop farms with 0% interests or provision of the project inputs at low cost. Indirect incentives could be certain discounts on electricity or water bills incase of implementation of rooftop farming projects.

Persuasive instruments(PI) are supplemental tools that encourage implementation of a project or a strategy through marketing, education, awareness campaigns, consultancy and project demonstration[62]. Persuasive instrumentsis criticized in some literature as "laborious" and "exhausting", owing to the many barriers between communication and establishing a sustained behavior manner [80]. However, in mostcases it is presented as an essential instrumentto achieve long term pervasive education [62]. One of the disadvantages of persuasive instrumentsis that the possible outcome could not be easily measured when compared to regulations and incentives [62].

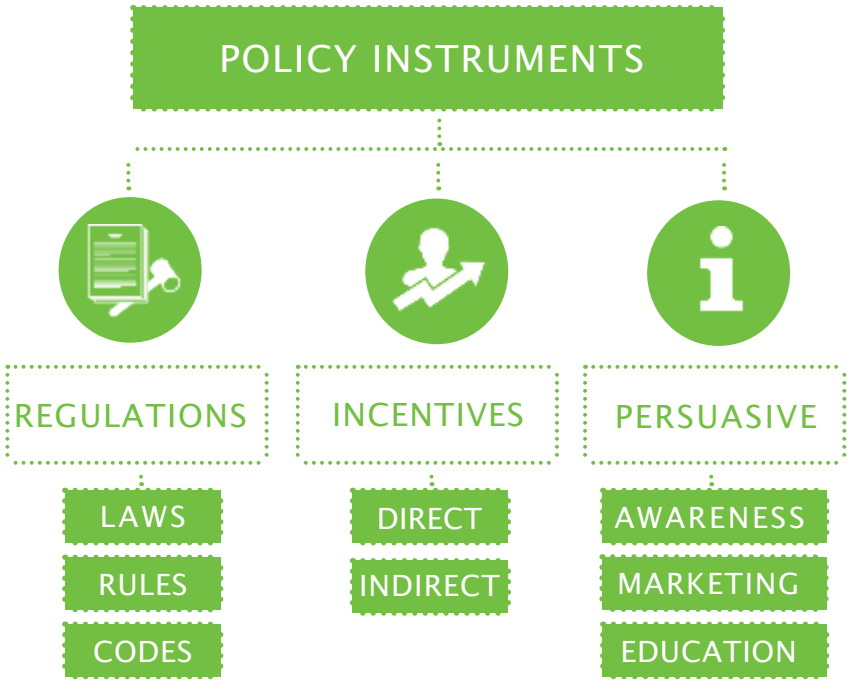


Figure 69:
The three types of Rooftop Agriculture Policy Instruments

Courtesy of the Author

Informal settlements could utilize the potential of PI through rooftop farming awareness campaigns. Educational materials such as banners, brochures or flyers could help raising the awareness of the locals. Preparing workshops that illustrate the basic knowledge of rooftop farming systems and the benefits of its dissemination could help properly market the concept. Another approach is to create educational farms on top of schools to provide practical training for interested students, which could help in spreading the concept among the youth.

5.2.3. Challenges & Limitations

The concept of PGRs for informal settlements is not as much appealing as it might seem. PGRs is calling for a brand new concept for the informal settlements' tenants of Cairo, who are a very sensitive layer of the society , especially to economic investment opportunities. Locals would prefer more secure types of investments, which are the already existing types found in their communities and had proven financial success. Risking their savings in an obscure type of investment –even if properly studied –might not be easily welcomed or accepted.

The lack of research in the field of rooftop agriculture on a commercial scale –which is almost absent in the developing countries –could decrease the confidence of stakeholders willing to invest in roof top farming themes. PGRs is a relatively unknown concept amongst the general public and has received minimal attention from academics and researchers. The absence of existing success stories that could guide and benefit an upcoming project could lead to reluctance in investing, to avoid any unknown consequences.

In terms of quantity ,the produce of PGRs is not likely to compete with commercial ground agriculture activity. Although hydroponic systems are characterized by their high yielding capacity, It is logical to state the difference between vacant agricultural lands dedicated to crops production and limited roof spaces on top of informal buildings. However, PGRs in some cases could have the edge if the quality of the produce is the matter. The produce –if not transported to distant markets –could maintain a higher quality, as handling and storage processes will be less.

The lack of government incentives, policies and industry guidelines supporting the dissemination of PGRs is leading to the loss of development opportunities that could have positively impacted the living conditions of the tenants of informal settlements.

“ The Present & Future of Imbaba “

Chapter 6

CONCLUSION

6. CONCLUSION

The transformation of informal settlements from being an exceptional phenomenon to a normal trend necessitates solid interventions to improve the living conditions of those areas. The main objective of this study was to analyze and investigate the urban characteristics and challenges facing informal settlements as well as proposing resilient strategies that could mitigate the negative impact that resulted from its formation.

Although most of Cairo's informal settlements share the same exterior, it is important to understand the "case specific" environmental, social and economic conditions that differs from one area to another. The proposed strategies and the presented solutions should be tailored to adapt to the living conditions of the focus area. Additionally, those solutions should provide the maximum benefits and achieve the genuine needs of the locals.

Study Objectives & Hypothesis

studying and analyzing informal settlements and investigating the application of rooftop agriculture to the urban patterns of Imbaba using the FSSD

The hypothesis of this thesis stated that the lack of green spaces in informal settlements is threatening the environmental quality of those urban areas as well as food security, food prices and food quality, and it proposed rooftop agriculture as a mitigation solution for those problems.

Rooftop agriculture all over the world is a relatively new strategy. The rapid development of different rooftop agricultural techniques and the increasing need for fresh produce in urban areas drive research in this field to expand and to be given more attention. The lack of awareness and research, the structural barriers as well as the high initial cost of systems are the biggest challenges facing it nowadays.

The proposed retrofitted project concluded that Rooftop agriculture could be one of many strategies that address environmental, social and economic challenges facing Imbaba. The primary benefit of this project is generating income and creating a new job market for a community in need for smart jobs and an extra source of income.

Rooftop agriculture could also have a positive impact on food security issues, especially with the rising prices of fruits and vegetables in the Egyptian market. It could help ease the burdens of buying the daily basic needs of some crops for middle/low income groups searching for any chance to decrease their living expenditures. Moreover, it could provide organic, fresh and clean produce for a community consuming a lower quality crops, which could usually be a victim to harmful pesticides and low standard fertilizers that negatively affect human health.

Rooftop agriculture could be a strategy that creates social gathering venues for the locals living in narrow parcels and lacking the availability of open spaces. Beside meeting their guests at the communal seating areas, which are usually found in front of each house, Rooftop farms could

Findings

Rooftop agriculture could provide environmental, social and economic benefits for Imbaba

Compatibility needs further investigations

provide a suitable gathering venue which contains reasonable amount of greenery, provides fresh air and a pleasant view for the locals (incase of adjacent farms). However, changing the mindset of the tenants to alter a habit that became a part of their traditions has previously proved to be a challenging task.

Rooftop agriculture could also decrease Imbabian vendors' long commutes to El Oboor market to purchase their produce. This could contribute to energy and money savings as well as GHG reductions produced from food transportation activity. However, the data regarding the amount of produce purchased from El Oboor market as well as the amount of energy and money consumed for food transportation is missing. Moreover, this study cannot prove that Imbaba's rooftop agriculture produce would be plentiful to have a tangible effect on the reduction of GHGs produced from food transportation.

Although rooftop agriculture can provide diverse layers of benefits as explained, it is soon to ensure the ultimate compatibility of this strategy with the urban context of Imbaba. Further studies should test the levels of acceptance of the locals to the proposed strategy. Incase of implementing a pilot phase, further studies should include precise monitoring and evaluation of all project stages. This could help creating future guidelines for researchers and stakeholders planning to develop the idea.

Although the concept might be promising, productive green roofs for commercial purposes is a brand new approach that needs further studies and a wider investigation, especially in the context of informal settlements. The lack of strategic guidelines, instruments and regulations that could lead the way for this approach hinders any chance to investigate the dissemination potential in the developing world. Future studies could examine the existing guidelines followed in the developed cities of North America, Europe and Asia and propose an adaptable retrofit to the urban patterns of Cairo.

Future Studies

Monitoring and evaluation of existing rooftop agriculture projects in informal areas

Investigating the application of commercial production in formal areas.

More project based research related to informal settlements

The rapid growth of population and the continuous expansion of Cairo, complemented by an increasing demand for food, grants urban agriculture practices a proper manifestation as a vital strategy that should be seriously considered. Further studies could propose introducing productive green roofs to formal areas. Administrative buildings, stand alone warehouses and shopping malls in the new cities of Cairo could be a good potential for commercial production.

Throughout the literature review of informal settlements of Cairo, it was noticed that a considerable amount of research are presenting their studies from an analytical perspective only, without examining the different dimensions of their briefly proposed solutions. This thesis is calling for more focus on project–based research and practical interventions adopting sustainable measures that aim to improve the living conditions of informal settlements.

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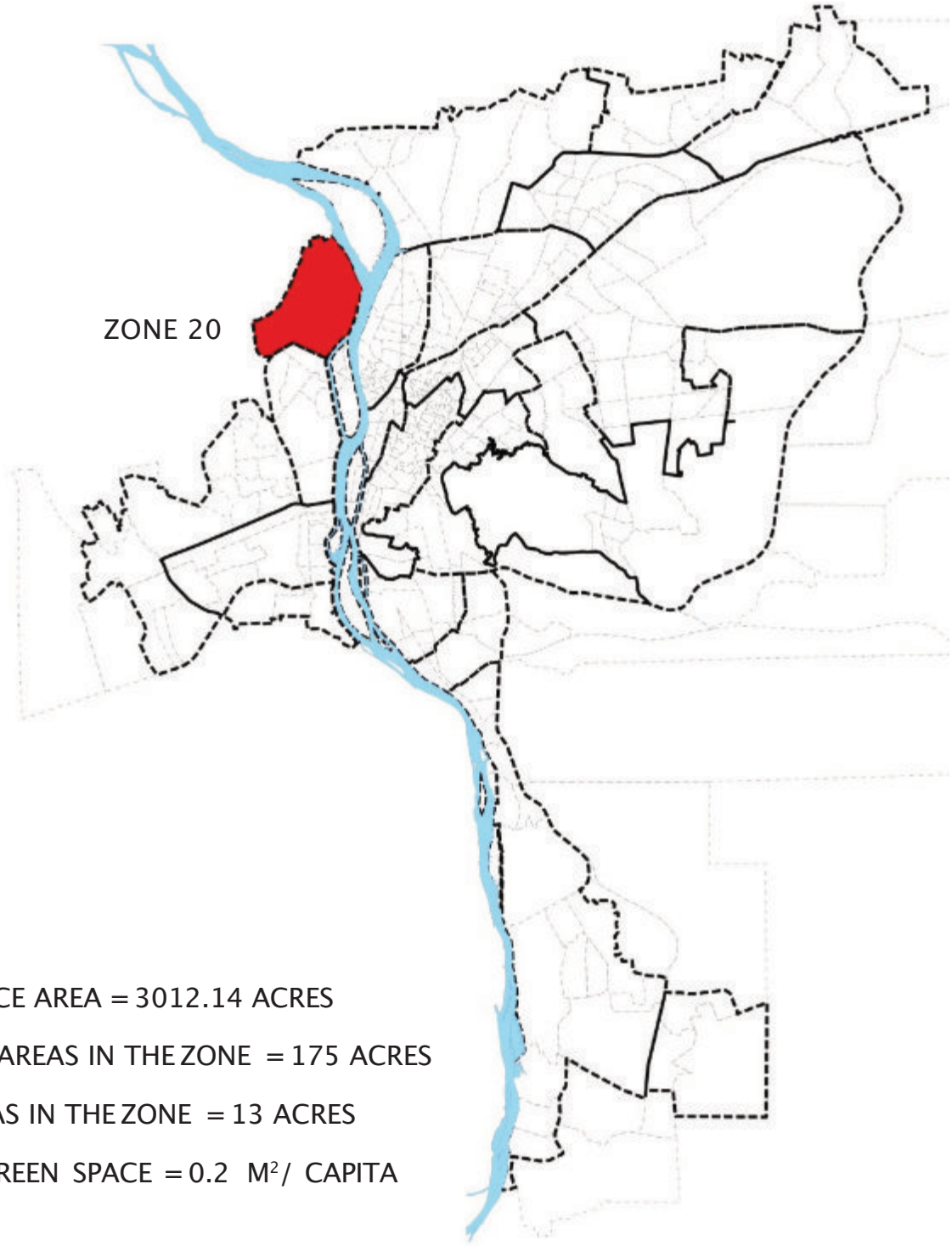
8. APPENDICES

8.1. APPENDIX (1) –LONGTERM STRATEGIC URBAN PLAN FOR GREATER CAIRO –

–ZONE 20 – IMBABA DISTRICT–



ZONE 20 :

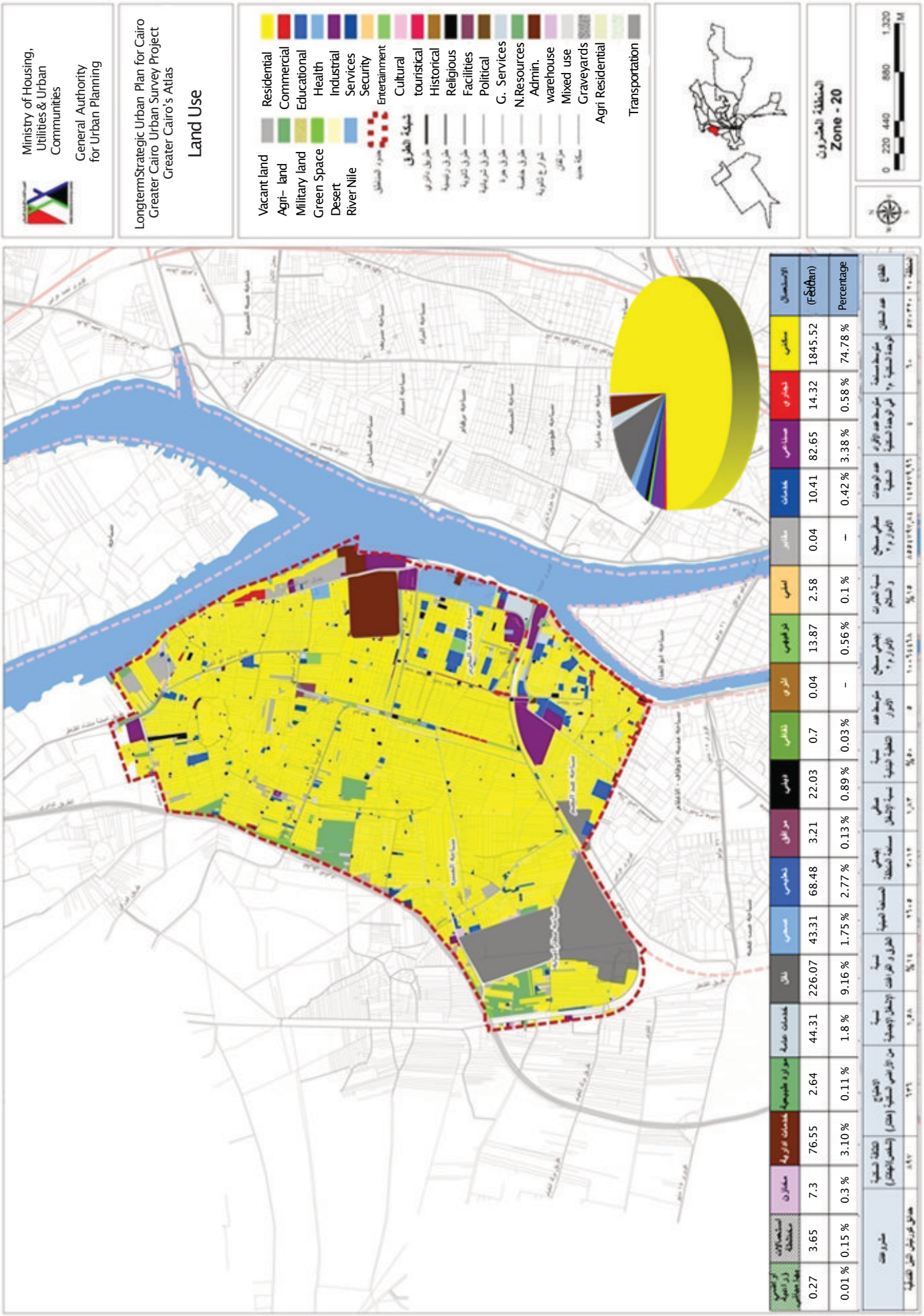
ZONE SURFACE AREA = 3012.14 ACRES

UNPLANNED AREAS IN THE ZONE = 175 ACRES

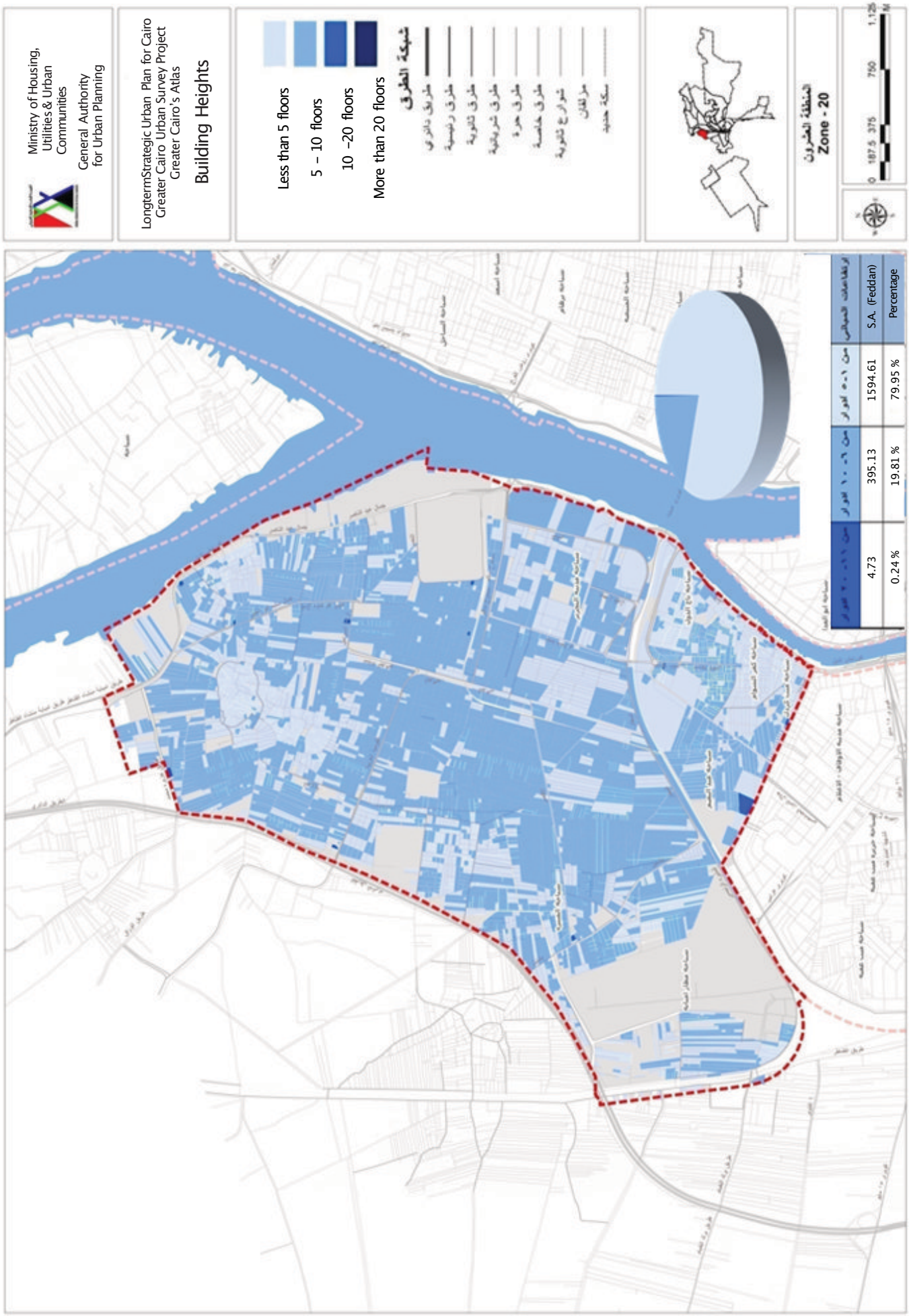
UNSAFE AREAS IN THE ZONE = 13 ACRES

PER CAPITA GREEN SPACE = 0.2 M^2/ CAPITA

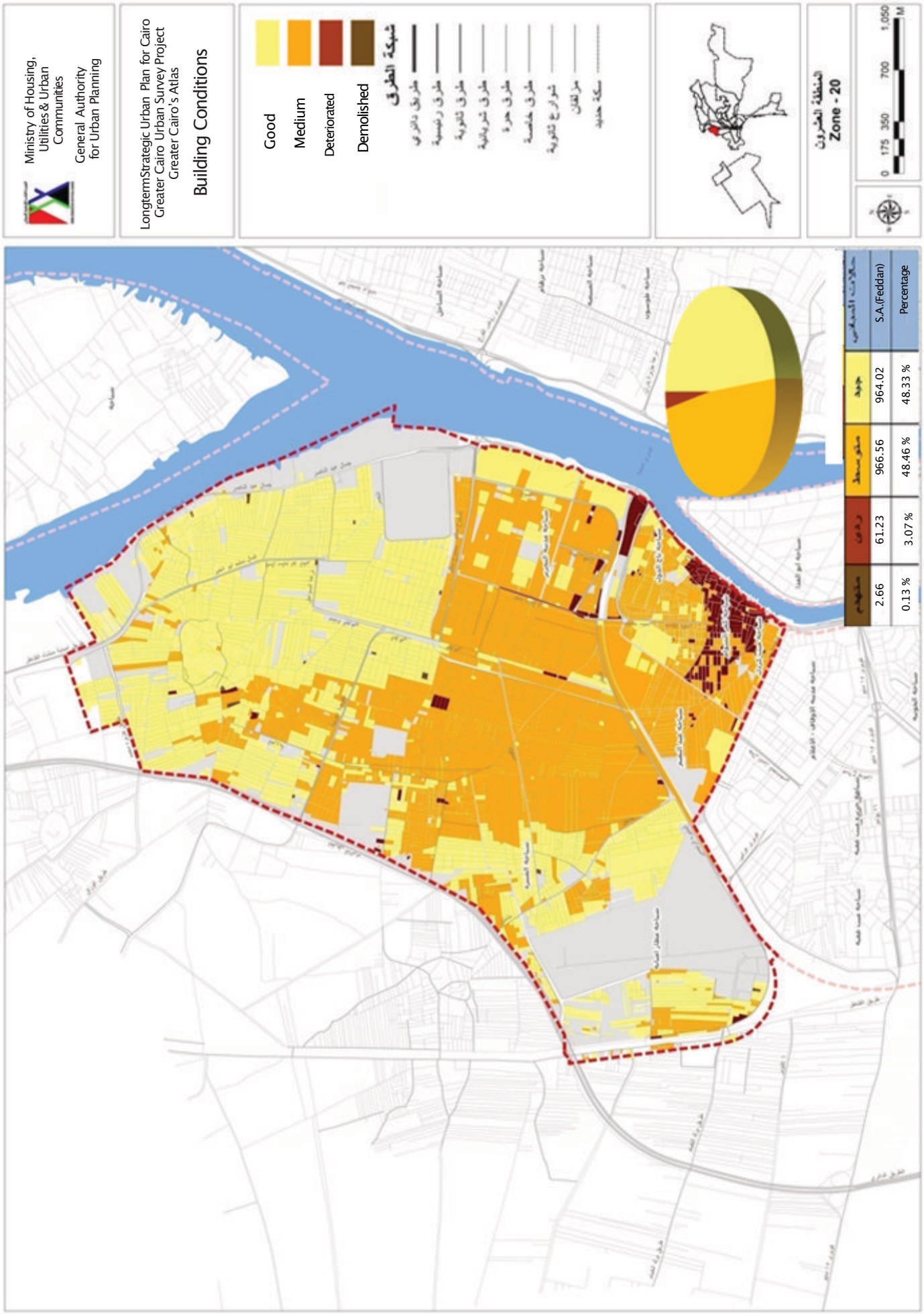
Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo



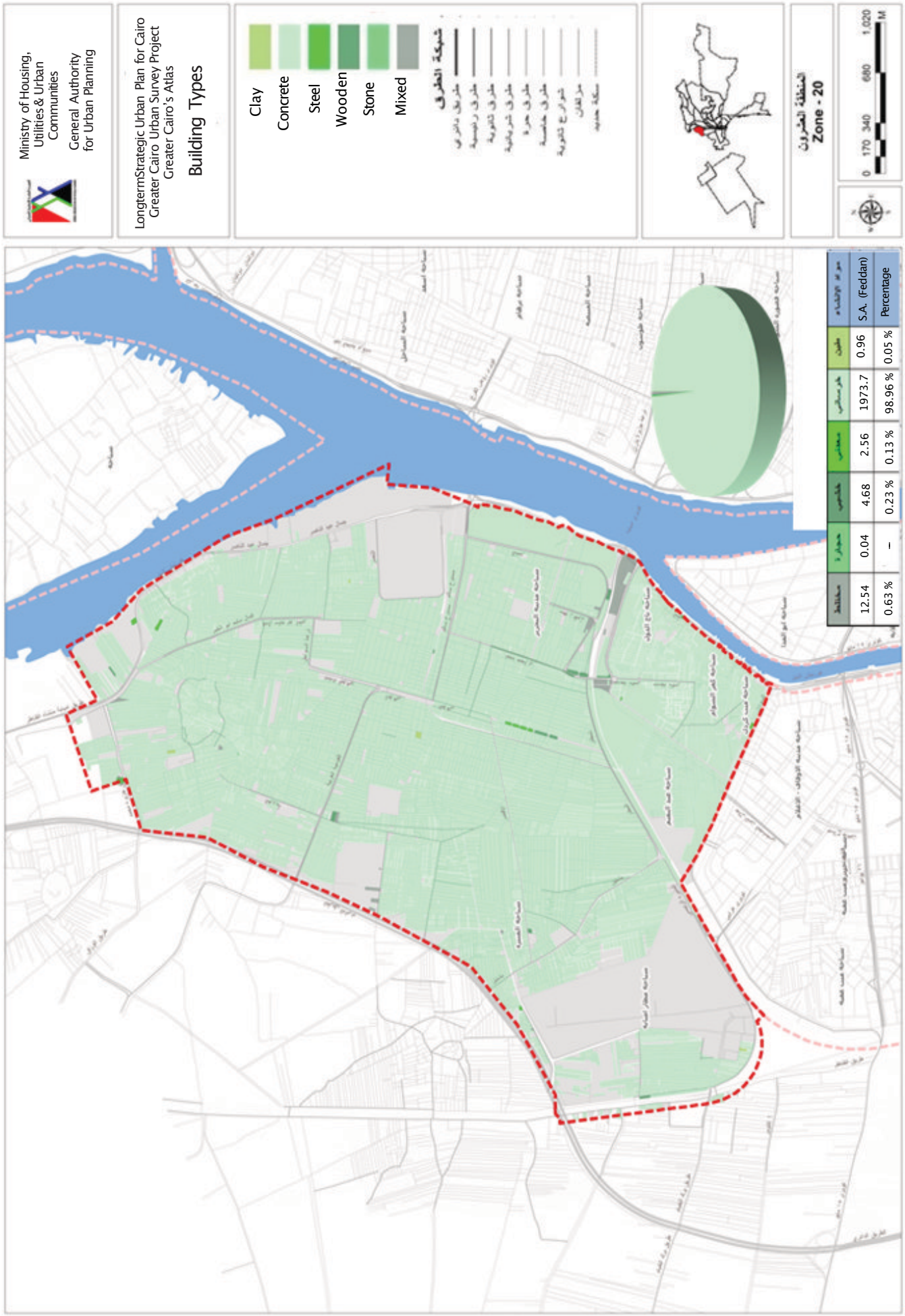
Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo



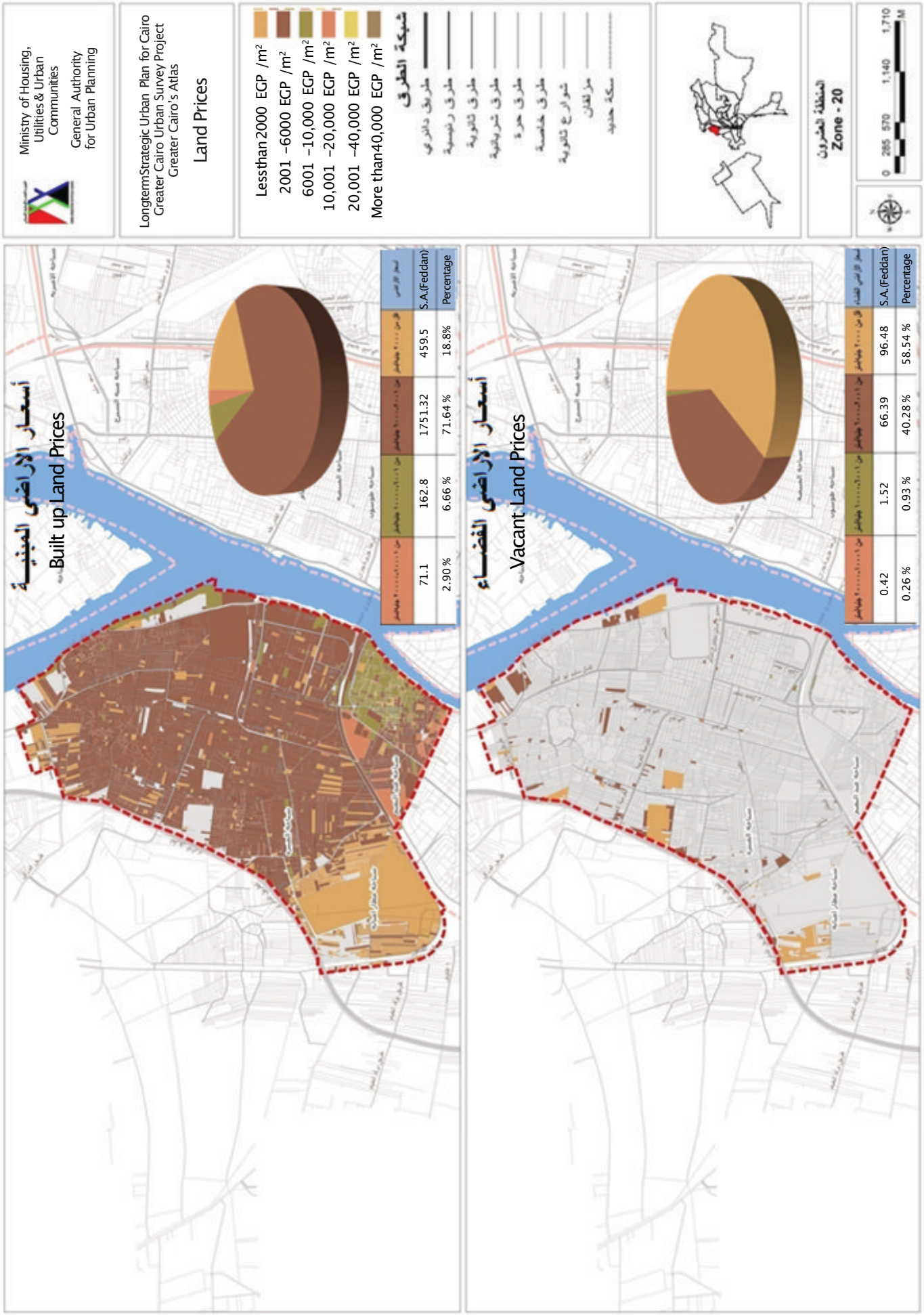
Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo



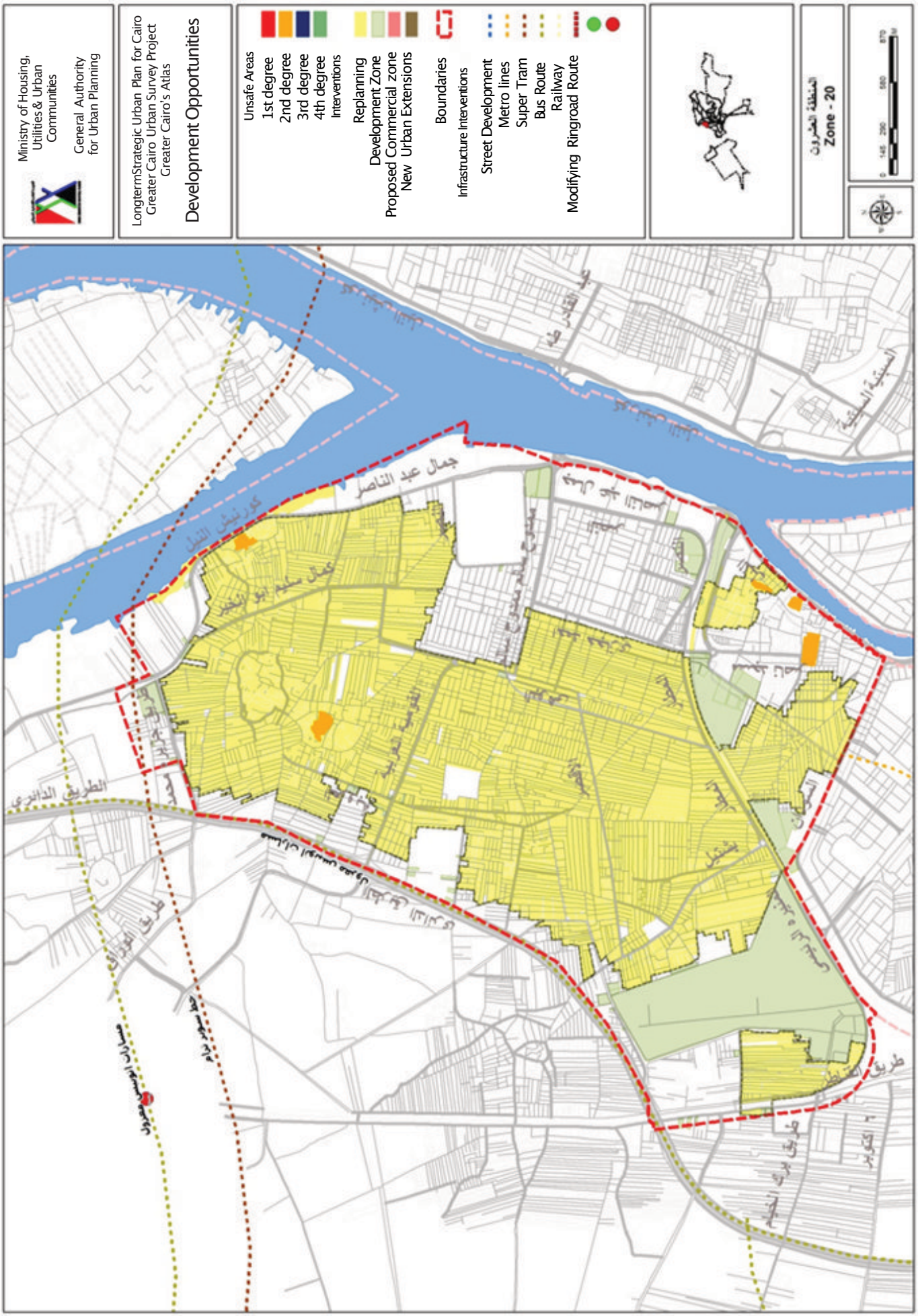
Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo



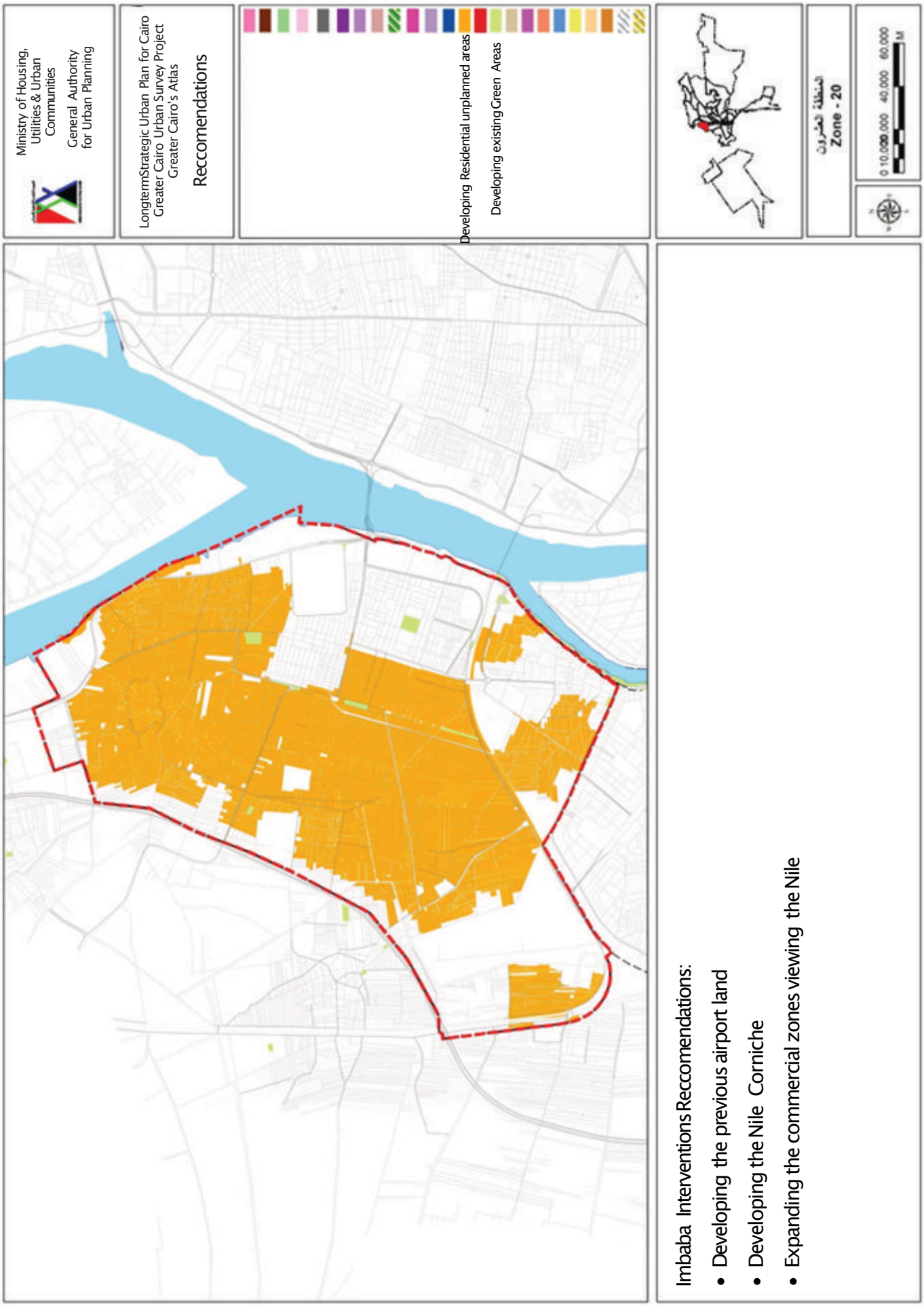
Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo



Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo



Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo



Data Courtesy of The General Organization for Physical Planning GOPP ,Cairo

8.2. APPENDIX (2) –PROPAGATION TIME FOR SOME CROPS IN EGYPT –

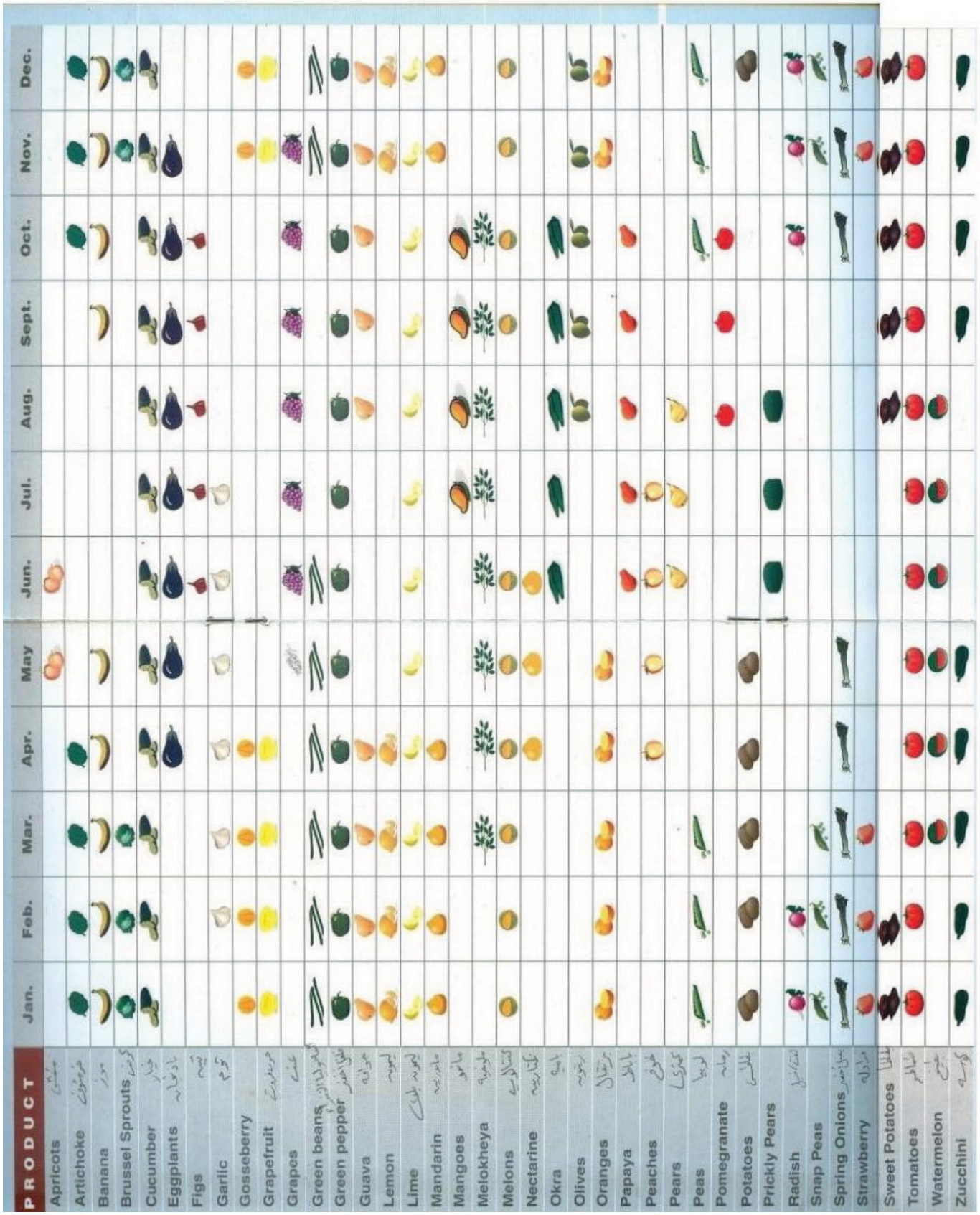


Image courtesy of Ministry of Agriculture and Land Reclamation, Cairo

8.3. APPENDIX (3)–PROPERTIES OF SOME ROOFTOP FARMING CROPS IN EGYPT [88] –

CROP	PLANTING SEASON	PLANTING TECHNIQUE	HARVESTING TIME	SPECIES
TOMATOES	Summer crop planted all year long. In cold months the farm should be covered with a plastic sheets to protect it from cold weather	Seedlings of 25 –35 cm distance depending on the species	after 80 –85 days from planting. Harvesting for 30 45 days	Castle rock – super red – GS12
PEPPERS	Summer crop: summer Planting season: March – April. Autumn planting season: june – july – august	Seedlings of 25 – 30 cm distance	Harvesting after 85 days and extend for 3 months	California wonder– Shatta Baladi – Gedion
CUCUMBER	Summer crop: summer Planting season: February – March – april . Autumn planting season: july – august	Direct seeding or seedlings in tables with distance of 50 cm between seedlings	Harvesting after 60 –65 days from early planting or 35 – 40 days in hot weather	Zaeem – Nems – Sweet crunchy
ZUCCHINI	Summer crop. Planting all year except extremely cold months	Seeds or seedlings of 50 cm distance	Harvesting 35 –60 days based on planting time and temperature	Alex – Top Capy – Mabroka
WATERMELON	summer crop. Summer planting season: march– april. Autumn planting season : june – july	Seeds or seedlings in tables with 1 meter distance	Harvesting after 95 – 100 days of planting	Giza – Aswan
STRAWBERRIES	September & october	Seedlings of 20 –25 cm distance	Harvesting late december till may	Camarouza – zowalinda – Montkhab el tahrir
EGGPLANT	Summer crop: summer Planting season: March – April. Autumn planting season: june – july – august	Seedlings of 50 cm distance	Harvesting after 85 days and extend for 3 months	black beauty

CROP	PLANTING SEASON	PLANTING TECHNIQUE	HARVESTING TIME	SPECIES
BEETROOT	Winter crop: september till february	direct Seed in lines of 15 cm distance	harvesting 60 – 80 days from planting day	Detroit dark red
ARUGULA	Winter crop. planting all year long except extremely hot months	Direct seeding through random spread	harvesting when reaching a suitable size	
SPINACH	Winter crop. From september to february	Direct seeding through random spread or in tables with 10 cm distance between lines	Harvesting after 60 –70 days of planting (after reaching suitable size)	Thesaloniki – Virgina sakoi
LETTUCE	Winter crop: October– november	Seedlings with 15 cm distance	harvesting 30 –90 days from planting	Baladi – romian –dark green
JAWMELLOW	summer crop. from march till august	dirct seeding through random spread in tables	after reaching suitable size	
GREEN BEANS	Summer planting season: july – august. Autumn planting season: february– march	direct seeding in line of 5–7 cm distances between seeds and 15 cm distance between lines	harvesting after 65–85 days and could extend to several harvests	Bronco – Polesta
BELL PEPPER	Winter crop. October – november	Direct seeding in pots with distance of 25 cm between plants	harvesting after 3.5 months of planting	gizablanca – cypriot
CABBAGE	winter crop. mid june til october	seedlings with a distance of 25 – 30 cm	3–4 months after planting based on planting season and species	Baladi – bronzoic
ONIONS	Winter crop from september till january	seedlings of 5– 7 cm distance	3–4.5 months after planting	giza 6 – giza 20

8.4. APPENDIX (4) –INTERVIEWS –

Interviewee: Laila Kenawy
Position: Project Officer , (United Nations Industrial DevelopmentOrganization) UNIDO , Cairo office.
Date: August, 2015

1–During your work in the agribusiness in Egypt, have you encountered any rooftop farming project that was meant to be for commercial production? (If no) , Why is it not popular (from your point of view)?

I have not encountered any rooftop farming for commercial production, especially when we are talking about horticultural production. While a more popular use of rooftops encountered especially in Upper Egypt is for poultry production and as a drying surface for various crops. Its scarce distribution might be related the lack of awareness about the possibility, the initial investment cost or the structure of the houses.

2–In the context of densely populated informal settlements, do u think implementing a rooftop farm would benefit the residents?

I think the concept of rooftop farming would not only be beneficial for densely populated informal settlements, but could also be implemented in formal settlements and on public buildings such as schools and hospitals.

3–Which species of plants from your point of view are best suited for rooftop harvesting and why?

Depending on the structure of the rooftop farm, a variety of crops would be suitable. The main crops would mainly be vegetables and medicinal and aromatic plants. While vegetables would include tomatoes, cucumbers, capsicum, green beans, peas, aubergine as well as leafy vegetables such as lettuce, spinage, jews mellow or ruccola, supplementing the household. Medicinal and aromatic plants would include peppermint, marjoram, chamomile, basil, thyme and many more.

4–what do you think of introducing the concept of Productive Green Roofs (PGR) for informal settlements, moving the project from a household level to a neighborhood one and increasing the scale of production?

The concept in its self seems plausible and feasible economically. I think the challenge would be in management and formalization.

5–how do you evaluate rooftop farming produce (if you had a previous experience with any) ? and to what extent can the produce of PGR competes with the ground agricultural products (in terms of Quantity/ Quality)?

I have not tried rooftop farming previously. In terms of quantity it would not have competitive advantage. Yet as the produce will not be transported to distant markets I would assume that higher quality can be maintained, as handling processes will be less. This in turn might affect the production and marketing cost of the produce, allowing for higher profits.

6–Based on your opinion, What are the (challenges / obstacles / limitations) that can face the implementation of PGRs in informal settlements? to what extent can it be accepted by the

community/private sector?

The main challenges I see for the implementation of productive green roofs are:

- High initial costs
- Lack of agronomic knowledge and need for capacity building
- Sustainability of capacity building once provided
- Formalization and organization of the communityfor collective purchasing and marketing
- Quality of produce in terms of pesticide residues and controlling them in addition to accountability. (what happens if one farmer has pesticide residues? How will you trace it? Will he/she be accountable?)
- Lack of storage facilities
- Informality of the settlements might affect attitudes of people to formalize their business

7-How can PGRs be institutionalized to provide a legal framework as well as a sustainable guide for governments and developers to facilitate the management of the crops produced?

In my opinion a good cooperatives structurewould be the ideal form on institutionalization. Yet I suspect that the informality of the settlements might affect attitudes of people to formalize their business. Perhaps an easier and more sustainable way of formalization would be throughan investor, who would rent out the rooftop farms and buy the produce.

8-What recommendations related to crop management do you have that could help accelerate the implementation of rooftops being used for agriculture production?

I would assure the provision of technical assistance and inputs for the implementation, and continuous support. I would set a simple crop rotation that allows for progression of technical knowledge with time, starting with easier crops to manage such as cucumbers, and advancing with crops such as tomatoes and peppers.

Interviewee: Mariam Haggag
Position: Rooftop farm Owner (Ezbet el Nasr)
Date: April, 2015

1-Do you live in a family based house or in an apartment with other owners?

I live in a family based house, 2 flloors + roof building.

2- Why did you choose a rooftop farming project?

I have an agricultural background, my dad used to work in agriculture and he encouraged me to help him, so i was raised loving the idea of cultivating and harvesting.

3- When did the project start?Who financed / excuted it?

it started 24-6-2014 totally funded by "Hamasat el sedk" (Local CBO), and was excuted by Schaduf.

4- Are you the only one responsible for everything in the rooftop farm ?

No , me and all my family, Schaduf provided a 7 hours training session for us on how to deal with the installed system

5-Do you have any experience or information with a non family based rooftop farm ?

I dont think so , actually schaduf puts a rule that the green roof installed mustbe a family based one.

6-How do you manage the produce?Do you plant whatever you like? do you sell it yourself?

Actually Schaduf is the decision maker, they specify the plant types that we could cultivate , and they are also responsible for selling the produce.

7- But ofcourse you can take some of the produce for your use?

defintely, i suffice myself, i dont need to visit the market to buy any kind of produce that i am planting on the roof.

8-Do you plant whatever you like?what kind of vegetables do you produce?

No , schaduf specify some kind of crops that i can choose from.I plant Spinach , Molokhya , Arugula.

9-would you mind telling me how much profit do you make from selling the crops ?

I make 125 EGP per table and i own 3 tables. so i make around 375 EGP per cycle.

10-Do you do any kind of maintenance for installed system?who pay for that?

No i dont, if i have any problem with the system Schaduf is responsible for any maintenance issues and i dont pay anything.

11-from your point of view whats the most important aspect for the success of a rooftop farming project?

A: For me it was the training session that we attended before installing the system.I think that education and agricultural background is the most important aspect for a project to succeed.

12- Do you want to add anything?

For me the farm was not only a source of income. I meet regularly with some of my neighbors who had rooftop farms as well. We meet in one of our roofs and we exchange information about agricultural techniques and i think its a good chance to bond more with my neighbors.

Interviewee: Saber Osman
Position: Project Officer, GIZ -PDP-Cairo Office
Date: August, 2015

1-Why did you choose Ezbet el Nasr to work on a roof farming project?

We did not specifically choose this area, we have an agreement with Cairo governorate to select some areas for future development. They specified 9 focus areas , Ezbet el nasr was one of them. We wanted to execute a project that can combat climate change. Based on the studies that we did we came up with a conclusion that we want to address the problem of Heat Stress in Cairo and help

people in informal areas to accommodate with it. In addition, we had another dimensionsbforthis approach, were we aimed to improve the living conditions of residents throughincome generation. Ezbet el Nasr was one of the areas sufferingfroma low socioeconomic standard. So picking rooftop farming as a strategy was –for ezbet el nasr –a multibenefit solution. Locals could improve their financial status, decrease food insecurityand produce clean and nutritiousfood. Moreover, the Locals –afterimplementing the project –stated that now they have a venue for social gatherings, especially at the end of the day were all the family could meet up. Not to mentionthat the roofs are now clean and they have a relatively good aesthetic value .

2–What are the key challenges that faced the project during implementation? and how did you deal with it?

I thinkthe biggest challenge was finding the right calibers for the project. Rooftop farming is not a popular concept for the people of informal settlements.It was not an easy job to find people who have a true interestfor agricultural practices. we set a selection criteria as well to make sure that the project functions properly and we had a contract with a rooftop farming firmthat worked on implementation of the project and buying the expected produce fromthe farmers. The project now has gained the trustof the locals as we had a lot of requeststo install rooftop farms in Ezbet el Nasr after the pilot project has succeeded.

3–So almostall of Ezbet el Nasr does not have any kind of agricultural knowledge?

No, on the contrary. Most of themare immigrantsfromvillages that used to work previously in agriculture. But when they migrated they never expected that they could one day cultivate a rooftop farm that could provide a big amount of produce that could not only suffice their needs but be utilized in income generation. Their perception of agriculture is an activity on a piece of land, but not on a roof top.

4–You worked with “schaduf” the rooftop farming firm in implementing this pilot project, Did you propose the farming system(Deep water Hydroponic) to work with or was it the selection and design of schaduf ?

We did not choose the type of systemto be implemented. We were only monitoringSchaduf through the implementationto solve any problems that mightshow up. We chose Schaduf since they have a complete business model compared to other entities that executes rooftop farming projects. An important reason for selecting Schaduf is that they market the produce and sell it in a formal market in Maadi for a higher price, which is a strongpositive point for the economic benefit of the project.

5–Can you tell me about some problems that faced you during monitoring the project?

There was a farm that a had a problem with the produce. The local who attended the training before the project implementationwas not the same person who was supposed to work in the farm, which led to some problems in production. We also had some problems with the rooftop farming firm. Although honestlywhen the firstphases of the project succeeded, they decided to create a small office as a branch of their firmin Ezbet el Nasr to deal with all kinds of problems related to the farm. This approach created an onsite consultant for the farmers and helped in solving urgent onsite problems related to planting, harvesting..etc. . I thinkthat if there is a chance to scale up this project , the option of self marketing the produce would be a better idea to avoid some of these problems.

5–Who chose the types of crops for the farms?

Schaduf is the one responsible for the selection, since they are the one marketing the produce. However, we gave some of the farmers the chance to plant some parts of the farm with the crops that

they desire. But i think Schaduf wanted to work on crops with a short shelf life that could provide a quick economic profit. That does not mean that the system could not afford different types of crops of longer shelf life. I think it depends on the strategy that the firm adopts. We were very understanding to such approach but at the same time there were some locals who wanted to plant other types of crops. That's why we gave them the chance to plant a part of their farm with the crops that they want.

6–Why did you choose in the eligibility criteria specifically 10 % confinance of the farmers for the project?

I think it is not a big amount that the farmers could not afford. We chose it just to make sure that the farmers will commit and also to assure their farm ownership.

7–How is the project functioning today?

the project was designed to implement 10 farms. We started the pilot phase with only 6 farms. Today 4 farms are properly functioning. Each farm could gain a profit of around 150 EGP/Month or more depending on how much effort the farmer could exert in his/her farm and how quickly can he/she responds to any troubleshooting that might happen for the installed systems.

8–What are your recommendations that could improve the implementation of any future rooftop farming project in informal settlements?

I would say that this kind of intervention might not be suitable for all kind of informal settlements. I think the option of providing this strategy for the people who are in need for income generation would push rooftop agriculture projects to succeed in informal areas. We had a previous example of rooftop farms that did not succeed when implemented in areas of relatively better financial status. However, i still think that we cannot spread the concept of rooftop farming in all informal settlements without studying the area, the structural aspects of the houses as well as the social and economic conditions of the tenants. i think each project should be tailored to adapt to the present circumstances of the locals. I would also say that rooftop farming is not the ultimate solution for the problems facing informal settlements. Of course it can provide a good solution for income generation, but other strategies could be integrated with roof top farming that could fit in the context of the studied area. I would also recommend to reevaluate the agriculture knowledge of farmers every now and then. I think training courses should be provided on a regular bases. I also recommend including children in the training sessions to increase their agricultural knowledge.

9–Have you thought of implementing a rooftop farming project on a school roof?

We thought about that but we faced some problems, including permissions from the educational authorities. Also schools do not work all year around, which could affect the sustainability of the project. However, we thought of using the schools as a rooftop agriculture training hub. We followed a similar concept in our project in Ezbet el Nasr. We used the rooftop of one of the CBOs to train the locals. Our future ideas could include training some of the CBOs representatives who could –also in a future plan –provide a sustainable training center on the CBOs headquarters' roof for the farmers. We also experienced a school rooftop farming project executed by an NGO Called Shagara. This project faced a problem of dealing with the financial profit. The lack of regulations and laws created a complicated situation in this case. This could rise a new development opportunity in cooperation with the local authorities to provide frameworks for such interventions, especially that schools roofs could provide a large space for farming practices.

10–Incase on nonfamily based houses, how were you able to deal with the financial profit of the farms?

our eligibility criteria state that the farmer mustown the roof. so in this case we are dealing with only 1 person or 1 family. All the houses that participated in our project are family based. I thinkthe traditions and habits of the people would not easily allow the sharing of profit. But i would say based on our studies that a big percentage of low income informal settlements(like ezbet el nasr) are family based houses compared to a higher income informal settlements(like Ard El Lewa) were a chance of a non family based house is found.

Interviewee: Zeinab Abdo
Position: Family DevelopmentCBO Representative , Imbaba.
Date: July , 2015

1-When did this CBO started? and what was its objectives?

My grandfather was the founder of this CBO in the year 1970. It was designed to provide crafts workshops for women ,a Nursery for the kids, a clinic and a wedding hall for the residents of Imbaba. It started in a small building in the inner parcels and later they moved out to this headquarters.

2-How many CBOs are found in Imbaba?

I don't thinki can count them, There are lots of CBOs. Since Imbaba is a big districtyou could easily find a CBO wherever you walk.

3-From your point of view, what are the main problems facing Imbaba at this time?

I thinkits the problems facing all informal areas of Egypt. I would say lack of security , Water shortage , sewage , electricity, garbage. As you mightknow the only planned area in Imbaba is Workers City. Other than that it is all informal, so we suffer from the deterioration of basic services.

4-Do you think there is a problem with open/green spaces in Imbaba?

Absolutely, we rarely have green spaces. Even the new park that was implementedis on the outskirts of Imbaba. I cannot feel its presence. Actually i have not visited it yet. Also it is very expensive. I don't thinkthe residents here can pay 20 EGP/person for the entrance or 25 EGP/person during the feasts and public holidays. It does not make sense here for a family of 5 memberto pay 100 EGP to just enter a park. Who will really benefit from this park?. Was it implementedjust to state that Imbaba now has green spaces?.i really don't know.

5-What about the prices of fruits and vegetables in Imbaba?

I thinkthe ranges are the same if compared to other areas in Cairo. I just think that it's the matter of quality here in imbaba. You do not get good quality of fruitsand vegetables compared to formal areas of Cairo.

6-Do you know where do the vendors of Imbaba purchase their produce?

I am not sure, but i guess they purchase their produce from ElOboor market. Others get their produce from agricultural farms around Imbaba. There are certain communities that used to work on the management of markets, crops and vendors. But that was a long time ago. I do not thinkit is working anymore.

7-Do you have any idea who usually owns the roof spaces of the houses in Imbaba ?

The houses here in Imbaba is usually family based. In El Monira, el Basrawi and others. i guess 65% of the houses here are family based. so the ownership of the roof is for the family. In the other cases the roof is the ownership of the building owner who might rent it to users or keep it for his own.

8 –Was there any kind of approaches to utilize roof spaces in Imbaba before?

I have not heard of any recent roof top utilization. I think in the former times people used roofs in raising poultry and pigeons. At this time roofs were clean and tidy since pigeons and poultry were a good source of income. Throughoutthe period of the Evian Flu this kind of activity has diminished gradually. Right now, i think people use it to store their useless leftovers and their old stuff.

9–Have you heard before about rooftop farming ?

Of course. If i remembercorrectly a team fromCairo university(Prof. Sahar Attia) collaborated with us previously in order to present this idea to the locals. A professor from the faculty of agriculture also was planning to donate the seeds , the seedlings and the nutrientsfor this pilot project, as the locals were reluctant to invest in a project they dont know. They were afraid of financial loss in case of failure of the system. I think people need to see a success story. If they find their neighboors making money out of the roof i thinkthey will be more encouraged. For this project We had a primary workshop with the selected locals and they said that providing some crops that they sometimescould not afford, as well as providing an extra source of income from selling the crops is a very good idea that they would like to encourage. But due to the political turmoilthat happened in Egypt during 2011, the project was cancelled.

10–If a rooftop farming project is planned to be implementin Imbaba, Can you propose roughly a location where a pilot phase should start? and why?

I would recommend the areas on the boarders of Bashtil. Bashtil is a less densely populated area compared to Imbaba and the residents are originally farmers. The people living on the boarders of Bashtil could still have an agricultural memorycompared to the people living in the center of Imbaba. The probability of finding locals with hands in mud and agricultural knowledge an interestsincrease as you go far away from the center of Imbaba.

9–Would you like to add anything?

I personally liked the idea of rooftop farming more than for example improving the quality of the streets and pedestrian walkways which is a very big challenge if you are talking about the streetsin Imbaba. I personally experienced a lot of trials to improve the pedestrian walkways but they were never successful.

Interviewee: Dr. Neveen Metwally
Position: Researcher in the Agriculture Research Center (ARC) ,Cairo.
Date: June , 2015
Note: Thiswas a phone interview and was not recorded (Data may not be accurate and is based on the authors memory)

1–Through out my research, i found out that most of the rooftop farming developers prefer the Deep Water Culture Hydroponic systemsIn most of the projects in informal areas, is there a reason behind that?

I thinkit is the matter of price, the systemis considered low cost and easy to maintain and has a high yielding rate, but i still think its not the ultimate solution for informal settlements, except if you are planning to work on a large scale so that the quantity of the final produce could be effective.

2–what are the problems of Deep Water Culture Hydroponics in Egypt?

Based on my knowledge, i would say that the system needs electricity for the air pumps, also the hot weather could negatively affect the nutrient solution and the crops. another problem that it does not provide a wide variety of crops and of course it does not have a strong impact on the environment compared to soil based systems.

3–What are the types of crops better used for Deep Water Culture farms that are planned for informal settlements?

I would say any leafy vegetables would work very well for this system. lettuce , cabbage , Rocca , spinach, also peas. Peppers and tomatoes also could be produced in deep water cultures.

4–Which other types of rooftop farming systems would you recommend in this context ?

I think it depends on what you want to plant, but based on my knowldege i would prefer working with a hybrid farm containing hydroponics and containers. Containers are easy and durable and flexible depending on the size of the roof. It also provides more variety of crops if integrated in a farm with hydroponics.

5–Containers would need a layer of soil, What about the weight of the containers? do you think it fits with the conditions of the roofs in informal settlements?

it depends on the surface area of the containers and the depth of the substrate.But generally if you are designing a small farm it will not be very heavy as you might think. i think it can fit with the roof conditions of informal settlements if properly designed.

8.5. APPENDIX (5) –ROOFTOP FARMING PROJECTS IN CAIRO –






–A rooftop Farm in Ezbet el Nasr –
(Images Courtesy of GIZ , 2013, 2015)

Schaduf Marketing for the produce of Ezbet el Nasr
(Images Courtesy of Schaduf Inc.)

–Hydroponic Lettuce Production –
(Images Courtesy of Schaduf Inc.)

–Different Lettuce Species –
(Images Courtesy of Schaduf Inc.)

–A rooftop Farm in Sakyet Mekki –
(Images Courtesy of Schaduf Inc.)

–Herbs Production in a Hydroponic Farm –
(Images Courtesy of Schaduf Inc.)

–Produce of Ezbet el Nasr –
(Images Courtesy of Schaduf Inc.)

–Am Hamed Rooftop farm producing Jawmellow –
(Images Courtesy of Schaduf Inc.)

–A Rooftop farm producing Jawmellow –
(Images Courtesy of Schaduf Inc.)