UNIVERSIDADE DE ÉVORA

SCHOOL OF SCIENCE and TECHNOLOGY

DEPARTMENT of LANDSCAPE, ENVIRONMET and PLANNING

The Green Rooftops: Discussion on the Possibilities of Applying it in Arab Region.

A Critical Review

Israa Alkahwaji

Supervisors: *Prof. Aurora Carapinha*

Prof. Rute Sousa Matos

Master in Landscape Architecture

Dissertation

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Os Telhados Verdes: Discussão das Possibilidades de Aplicação na Área Árabe.

Uma Revisão Crítica.

Resumo:

Os telhados verdes vêm sendo aplicados a cerca de 100 anos e terminaram por ser considerados como um elemento fundamental das áreas urbanas nas últimas décadas. Eles têm sido utilizados em iniciativas sustentáveis para a redução do dióxido de carbono na atmosfera, tanto no local como em seu exterior, a diminuição do volume do escoamento e dos poluentes da água da chuva, a redução das poluições sonora e do ar e também para criação de pequenos ecossistemas. Em termos económicos, os ganhos a longo prazo acabam por compensar rapidamente as despesas da instalação do telhado verde, os quais são projetados para ter a mesma vida útil de um telhado convencional. Baseando-se nestas condições – além de fomentar uma publicidade positiva, um maior recrutamento de usuários e incentivar a agricultura local – o presente trabalho recomenda de forma incisiva a inclusão dos telhados verdes nas construções.

O objetivo é fazer uma análise crítica sobre questões referentes ao sistema de telhado verde, além de apresentá-lo como uma solução para o futuro. Esta análise também evidenciará o escasso conhecimento tecnológico que ainda existe sobre este tipo de cobertura e colocará em destaque a necessidade de investigações locais para a instalação dos telhados verdes em países sub-desenvolvidos e em desenvolvimento. Esta análise, baseada no sistema do telhado verde e seus diferentes tipos, será acompanhada por uma revisão bibliográfica e, por último, pela apresentação do valor ecológico, social e económico deste sistema. O trabalho ainda discutirá sobre o uso do telhado verde nas regiões árabes apresentando uma

análise da sua situação atual, dos desafios que ele ainda enfrenta juntamente com as possíveis soluções e, finalmente, apresentará alguns projetos destas regiões.

The Green Rooftops: Discussion of the Possibilities of Applying it in the Arab Region

A Critical Review

Abstract:

Green roofs have existed since more than one hundred years ago and have been proved to have so many sustainable benefits, from reducing pollution, to reducing the urban noise in addition to reducing storm water runoff.

And economically it has been shown that the long term benefits which come from having green roofs offset the costs which are necessary in the beginning to install these green roofs. In addition, it offers the possibility of implementing local agriculture on the rooftops and providing more jobs opportunities.

Therefore, after researching all the advantageous aspects, this study recommends the considerations regarding applying green roofs on the buildings nowadays.

The intention of this paper is to make a critical analysis towered green rooftop issues. In addition to that to present the green rooftop gardens as a future possible solution.

This Thesis also reviews the gap in knowledge regarding green roof technology and its benefits and it shows the need to research locally into the application of the technology of green roofs and make it possible especially in developing and underdeveloped countries.

Therefore this study basically, will include a review about green rooftops and the types and will present a historical overview about green rooftop gardens. It will

also show the valuable factors which green rooftops play as a critical environment role whether be it ecological, social or for economic benefits.

In addition to that, this thesis will discuss the green rooftops in the Arab Region presenting the current situation, the challenges and the possible solutions and finally it will name various projects for Arab Region.

Acknowledgment

First and foremost, I am thankful for Global Platform Organization under supervision of Mr. President Jorge Sampaio for giving me the opportunity to continue my studies in Portugal and for supporting me in the difficult times and special thanks for Dr. Helena Barrocco for her efforts and Sponsorship.

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At a personal Level, thanks to my family, my father, my mother, my sister and my two brothers, without whom my master degree could not have been pursued till the end. Especially my older brother Bashar who has been giving me a wonderful support and took care of me since the beginning of my study journey earlier in Syria till lately in Portugal.

Despite the current events in Syria and the enormous distance between me and my family, they have constantly maintained their support and love.

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I. INTRODUCTION

The remarkable increase in the number of buildings, schools, hospitals and factories, has resulted in a sharp decrease of the green areas within the cities, which in turn has led to many problems such as air pollution, in addition to water pollution including a variety of wastes. The health of the human being has been affected due to overcrowding, lack of oxygen, lack of ecological structures and networks represented by plants in the surrounding environment, which has resulted in a change in the general behavior of people.

As a result the increase in the number of buildings has decreased the area that can be cultivated between buildings and increased surface areas and disappearance of green spaces; hence the idea of surface cultivation in cities has arrived.

The surfaces are usually used to store trash and old useless objects, which blemishes the overall appearance of the building and increases the chance of harmful organisms that threaten human health from insects, rodents and reptiles. This requires increased use of chemicals to get rid of these organisms, so maybe green rooftops could be a solution to these problems.

In some places it could be useful, in the absence of large areas of land, to enjoy the beauty of plants that bring joy and tranquility, and give a sense of relaxation to anyone.

In addition to the enjoyment and relaxation elements that can be provided by roof gardens to anyone, they have a practical advantage, especially for the occupants of the top floors, they are protected from the affects of weather conditions, the cold during the winter or the heat during the summer.

The gardens of the roofs could play a role as a solution to the phenomenon of “visual pollution”, noting the absence of aesthetic appearance of buildings, the presence of aesthetics undoubtedly helps to achieve the quality of life indirectly

and rebalances the environment with its resources after the human impact of negative results of the activities exceeded the lines and allowed limits.
This is in addition to the possibility of cultivating medicinal and aromatic plants of various kinds, as well as ornamental plants, whether for internal or external decoration or even the production of cut flowers. This can be used for commercial production or used to decorate and beautify the building's surface and transform the roof into a fruitful garden enjoyed by all residents of the building and their visitors.

Nowadays with the scarcity of water facing some or most of the Arab countries, it has become a necessity to resort to more sophisticated and non-traditional means, and the safeness of healthy food has become so scarce that it can be said that most of the food available is not safe by a large proportion and so on for the large recourse to chemical pesticides and industrial hormones to improve the quantities of agricultural products, which ultimately lead to the deterioration of the health of the consumer of these products.

Therefore, the tendency to exploit the method of agriculture on the rooftops may provide food that is not harmful to the consumer and may generate income that helps to secure some of the cost of living.

It is very important to mention that the green rooftop is a sizable topic. Therefore, researching into the issues related to green rooftops requires a good knowledge and background information regarding it and the factors which might affect it. So this thesis shows a part of the facts regarding green rooftops through the history and it also reflects some hopes for the future use of green rooftops in the Arab Region, the underlying thread of this study concerns the differences between the places where the green rooftops idea has been applied and developed (such as Europe and the United States) and the areas which might use and install

green rooftops in the future (like the Middle East and North Africa), that's why during the development of this study it is been observed that it is very important to compile more local research to help and figure out the possibilities and the correct ways of applying green roofs in different conditions and under other factors' effects.

For the most part, the references used in this study were from the United States (U.S) due to the availability of English language resources.

II. Literature Review

1. Concept of Green Rooftops

The green roof has environmental, social, economic and aesthetic benefits within the urban and suburban context.

In this thesis, the literature review looks at the wide range of perspectives that exist in the literature written about rooftop gardens and green roofs.

These perspectives come from various subjects such as landscape architecture, architecture, and horticulture and those perspectives work together to create the "complex whole"[1] of current green roof knowledge.

Green roof technology has been used extensively in Germany for many years due to these benefits. However, in the United States the green roof concept has not been widely accepted. "The reason for the low popularity of the green roof in America is because little technical information about green roof systems has been published in English".[2]

A search of green roof literature available in English reveals that most of the information has been written about rooftop garden design rather than green roofs.

[1] (Greenblatt, Culture, 1995, p. 225)

[2] From an article published in the May 1998 under the title "Grass-Roofs Movements" issue of *Landscape Architecture Magazine*, J. William Thompson

In this thesis it was important to study both rooftop gardens and green roofs because they are related and are often times confused with each other because they both exist on rooftops and they share the same history.

However although green roofs and rooftop gardens may seem like similar entities, they are truly different in both structure and purpose as seen in the following brief definitions:

-Rooftop Garden: any planted open space, intended to provide human enjoyment or environmental enhancement that is separated from the earth by a building or other structures. A roof garden's primary purpose is to provide a place to be among or to view plants (Osmundson, 1999, p. 13).

-Green Roof: a thin-growing medium spread over layers of drainage medium or waterproofing that may cover the entire roof. The primary goals of a green roof are environmental, such as decreasing storm water runoff, absorbing solar radiation, decreasing air pollution, and insulating the building (Thompson, 1998, p. 38).

In addition we could say the difference between rooftop gardens and green roofs is the type and amount of literature available on each topic.

The rooftop garden concept dates further back in time than the green roof, so there is naturally a larger amount literature published on rooftop gardens. Most rooftop garden data can be found in books, journal articles, and magazine articles. These books range in subject from historical accounts of rooftop gardens during ancient times to “how-to” books for the construction of simple residential rooftop gardens. Since the green roof is a fairly new idea, very few books have been published on them at this time. Most green roof information can be found on the Internet, in magazine articles, and from company brochures.

Theodore Osmundson's book, *Roof Gardens: History, Design and Construction*, is a major comprehensive resource on rooftop gardens. Published in 1999, this book outlines the evolution of rooftop gardens from the ancient Hanging Gardens of

Babylon to the popularity of rooftop gardens after World War II. Although Osmundson's book reviews a vast array of rooftop gardens over time, it does not discuss the state of the most current green roof technology available. However, Osmundson's rooftop garden historical timeline is a fundamental framework in which to study the evolution of the current green roof.

Regional history books are key resources for information on ancient rooftop gardens. Books on the history of ancient Mesopotamia and Babylon commonly discuss the legendary Hanging Gardens of Babylon. Similarly, detailed information on the rooftop gardens of ancient Pompeii, the Italian Renaissance, or the Hermitage is located in specific books on each of these topics.

Rooftop garden historical information for specific areas such as the Kremlin and Tenochtitlan is scarce and a detailed literature search revealed only minimal descriptions of gardens in history books. Nonetheless, these stark descriptions give clues to the history of rooftop gardens and are important in compiling a complete evolutionary account of rooftop gardens.

Urban rooftop gardening techniques are widely discussed in books ranging in date from the 1920s to the 1970s. These books illustrate the advantages of residential rooftop gardening and mostly focus on simple container plantings. Early rooftop gardening books, such as Ida Mellen's *Roof Gardening* published in 1929, promote the rooftop garden as a profitable real estate investment and a place to practice the hobby of urban gardening. Mellen's book, the first of its kind, explains her experimentations with rooftop gardening on the tin roof of her New York City apartment. The writer describes the elements of her garden from small seating areas to specific plants that thrive in the rooftop environment.

Residential rooftop gardening books published in the 1960s and 1970s focused on more elaborate designs than Ida Mellan's simple rooftop container garden. During the 1960s, rooftop gardens were becoming more complex and

evolving into different types: balcony gardens, terraces over parking spaces, simple roof gardens, and decorative penthouse gardens (Smith, 1969, p. 138). These books advocated for creativity in rooftop design by using fountains, brick planters, and outdoor carpeting. A book entitled *The Secret Gardens of Watergate* described a balcony garden that even utilized mirrors to give the illusion of a larger garden space (Innis, 1986, p. 20).

Alice Upham Smith's 1969 book, *Patios, Terraces, Decks, and Roof Gardens*, started to discuss the environmental function of rooftop gardens such as shade creation and sun reflection from the plants. Furthermore, a book entitled *Rooftop Gardening* published in 1977, as discussing the role rooftop gardens play in decreasing air pollution (Tinkel, 1977, p. 115).

Regarding the magazine and journal articles on rooftop gardens in the 1960s and 1970s, these articles focused most of the time on large urban rooftop gardens (mostly ground level rooftop gardens built above underground parking garages). These were favoured social spaces due to their location within highly populated urban environments. These public spaces were so popular that the October 1962 issue of *Landscape Architecture Magazine* dedicated half of the issue to rooftop gardens. Descriptive articles featured prominent rooftop gardens of the time like *Kaiser Center in Oakland, The Equitable Plaza in* Pittsburgh, and *Tower Square* in Hartford.

In 1976 a book entitled *Roofscape* was published. According to the author, Gary Robinette, the purpose of the book was "to collect and chronicle readily available information concerning the landscape development which has taken place on rooftops throughout North America". As populations grew and cities expanded in the 1970s, it was important to explore "the potential for the use of rooftops as spaces for landscape development" (Robinette, 1976, p. 1). This book included information on designing public rooftop spaces, construction of large-scale rooftop

development, elements of the urban roof scape, and concluded with several case studies. Similar to the October 1962 issue of *Landscape Architecture Magazine*, many of the cases in studies discussed in roof scape focused primarily on large urban rooftop plazas and squares just such as the Constitution Plaza, Mellon Square, and the J.F. Kennedy Center to name a few. Although this was an important publication on rooftop development, it was only a first attempt at collecting information and it admitted that much more information was needed in order for it to be considered a comprehensive resource.

Rooftop gardening in the 1980s was not prevalent. Little information on rooftop development at this time can be found in books, magazines or articles. However, the 1990s saw a renewed interest in rooftop gardening with many articles published in landscape architectural magazines and also in architectural periodicals. A disproportionate amount of this rooftop garden information was found in architectural periodicals more than landscape architectural magazines and journals.

The field of architecture has seen how a "heightened awareness of earth-centric information has influenced architecture in the 1990s" with the popularity of "green architecture" (Wines 2000, p. 9).

According to an article[3] "Green architecture is sustainable and "focuses on the environment, economy, public health and comfort.

It's about quality, durability, and longevity. It concerns environmental consciousness, energy saving design, the use of nontoxic materials, and the use of efficient techniques to construct a more cost-effective [building]".

In the United States, green roofs have not been widely publicized especially in the field of landscape architecture. However, since 1998 green roofs have been gaining more attention in landscape architecture and horticultural periodicals such

[3] By Centerline Designs. "Green *Architecture in the 21st Century."* Residential Environmental Design Featured Article. 15 February 2001.

as *Landscape Architecture Magazine* and *Garden Design*. However, not one scholarly journal in the discipline of landscape architecture, such as *Landscape Journal* or *Landscape* has published any articles, editorials, commentaries, and/or critiques on green roof design.[4]

In European countries from 1999, cities adopted types of support and policy, with several mid to large-size cities incorporating roof and vertical greening into their bylaws and planning regulations. As a result of government policy and programs supported in Europe, a new green roof industry was created for plants and material suppliers, roofing professionals, installers and maintenance crews. In Germany, France, Austria, Norway, Switzerland and other European countries, green roofs have become a commonly accepted feature in the construction industry and urban landscape (Peck *et al*., 1999, p. 11-12).

Europe has more than thirty years of green roof research and product development to support its successful green roof industry. The largest portion of Europe's early green roof research took place in Germany, Switzerland, and Scandinavia, and was not written in English (Dvorak, 2010, Koehler, 2007, Mentens *et al*., 2006).

And according to research papers[5] "developments of guidelines were constructed based on academic research, product/component development, and field observation. These guidelines, called *Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau* (FLL) or in English; the German Landscape Research, Development and Construction Society, are often used for green roofs throughout Europe".

[4] Peterson, S. L. (2001). *Retrospective Theses and Dissertations*, "Analyzing the green roof: a critical dialogue". Retrieved May 03, 2017, from lib.dr.iastate.edu: http://lib.dr.iastate.edu/rtd/326/

[5] Magill, J. D., Midden, K., Groninger, J., & Therrell, M. (2011). "A History and Definition of Green Roof".Research Papers. Retrieved May 04, 2017, from http://opensiuc.lib.siu.edu/gs_rp: http://opensiuc.lib.siu.edu/gs_rp/91

Formally, they are the Guidelines for the Planning, of Green Roof Sites, and are used for green roof design, and maintenance.

The North American green roof industry is only beginning to develop its own green roof guidelines, but nothing comparable to the FLL guidelines exists for the North American sector. The Association of Standards and Testing Materials (ASTM) has released several guidelines that describe design characteristics for North American green roofs including the requirements of structural cargo, permeability (drainage and green roof growing substrate), and a guide for plant selection and maintenance.

In North America, research is taking place at several universities, including; Michigan State University, Southern Illinois University Edwardsville, Penn State University, Columbia College, Kansas State University and others. The research findings made by these universities will add to the literature that will create the North American standards for green roofs.

In regard to the websites on the Internet, and from the few architectural and landscape architectural firms that try to promote green roof design. These sources generally focus on the construction technology of green roof systems as well as the specific design and layout of the green roof rather than theoretical and critical critiques of the overall concept.

It is apparent in the search of available literature that green roof design lacks a critical foundation; there has been no critical inquiry into the complex issues or theories about the green roof concept.

Unfortunately, little information is available on the widespread perspectives that inform the cultural aspects of the green roof.

2. Types of Green Rooftops' gardens

Nowadays, there are many types of green roofs which have been designed for different types of buildings and each type has different depth of substrates which is particular to many types of plants which require a specific depth of growing media. The timeline of the installation of the green roofs for example intensive green roof is generally built at the same time of the construction of the building and its plants need a huge investment and care. However the extensive green roofs are limited in plant varieties, so require less maintenance than the intensive one.[6]

And can be installed in an existing building.

The traditional green roof gardens normally require containers or a layer of normal soil. (N. Dunnett & Kingsbury, 2008)[7]. While the contemporary green roofs need an organic growing media.

There are three types of systems (Figure.1) -intensive (deep), semi-intensive (moderate depth) and extensive (shallow) (NRCA, 2007)[8]. These categories are derived from the contemporary German tradition of green roofs (N. Dunnett & Kingsbury, 2008).[9]

[6] According to an Article (Oberndorfer, et al., 2007), "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services" from http://www.bioone.org/doi/full/10.1641/B571005. Accessed (August,20,2017.1:05:10PM)
[7] According to Thesis by (Srivastava, 2011) under the title" green Rooftops Design and Practices: A Case of Delhi".
[8] N. R. C. A. (2007). *The NRCA Green Roof Systems Manual 2007 Edition*. Rosemont, IL: National Roofing Contractors Association.
[9] N. Dunnett, & Kingsbury, N. (2008). *Planting Green Roofs and Living Walls*. Portland, Oregon: Timber Press Inc.

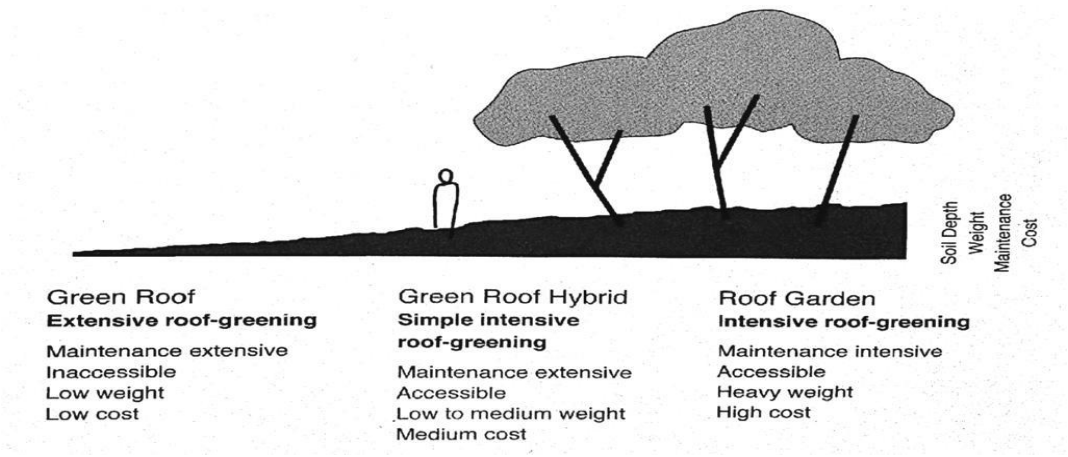

Figure 1. Illustration of Green roof systems and an overview of their characteristics. (Werthmann, 2007)[10]

In intensive type roof-greening; many species of plants are used such as shrubs, lawn or even some trees and the minimum depth of the soil is 25 cm, so it has a substantial weight. And everything is designed in a way which provides paths to be accessible to people and these types of green roofs need regular maintenance.

For the semi intensive type roof-greening; a combination of plants such as small shrubs, grasses and herbs can be used. A medium soil is between (15-25) cm. And this system of green roofs in its weight is between the extensive and the intensive one, so it's heavier than the extensive but lighter comparing with the intensive roof and it also needs less maintenance.

As for the extensive type roof-greening; these types of green roofs are for 'ecological' goals. As it is an ideal roof for biodiversity for birds, insects …etc. The plant species are fewer in this type such as grasses and mosses, so the soil depth is less than 15cm, its weight it the least among the three types, and it does not require regular maintenance.

As a summary the following (table.1) shows the differences among the Green roof systems and the advantages which we acquire from each type.

[10] Werthmann, C. (2007)." Green Roof: a case study". New York: Princeton Architectural Press.

	Extensive	Semi- Intensive	Intensive
Depth of Growing Medium	0.15 m or less	25% above or below 0.15 m	More than 0.15 m
Full Saturated weight	48.8 – 170.9 kg/m²	170.9 – 244.1 kg/m²	244.1 – 1,464.7 kg/m²
Plant Diversity	Low	Greater	Greatest
	Lightweight	Combines best features of extensive and intensive	Greater diversity of plants
	Suitable for large areas	Utilizes areas with greater loading capacity	Best insulation properties and storm water management
	Low maintenance costs and no irrigation required	Greater coverage at less cost than intensive	Greater range of design
	May be suitable for retrofit projects	Average maintenance	Often accessible
	Lower capital costs	Greater plant diversity than extensive	Greater variety
	Easier to replace	Greater opportunities for aesthetic design than extensive.	Greater biodiversity potential
	Suitable for sloped and flat roof	Suitable for flat roof	Suitable for flat roof

Table 1**. Green roof system attributes. Courtesy of: Green Roofs for Healthy Cities (Peck, 2008) + General Advantages of Different Green Roof types**
Source: "Green Roofs in Sustainable Landscape Design", Cantor, Steven L., foreword by Steven Peck, 2008, page 29.

And to classify different types of vegetative roofing structures such as rooftop gardens and green roofs. Therefore, as I mentioned in the beginning of this paper it is important to distinguish between rooftop gardens and green roofs because their definitions are distinctive, and the terms cannot be interchanged - rooftop gardens and green roofs are dissimilar entities that serve very different purposes.

A thorough investigation into the rooftop garden and green roof has yielded vague definitions. When these definitions are applied to roofing structures, they do not clearly explain a variety of situations. The rooftop garden and green roof have been used to define the same structure, even though in reality these describe very different structures.

In the book, *Roof Gardens: History, Design, and Construction*, Theodore Osmundson defines rooftop gardens as the following: "Any planted open space, intended to provide human enjoyment or environmental enhancement that is separated from the earth by a building or other structure. It may be below, level with or above the ground. While it may serve other functions - as a means of circulation or access or as a dining space, for example - a roof garden's primary purpose is to provide a place to be among or to view plants"[11]

In the above definition, Osmundson states that the rooftop garden's primary purpose is to "provide a place" for people. This definition stresses that the major function of the rooftop is as a social space to stroll through, dine in, or view plants.

According to Charlie Miller of *Roofscapes*, a green roof technology supplier, a green roof is based on a completely different concept than a rooftop garden. He defines a green roof as: "A thin veneer of living vegetation installed on top of a conventional roof. It is important to distinguish green roofs from conventional roof gardens, which are essentially container plantings on a roof and may incorporate trees and other plants that require deep rooting.

A green roof, by contrast, is a thin growing medium spread over layers of drainage medium or waterproofing that may cover the entire roof."

In terms of plantings, then, green roofs more closely resemble meadows than what we normally think of as gardens. If the primary purposes of a conventional roof garden are outdoor seating and enjoyment, the primary goals of a green roof are environmental, primarily the following: soaking up storm water; absorbing solar radiation and converting it into plant foliage through photosynthesis; and insulating the building (Thompson, 1998, p. 38).

Other purposes, the terms rooftop garden and green roof to be defined according to the function the roof carries out - function being defined as the action or special

[11] (Osmundson, 1999, p. 13)

duty that the roof performs. As mentioned in the definitions of Osmundson and Miller, the function of the rooftop garden is primarily social while the function of the green roofs primarily environmental. The following definitions also apply social, aesthetic, environmental, and ecological:

-Social: related to human interaction with other humans (Guralnik, 1987, p. 567).

-Aesthetic: the conditions of sensuous perception that define beauty (Williams, 1983, p. 31).

-Environmental: related to the circumstances or conditions that surround an organism or group of organisms as well as the complex of social or cultural conditions that affect an individual or community, concern with the interaction between the human and natural habitat (Cunningham, 1997, p. 614).

-Ecological: related to the relationships of living organisms with each other and with their environment. These relationships between living and non-living entities exist. It is concerned with the life histories, distribution, and behavior of individual species as well as the structure and function of natural systems at the level of populations, communities, and ecosystems (Cunningham, 1997, p. 614).

However, not all vegetated roofing structures fall into either one true type of [rooftop garden] or the other [green roof]. Therefore, this typology proposes a *continuum* of types of green spaces; this typology is implementing the strategies of cultural criticism.

Stephen Greenblatt asserts that the principles of cultural criticism are based on an "awareness of a complex whole"[12]. This typology is also based on an awareness of a complex whole in that it acknowledges that various types of vegetative roofing structures are the product of cultural forces. These cultural forces determine the

[12] Greenblatt, Stephen. "Culture" Critical Terms for Literacy Study. Eds. Frank Lentricchia and Thomas McLaughlin. Second Ed. Chicago: The University of Chicago Press, 1995, p. 226.

specific duty each vegetative roofing structure should perform such as social or environmental functions.

This *continuum* also implies movement along cultural lines. As the *continuum* shifts from ‘‘end to the other, the cultural contexts also shift from social to environmental, public, private and from low-brow to high-brow. These cultural contexts and elements will be discussed in greater detail within the values of green rooftops in this thesis.

This is a *continuum* that describes both past and present rooftop structures. At one end of the *continuum* lies social function and at the other end lies environmental function. The benefit of aesthetic function is not considered in this vegetative rooftop descriptive *continuum* diagram because all rooftop gardens and green roofs are assumed to be aesthetic compared to a conventional roof whether they are designed specifically to be aesthetic or not.

However, it is important to note that aesthetic function is intentionally designed into a majority of vegetative rooftop structures. Most of these vegetative roofing types are specifically designed to have a high aesthetic when a social function is involved. This will be explained in more detail in the following type descriptions.

Within the scope of social and environmental function, lies the issue of accessibility. Accessibility is defined as that which can be obtained, approached, and/or entered easily by humans. It should be noted that in this thesis accessibility does not refer to the accessibility standards of the Americans with Disabilities Act, but rather the ability for a non-disabled person to enter onto a rooftop area. As the *continuum* shifts from purely social function on the left to environmental function on the right, accessibility also shifts from highly accessible to not accessible.

A true rooftop garden, designed for pure social function, is a highly public and accessible place. On the other hand, a true green roof that is designed for only

environmental function would more than likely be private and would not be accessible to any person (except for maintenance) because its design elements do not include paths, benches, or other social elements.

This typological study will highlight five major vegetative roofing types that exist along this descriptive and functional *continuum*. These rooftop gardens and green roofs will be described in more detail in the historical overview section of this thesis.

Type 1: True Rooftop Garden

This type is purely social in function; therefore it is largely accessible to the general public. Because of this social function, this roofing structure is truly a rooftop garden according to the definition described earlier. Since a large number of people utilize true rooftop gardens, they are designed to have a strong visual aesthetic. A type I roofing structure is a large public urban plaza that is both visible and easily accessible. Typically, a true rooftop garden is located at or slightly above ground level to heighten its accessibility and social function. Most of these Type I rooftop gardens sit atop underground parking garages in urban environments. Examples of this type of rooftop garden are Gulbenkian Garden in Lisbon (Figure.2) and Union Square in San Francisco (Figure.3).

Figure 2. **Gulbenkian Garden in Lisbon**

Figure 3. **Union Square in San Francisco**

Source: http://4.bp.blogspot.com/-I_2IqfnaA1I/VZvlmvNKK4I/AAAAAAAAAjw/V-ae8Aba4Nc/s1600/LL_Gulbenkian.jpg,

Accessed:(November 4, 2017, 8:07:57 PM)

Source: http://texaswatertowers.com/kayandlyn/postcard_sanfranciscoca.html

Accessed:(June 12, 2017, 2:03:39 AM)

Type 2:

As to this type, the vegetative roof structures are also highly accessible and built for social reasons, but not for the general public. The roof structures are also considered rooftop gardens, so these structures also incorporate a designed visual aesthetic. These rooftop gardens consist of terrace sitting areas and container gardens that are only accessible to certain groups of people. Specifically, the people that are allowed to access these gardens are owners of the residence on which the rooftop garden is located, employees of the building where the rooftop garden is built, and/or people involved in tours that pay to access the garden. Examples of type II rooftop gardens include the rooftop gardens on the residences of ancient Pompeii (Figure.4) and The Derry and Toms Department Store rooftop garden in London, England (Figure.5) and common residential rooftop gardens that are found atop urban apartment buildings.

Figure 4.**The rooftop gardens on the residences of ancient Pompeii**

Source: http://www.thais.it/speciali/Pompei/intrvm.htm
Accessed: (June 12, 2017, 2:09:13 AM)

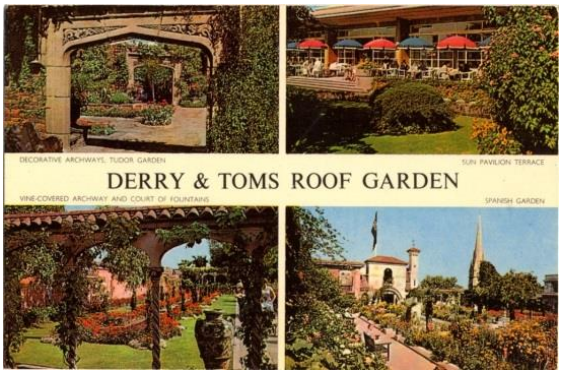

Figure 5.**The Derry and Toms Department Store rooftop garden in London, England**

Source: https://rbkclocalstudies.wordpress.com/2013/08/08/the-adventures-of-jerry-cornelius-at-derry-and-toms-famous-roof-gardens/
Accessed: (June 12, 2017, 2:09:13 AM)

Type 3:

These types of rooftop structures contain characteristics of both the rooftop garden and the green roof. Therefore, they can be called either rooftop gardens or green roofs depending on the priority of their functions. Most of these structures are still considered rooftop gardens because of their primary social function and accessibility. However, whether it is their primary function or not, type III roofing structures also have an environmental component. Type III vegetative roofing structures have a designed aesthetic because of their social function. Examples of type III rooftop gardens are the Ancient Ziggurats of Mesopotamia and the Hanging Gardens of Babylon (figure.6).

Although these rooftop gardens were designed primarily for their social function or, these gardens utilize vegetation on the roof for climatic control because of their location in a warm climate. These environmental benefits can be felt both as shade on the roof and cooling insulation inside the building on which they are located. Modern examples of Type III green roofs can be found in Germany. These are called green roofs because they are designed primarily for the environmental benefit of storm water management but are placed in the type III category because they perform a secondary social function by containing seating areas, benches, and/or paths to make them accessible for social uses.

Figure 6.**Hanging Gardens of Babylon** (Hypothetical)

Source: https://www.pinterest.pt/pin/113504853085454474/

Accessed: (June 12, 2017, 2:21:22 AM)

Type 4:

Type IV rooftop structures are green roofs accessible only for maintenance purposes. These structures are considered green roofs because their primary functions are environmental – storm water management, reducing air pollution, climate regulation, and wildlife habitat. Although this green roof is designed primarily for environmental function, a second function evident in the green roof is a designed visual component for the viewing pleasure of those that can see the rooftop from surrounding buildings. This green roof is designed because the plants

chosen for this roof are placed in a particular manner or pattern to create a visual aesthetic. Example of type IV green roofs is Chicago City Hall rooftop (Figure.7).

Figure 7. **The green roofs are Chicago City Hall**

Source: http://www.sactownmag.com/August-September-2010/Raising-the-Roof/

Accessed :(June 12, 2017, 2:27:13 AM)

Type 5: True Green Roof

A true green roof is constructed specifically for the environmental functions of storm water management, air pollution control, insulation of the building on which they are located, and environmental climate control to name a few. The true green roof is not accessible to humans for social purposes, although it may be accessible strictly for maintenance purposes. The true green roof is highly accessible to wildlife such as birds and insects. Also, the vegetation on a true green roof is also not specifically placed or designed in patterns for a visual aesthetic. The green roof vegetation mimics a vast meadow or lawn. Examples of Type V true green roofs are the roofs on the buildings on the corporate campus of Gap, Inc. in California see (figure.8) and the roofs on the Great Plains sod houses built by the Native Americans and early American settlers.

Figure 8.**The roofs on the building on the corporate campus of Gap, Inc. in California**

Source: http://www.greenroofs.com/projects/pview.php?id=26

Accessed :(June 12, 2017, 2:31:06 AM)

III. Historical overview

Since ancient times the cultivation of vegetation on rooftops has been a tradition. Many different cultures have adapted vegetative rooftops to perform a variety of functions from social to environmental one. A broad historical overview is a necessity to the evolution of the rooftop gardens and green roofs.

The context of this historical overview investigates the use of rooftop gardens and green roofs in many different cultures, places and settings from ancient Mesopotamia (Iraq) to the United States nowadays. So it offers a richly illustrated tour of rooftop gardens around the world and through the history.

So we have a timeline to show the development of the green rooftops overtime and all the related issues.

The history of the green roof concept dates back to antiquity. Rooftop structure is documented in a resource, Theodore Osmundson's book, *Roof Gardens: History, Design, and Construction*, which contains the evolution of rooftop gardens and green roofs from the ancient Hanging Gardens of Babylon to the popularity of rooftop gardens after World War II.

Green roof was a traditional technology. It began in the ancient gardens of; Ziggurats of Ancient Mesopotamia; Hanging Gardens of Babylon and Mysterious in Pompeii. After that in the Middle Ages the Renaissance Garden; Mont-Saint-Michel in France; Palazzo Piccolomini, Pienza in Italy; Tower of the Guinigis, Lucca, Italy; Medici Roof Garden, Careggi, Italy. Then, it was followed by Scandinavian countries, namely the sod roofs. Lastly it started to develop in many other countries in the world. (Köhler, 2001, p 151; Oberndorfer, p. 823-833, 2007; Osmundson, 1999, p. 112-3).[13]

After that in the sixties, Reinhard Bornkamm, a researcher in Free University of Berlin, studied the vegetation ecology of Koch's roof. And he designed a rooftop garden which merged both types of green roofs, the extensive and the intensive, on the building of the university.

In the 1980s scientists continued studying to discover more in respect to the issues of green roofs after Bornkamm and Koch by evaluating the waterproofing materials and their durability which had been used by the previous projects, they wrote many papers but in German. (Mentens, 2005, p. 217-226).

In Asia, in 1914, a rooftop garden was built in Tokyo on top of the Mitsukoshi department store. This garden had a traditional Japanese garden design.

In 1936, Asakura, the founder of Japanese modern sculpture built a green rooftop garden on top of the Asakura Sculpture Museum.

And after the World War II and because of its effects to the environmental climate there was an increased interest in the technology of green rooftops in Tokyo in 1939. After that Japan supported the idea and passed a legislation that required

[13] According to study by Syumi Rafida Abdul Rahman, and Hamidah Ahmad , " Green Roofs as Urban Antidote: A Review on Aesthetic, Environmental, Economic and Social Benefits" From: http://www.academia.edu/2283321/Green_roofs_as_urban_antidote_A_review_on_aesthetic_environmental_economic_and_social_benefits. Accessed :(May,27,2017)

each new urban area to contain at least 20% green landscaping on the rooftops, thus advancing the green roof industry.

However, in general if we want to compare the western counties with the scarcity of the development and implementation of green roofs in Asia, it is due to many reasons; such as the lack of research in this field, how to apply it in different climate conditions, what type of plants are suitable for that region and of course the high cost analysis and funding for that.

-From Ancient Rooftop Gardens:

- **Ziggurats of Ancient Mesopotamia**

Historical references of human-made roof gardens have been found as early as the fourth millennium and 600 B.C. with the Ziggurats of ancient Mesopotamia. Ziggurats (figure.9) are "great stepped pyramid towers of stone built in stages" (Osmundson, 1999, p. 112). The large steps within the pyramid were accessible by smaller staircases that stretched up the sides of the ziggurat. These large structures were typically placed within the courtyards of temples in major cities (Osmundson, 1999, p. 112).

Figure 9.**Ziggurats of ancient Mesopotamia** (Hypothetical)

Source: https://www.pinterest.pt/pin/307863324511670137/

Accessed: (May 24, 2017, 9:50:29 PM)

According to the archaeological accounts of Sir Leonard Woolley, each large step was planted with trees and shrubs that acted as an oasis or point of relief during the workers' climbs up the sides of the ziggurats during their construction (Osmundson, 1999, p. 112). This description of vegetated above ground "steps" is what places them within the ranks of the earliest known rooftop gardens.

Etemenanki is the most well-known of the ancient Mesopotamian ziggurats. This ziggurat was located in the great square of the temple Esagila in the ancient city of Babylon. The structure was approximately 300 feet tall and measured 100 yards in length on each of its four sides. It was seven stages tall, which means, it had seven "steps" and therefore seven levels of gardens. Although Etemenanki was an important structure in Babylon, it was destroyed in 482 B.C. during revolts against the Persian king Xerxes I (Osmundson, 1999, p. 112). There are, however, preserved examples of the ancient ziggurats such as the ziggurat of Nanna in the ancient city of Ur (Osmundson, 1999, p. 112). The structure of Nanna was constructed of a mud core and brick facing and measured 68 feet tall (Osmundson, 1999, p. 113). Nanna is the best preserved of the ancient ziggurats and provides a glimpse back to the beginnings of vegetated roofs.

- **Babylon Gardens in Iraq**

Babylon Gardens (Alkatif)[14] (figure.10) are a great legend in history and are one of the Seven Wonders of the World and despite the full certainty of their existence, we did not know the position specifically, but it is close to Hilla as it is called today. The name of the city of Babylon is mentioned in the Qur'an with the story of the kings Harout and Marot, which was the capital of the ancient Babylonian civilization that arose in Iraq. In the Akkadian language Babylon

[14] Alkatif, J. (n.d.). "Hanging Gardens of Babylon in Iraq". Retrieved May 26, 2017, from : www.thaqafnafsak.com: https://www.thaqafnafsak.com/?p=12931

means “the door of God,” as the ancient Babylonians called it, located in the Mesopotamia.

Figure 10. **Babylon Hanging Gardens** (Hypothetical)

Source: http://www.dailymail.co.uk/sciencetech/article-2513819/Mystery-missing-Hanging-Gardens-Babylon-solved-Expert-claims-elusive-wonder-world.html
Accessed: (May 24, 2017, 10:05:29 PM)

Babylonia was an ancient state and cultural region based in Mesopotamia (present-day Iraq). It emerged as an independent state in ca. 1894 B.C, the city of Babylon being its capital. It became the major power in the region after Hammurabi (fl. ca. 1792- 1752 B.C middle chronology, or ca. 1696 – 1654 BC, short chronology) created an empire out of the territories of the former Akkadian Empire. (Slayer, 2012).

According to Diodorus Siculus in *The Library of History*, the Hanging Gardens were built by Syrian king for his wife. For they say that she was of Persian race and that, as she missed the meadows in the rolling hillside, she asked the king to imitate the distinctive features of her native Persia by means of a wonderfully designed garden and for which he created an enormous oasis filled with green in the rid desert of Iraq at that time.

The Hanging Gardens of Babylon were discovered from some of the ancient

Roman texts, which they spoke of with great admiration and which in their view represented the peak of romance in this age.

The name of the Babylon Gardens is suspended with no cables or ropes being used in its construction because the gardens were planted on the balconies of the building and not on the ground (see figure.11) as it used to be the height of its building was approximately 24 meters and was surrounded by a strong wall with a thickness of 6.7 meters and length was 17 meters and an area of 14864.5 square meters.

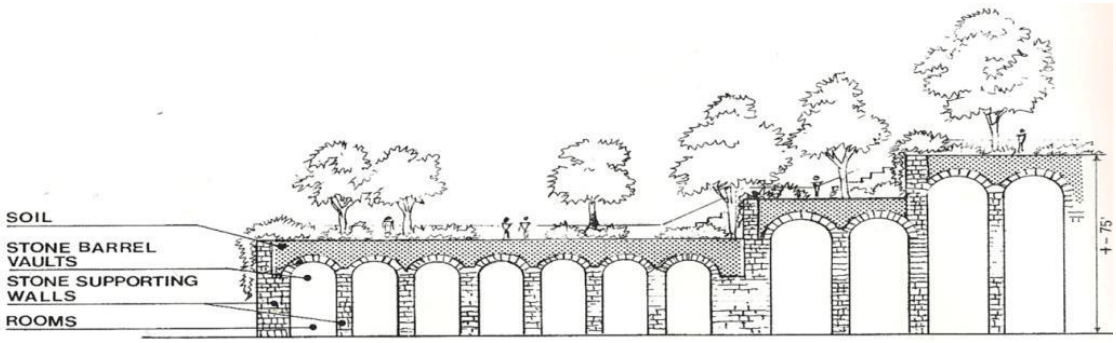

Figure 11.The section drawing of the Hanging Garden of Babylon, circa 500 B.C based on archeologist Robert

Koldewey's description. From ROOF GARDENS: HISTORY, DESIGN, AND CONSTRUCTION by Theodore Osmundson. Copyright © 1999 by Theodore Osmundson. Used by permission of W.W. Norton & Company, Inc

The ancient historian Strabo described the method of raising water to these gardens as a genius. The rain in this region is rare in nature due to the surrounding desert environment, so it was necessary to have a source of water and an advanced system for irrigation of plants through the terraces of each floor of the building. The ancients used a serial pump to raise the water to the upper floors. It consisted of two huge wheels, one on top of the other, and connected to a large chain of suitable size (figure.12). When the wheel in the water source revolves, it moves the chain and the buckets are filled with water, allowing it to be lifted up and water thrown into the upper floors and then filled again when it returns. (Saleh, 2009).

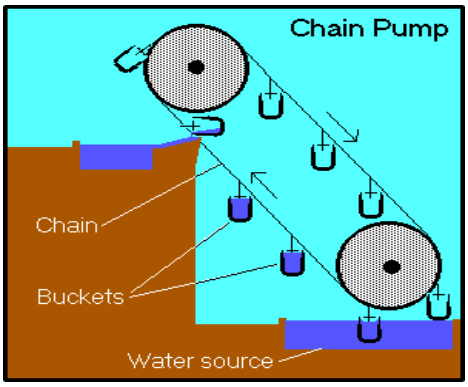

Figure 12.Irrigation System in Babylon Gardens

Source: https://www.slideshare.net/iraqitheboss/hangging-gardens

Accessed: (May 26, 2017, 12:27:16 AM)

The building of the garden is made of hard-boiled bricks like all the houses shown in Iraq at that time, it did not harm the ordinary houses. However, the Hanging Gardens of Babylon were a unique building and many treated with water. The bricks are separated from the water used to irrigate the plants on the garden floors. (Z, L, & G)[15]

-From the Middle Age Rooftop gardens:

- **Palazzo Piccolomini, Pienza, Italy**

Palazzo Piccolomini is an example of a well-preserved Italian Renaissance rooftop garden. Commissioned by Pope Pius II, the palazzo was built as the summer papal center in the mid of the fifteenth century (Osmundson, 1999, p. 116). The palace was built on a ridge and the rear of the building looks out on the valley of the river Orcia (figure13). The palazzo is constructed with stone and is located next to the town's cathedral. Although designed by Rossellino, the Pope provided much of the inspiration for the design. Pope Pius highly appreciated the surrounding Tuscan

[15] Z, R., L, E., & G, A. (n.d.). "The Hanging Gardens of Babylon". Retrieved May 24, 2017, from www.angelfire.com: http://www.angelfire.com/ny/anghockey/hanginggardens.html

landscape and encouraged the rooftop design to include spectacular wonderful views of it from the garden (Masson, 1961, p. 76) as it is been shown in figure.14. Since the palace was built along the slope of a ridge, the building consists of lower floors under the main floors as the grade slopes away. Specifically, as one exits the palazzo's street-level main floor onto a rear courtyard they find themselves standing on top of a rooftop garden. This is because the street-level grade slopes down as the building's main floor remains level so that a lower floor fits under half of the main level. This causes the rear courtyard to sit on top of a rooftop, therefore making it a rooftop garden. The lower floors under the rooftop garden consist of four rectangular rooms that house artisans' shops and storage (Osmundson, 1999, p. 116).

Figure 13. Palazzo Piccolomini, Pienza, Italy

Source: https://www.pinterest.pt/pin/546624473496209770/

Accessed: (May 29, 2017, 1:09:00 AM)

Figure 14. Rooftop garden of Palazzo Piccolomini, Pienza, Italy

Source: www.beatesca.com

Accessed: (May 29, 2017, 1:11:17 AM)

-From the period after 1600 A.C.:

- **The Kremlin, Moscow, Russia**

In czarist Russia, the nobility regarded rooftop gardens as a luxury. During the rebuilding of the Kremlin in the seventeenth century many "house-chapels" were erected, the living quarters of the royal family were extended and remodeled and many indoor and "hanging" gardens were laid out on the upper levels (Markova,

1981, p. 10). Specifically, an extensive two-level hanging garden called the Winter Garden was installed on the roof of one Kremlin palace.

The Grand Princes' Wing was connected to the Great Kremlin Palace by a passageway that was built from arched vaults upon which the Winter Garden was placed (Markova, 1981, p. 12). Lead plates waterproofed the roof of the passageway and weighed approximately 10.24 tons (Osmundson, 1999, p. 120). The lead sheets were covered with a layer of soil that measured one meter thick and supported the growth of trees, shrubs, and flowers (Markova, 1981, p. 44). This rooftop garden was so heavy that it required extensive reinforcement of the vaults on which the garden was built (Osmundson, 1999, p. 120).

With regards to the upper level of the Winter Garden, it had an area of 10 acres and was measured at 400 feet long. It was surrounded by a stone wall with embrasures and it had fruit trees, shrubs, and vines planted in boxes or tubs. The upper garden featured a 1,000 square foot pond with fountains fed with water from the Moscow River that was located next to the palace (Osmundson, 1999, p. 119).

The lower terrace garden was built in 1681 and also it had a large pond with a water-lifting tower and a lead-lined reservoir. The stone walls enclosing the lower garden were painted with scenic landscapes in order to create "the illusion of visually expanding the space" (Osmundson, 1999, p. 120).

- **Malta Garden in the National Palace of Queluz in Lisbon, Portugal**

According to an article by Patrice Todisco [16] the gardens are a "paradise dotted with masterpieces of English sculpture." King Pedro III is the one who built the gardens in the eighteenth century basically for leisure.

[16] Patrice Todisco May.30, 2017 "Gardens of the National Palace of Queluz: Portugal". From: https://landscapenotes.com/2017/05/30/gardens-national-palace-queluz-portugal/. Accessed:(November,19,2017)

The Robillion's Hanging Garden was built over a water reservoir which served the formal court in the entrance. In the center there is Neptune fountain. (Figure .15)

Figure 15. Garden of Malta in Lisbon, Portugal

Source: http://www.parquesdesintra.pt/noticias/palacio-de-queluz-encerrado-na-manha-de-16-de-janeiro/

Accessed :(November, 19, 2017, 11:04:01pm)

There are two formal gardens and they are separated from the landscape which surrounds them by stone, flower pots and many statues.

The paths were drafted before the construction of the garden. And also there are many paths to link the different rooms of the gardens which all decorated with lakes, fountains and sculptures.

Irrigation of the gardens was by a complex hydraulic irrigation system which depended on the channels of the Jamor River which crossed the whole garden.

- **Sod Roof In Norway and America**

The sod roof was "a roof covered with soil for insulation that was planted with grasses and other plants to stabilize the soil" (Osmundson, 1999, p. 121). (See figure.15).

Although their benefits were many, the sod roofs did have their drawbacks. They were not necessarily waterproof and leaked constantly. Because of this inefficiency, they were quickly abandoned when better building materials became available (Osmundson,p. 122).

Sod roofs have been used in Scandinavia and America for over a century. The freezing temperatures of Norwegian winters led to the use of this kind of the sod roof.

Figure 16. **Norwegian Grass Roofs**

Source: https://www.pinterest.pt/pin/190699365441139273/

Accessed: (May 31, 2017, 2:21:48 AM)

The Native American Omaha tribe of eastern Nebraska utilized the tall grass prairie's coarse grass sod on the roofs of their lodges. As little timber was available on the open plains, they cut up the sod into rectangles and overlapped them like modern day roofing shingles to keep their homes dry (Welsch, 1991, p. 5).

The Mormons established "Winter Quarters" in eastern Nebraska and built sod houses to carry them through the harsh Plains winter.

According to Cass G. Barns in *The Sod House*," the Mormons continued to build sod houses on their journey across the prairie" (Welsch, 1991, p. 14).

These earthen structures were built with bricks of soil and buffalo grass. The roofs were made of growing sod, which functioned as insulation from the harsh prairie winters and protection from the intense heat of the summer (Welsch, 1991, p. 24). The roofs were said to be the most important element of the sod house. According to Roger Welsch in *Sod Walls,* "if the roof failed, the house failed, for the endurance of the walls depended ultimately on the protection of the roof" (p.48).
The typical sod roof rested on a base of cedar beams and willow-pole rafters. On top of these poles was were three more layers of organic materials such as wild plum or chokecherry brush, wild grass, fine clay or gypsum. The sod was placed on the outermost layer and was anywhere from one to three layers thick depending on the strength of the underlying structure. It was laid "grass side up so that it would continue to grow, to re-establish roots, to form a protective layer of grass and prevent erosion" (Welsch, 1991, p. 71).
Although not intended as a primary function, the roofs also had an aesthetic value. Typically, colorful wildflowers blossomed from season to season to decorate the roofs.

-From the period before the world war II

- **Theatre rooftop gardens**

The idea for these rooftop spaces was conceived from European theaters located in gardens. The writings of Vitruvius explained that in ancient Rome a close relationship existed between theatrical and garden design. American theaters borrowed this ancient Roman style and retrofitted it to rooftop gardens. These garden theaters were designed on the roofs of existing theater buildings for use in the summer months due to the lack of ground-level open space in America's major cities. The rooftop theaters often had a full or partial sliding-glass roofs that offered protection from the rain. Plantings consisted of palms, ivy, and flowers in containers that were strategically placed to enhance the atmosphere of the theater

while allowing space for chairs and tables for the audience (Osmundson, 1999, p. 124). Some other amenities of the theaters were running streams, fountains, grottoes, bridges, arbors, and even simulated mountain crags (Osmundson, 1999, p. 124).

- **Residential and Hotel Rooftop Gardens**

Figure 17.Waldorf-Astoria Hotel rooftop garden

Source: https://www.pinterest.pt/andersonrandall/the-waldorf-astoria/?lp=true

Accessed: (May 31, 2017, 8:08:21 PM)

Hotels and restaurants were the next types of buildings to adopt the rooftop garden concept brought about by theaters. New York hotels such as the Waldorf-Astoria (figure.17) and the Hotel Astor and restaurants such as Delmonico's advertised dining and dancing on top of roofs with a view of the city (Osmundson,1999, p. 124). These roofs, similar to the rooftop theaters, featured gardens, potted plants, fountains, vine-covered pergolas, topiary trees, and brick and flagstone paving (Osmundson, 1999, p. 124).

-From the Period after world war II

- **Kaiser Center Rooftop Garden**

The Kaiser Center rooftop garden in Oakland, California, is one of the largest rooftop gardens in the United States (figure.18). The garden is a semi-public park, which is located above a parking garage.

According to designer, Theodore Osmundson, the rooftop was designed to exemplify the progressive nature of the company, the management wished to design a symbol, as well as an office building.

Figure 18.Kaiser Center Rooftop Garden

Source: https://www.pinterest.pt/pin/404057397791516320/

Accessed: (May 31, 2017, 8:15:02 PM)

The rooftop garden is sustained independently from the ground by its own drainage system that consists of gravel aggregate, downspouts, and a catch basin that ultimately direct water into the city's storm-sewer system.

The thin garden soil holds trees such as Holly Oak, Olives, Magnolia, Cork Oak, Japanese Maple, Flowering Crabapple, and Cherry that are irrigated from an extensive system under the soil. The garden also features an 8,800 square foot pool with circulating water, extensive lighting, and paved walking paths.

- **Harvey's Department Store**

Harvey's Department Store rooftop garden in Surrey, England (figure.19) is designed by G. A. Jellicoe and Partners, the garden features a matrix of shallow organically shaped pools and planting beds. Stone bridges and small paths connect the "islands" of planting beds which float on the water.

Figure 19. Harvey's Department Store rooftop Garden

Source: https://www.architecture.com/image-library/RIBApix/image-information/poster/roof-garden-for-harveys-department-store-guildford-surrey/posterid/RIBA25400.html

Accessed: (June 1, 2017, 12:39:04 AM)

The vegetation is grown in shallow soil with an average depth of only 15cm. Because of this thin stratum, few shrubs were included and the three willow trees in the design are planted in large tubs. Due to the amount of water in the garden, all the plants are those that are found in water gardens such as Irises, Primulas, Astilbes, and Ferns. The pools of water also average six inches in depth but different colored gravel placed on the ground of the pools gives the illusion of varying water depths.

-From the Recent 60 years:

In this period the green roof is not only built for aesthetic reasons but also for environmental reasons. According to J. William Thompson[17] "if the primary purposes of a conventional roof garden are outdoor seating and enjoyment, the primary goals of a green roof are environmental, primarily the following: soaking up storm water; absorbing solar radiation and converting it into plant foliage through photosynthesis; and insulating the building".

In the 1960s green roof technologies were researched in many countries, certainly in Switzerland and Germany.

Regarding the development of the green roofs in the sixties, it was basically to try to help in reducing water runoff and its problems and reducing water pollution.

In 1961 Reinhard Bornkamm, a German researcher who has been mentioned previously published his work regarding green roofs.

After that, in the 1970s many technical researches followed whether in issues about waterproof layer or about the growing media and vegetation.

One such work was Roof Areas Inhabited, Viable, and Covered by Vegetation, by Gerda Gollwitzer and Werner Wirsing. The development of green roof markets in Germany expanded fast in the 1980s, with average annual growth of fifteen to twenty percent. By 1989, the remarkable growth continued till nineties and was encouraged by state legislation and municipal government grants of thirty five to forty Deutsch Marks per square meter of roof.

Other European cities have adopted similar types of support and policy, with several mid to large-size cities incorporating roof and vertical greening into their bylaws and planning regulations. As a result of government policy and program support in Europe, a new green roof industry has been created for plants and material suppliers, roofing professionals, installers and maintenance crews. In

[17] According to J. William Thompson in an article for *Landscape Architecture Magazine*,in 1998, p. 38.

Germany, France, Austria, Norway, Switzerland and other European states, green roofs have become a commonly accepted feature in the construction industry and urban landscape (Peck *et al*. 1999, p. 11-12).

The FLL members began to develop the guidelines in 1975; they were published in German in 1982 and in English in 2002.

"The FLL guidelines are prepared around German green roof research and are the most respected guidelines on the subject.

So, the developments of FLL guidelines were constructed based on academic research, product/component development, and field observation"[18].

Europe has more than thirty years of green roof research and product development to support its successful green roof industry.

In the current time green roofs is the most common in the United States

Since human development began causing wide scale disturbance, soil and vegetation managed storm water and solar energy effectively (Getter & Rowe, 2006, p. 1276), no longer the case of green roofs have become one aspect of effective storm water and solar energy management. The introduction into the U.S. urban environment only occurred recently, gaining popularity in the last few decades[19].

And according to research papers : the North American green roof industry is only beginning to develop its own green roof guidelines, but nothing comparable to the FLL guidelines currently exists for the North European sector. The association of Standards and Testing Materials (ASTM) has released several guidelines that describe design characteristics for North American green roofs including the

[18] According to study by Magill, John D.; Midden, Karen; Groninger, John; and Therrell, Matthew, "A History and Definition of Green Roof Technology with Recommendations for Future Research" (2011). *Research Papers.* Paper 91.From: http://opensiuc.lib.siu.edu/gs_rp/91. Accessed: (May,4,2017)

[19]. According to research papers by Magill, John D.; Midden, Karen; Groninger, John; and Therrell, Matthew, "A History and Definition of Green Roof Technology with Recommendations for Future Research" (2011). *Research Papers.* Paper 91.From: http://opensiuc.lib.siu.edu/gs_rp/91. Accessed: (May,4,2017)

requirements of structural loads, permeability (drainage and green roof growing substrate), and a guide for plant selection and maintenance.[20]

The green rooftop on GAP headquarters building was built in San Bruno in 1997 (figure.20) and after that many green rooftops projects followed in San Francisco such as in 2008 the new California Academy of Science and others like Moscone West convention center and North Beach Place.

Figure 20. GAP headquarters building

Source: http://www.greenroofs.com/projects/pview.php?id=26

Accessed: (October 8, 2017, 7:23:39 PM)

- **Chicago City Hall**

The cooperation of several design firms and contractors from around the country led to the recent development and construction of a green roof that sits atop Chicago's City Hall (figure.21).

Chicago's City Hall green roof reflects the sun in order to cool the temperature. The vegetation filters and cools the air by evapotranspiration, by utilizing carbon dioxide and releases oxygen and water. The humidity from the released water brings temperatures down. The roof also functions to decrease storm water runoff because the plants will naturally absorb rainwater before it falls of the building.

[20] These guidelines are: ASTM E 2397, 2005, ASTM E 2399, 2005, ASTM E 2400, 2006, and ASTM WK 14283 (Dvorak, 2010, p. 198).

Figure 21. Chicago City Hall Rooftop

http://www.museumofthecity.org/project/green-roofs-in-cities/

Accessed: (June 2, 2017, 5:32:15 PM)

The vegetation used on the City Hall green roof is primarily native, because it is best suited to survive the conditions of Chicago's warm summers and cold and windy winters. Specifically, groundcover plants such as sedum, mosses, and grasses are used because they are highly drought tolerant species (Lenart, 2000, p. 17). The 20,000 plants that make up the green roof are grown in soil that measures between three to thirty inches deep (Lenart, 2000, p. 16).

The soil is layered over extensive waterproofing and drainage structures to prevent leakage.

Because of its research purpose and safety issues, the roof is not open to the public. However, the design for the roof does include paths to aid in roof maintenance.

Urban Heat Island Initiative, whose goal is to reduce the rising temperatures in cities caused by air pollution and the concrete of the urban areas of the five cities chosen to participate in the project, Chicago was the only one to develop a green roof (Lenart, 2000, p. 16).

IV. Green Rooftop Values

Implementation of green roofs has many benefits as it changes the wasted places in urban areas into multifunctional structures with different values:

1. Ecological Value

It is important to understand a few of the basic ideas and theories of ecology in order to fully comprehend the ecologist's ideology of nature and maybe to expand the cultural possibilities of green roofs.

These relationships form systems in which living and non-living entities exist. Ecology is concerned with the life histories, distribution, and the behavior of individual species as well as the structure and function of natural systems at the level of populations, communities, and ecosystems (Cunningham, W. P., & Woodworth Saigo, B., 1997, p. 614).

Ecology has also branched off from this technical definition to include other areas such as general human relations with the social world and also addresses concerns with human and natural *habitat*.

These areas of ecology are evident in relationship to nature and culture of the green roof.

Urbanism caused many Environmental problems, for that reason it is a positive solution to apply green roof system as it reduces Urban Heat Island effect (UHI) (figure.22). And that depends on the building type; the size of the green roof, the bigger is more efficient.

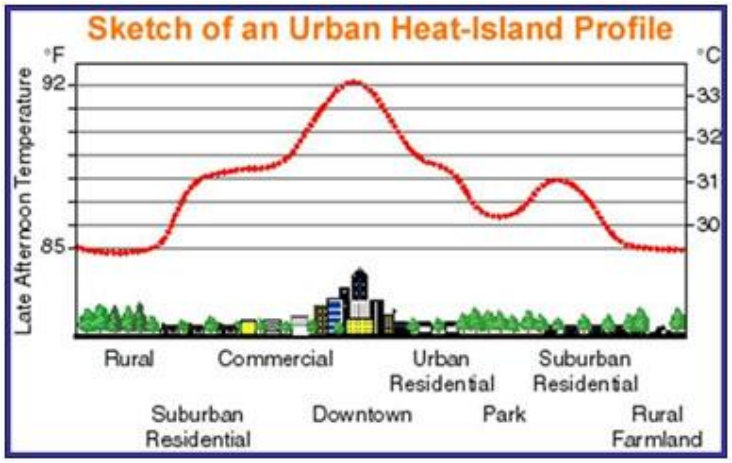

Figure 22. Urban Heat-Island Diagram

Source: https://commons.bcit.ca/greenroof/faq/why-green-roofs-benefits/

Accessed: (October 9, 2017, 8:18:45 PM)

The technology of green roofs helps to keep a cool temperature inside the building as it slows down the gain and loss of the temperature while the plants convert the sunlight to chlorophyll and release water vapor into the space to cool the surfaces in the urban areas and by that limits the heat island effect which been caused by the materials of the building itself.

Green rooftops could decrease storm water runoff (Weiler & Barth, 2009)[21] see (figure.23). And that is because of the existence of the plants and the percentage of the reduction depends on the type of plants and the depth of the media, so deeper media equals less runoff.

Likewise, the vegetation on the rooftop works as a buffer and protects the roof from the harmful effects of wind, rain, cold and extreme heat. (figure.23). Therefore, it is clear the long term benefits for longer lifespan for the roof.

[21] (Abdul & Ahmad), " Green Roofs as Urban Antidote: A Review on Aesthetic, Environmental, Economic and Social Benefits". From: http://www.academia.edu/2283321/Green_roofs_as_urban_antidote_A_review_on_aesthetic_environmental_economic_and_social_benefits. Accessed :(May,26,2017)

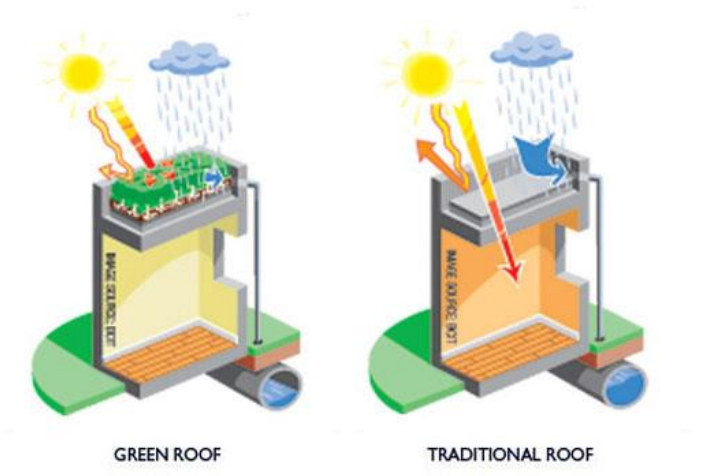

Figure 23.Some of Green Rooftop Benefits

Source: https://commons.bcit.ca/greenroof/faq/why-green-roofs-benefits/

Accessed: (October 9, 2017, 8:16:02 PM)

On the other hand, green roof encourages biodiversity in urban areas as it provides natural habitats for many species such as ants, bees, etc. and even perfect nests for birds[22].

Another benefit according to an article by Syumi Rafida Abdul Rahman and Humaidah Ahmad is that it could help in treating air pollution which damages the health and which is increasing in most of urban places, by catching the air pollutants so it makes like purification for the air.

2. Social Value[23]

The absence of green spaces in urban areas affects people's behavior negatively.

[22] Chrisman, S., *Green Roofs: Ecological Design and Construction*. Earth Pledge. Schiffer Publishing Ltd, 2005.According to (Abdul & Ahmad) " Green Roofs as Urban Antidote: A Review on Aesthetic, Environmental, Economic and Social Benefits". From: http://www.academia.edu/2283321/Green_roofs_as_urban_antidote_A_review_on_aesthetic_environmental_economic_and_social_benefits. Accessed :(May,26,2017)

[23] According to study by Syumi Rafida Abdul Rahman, and Hamidah Ahmad ," Green Roofs as Urban Antidote: A Review on Aesthetic, Environmental, Economic and Social Benefits". From: http://www.academia.edu/2283321/Green_roofs_as_urban_antidote_A_review_on_aesthetic_environmental_economic_and_social_benefits. Accessed :(May,27,2017)

Based on research by Kaplan and Kaplan (1989) and Godbey *et al*. (1992) regarding who might visit the parks and the result was most of them reach it on foot. What has also been confirmed in a research in 1977 by Alexander et al. is that people prefer to walk to a park if the distance is three to five minutes. Therefore it is clear that green rooftops will be the best to create a relationship between the space and the people from one side and among people from another side as it is easy to reach by the people who are living or working in that building or nearby it, because it would be a natural beautiful refuge to refresh and to have a healthy break to relax in that nice green space. Due to the fact that when people see vegetation and nature they feel better, less stressed, which will improve health and reenergize to return to life or work with more productivity. So in general we could say it improves people's quality of life.

Green roofs promote awareness among ownership, foster community interaction.

And the role which green roofs plays for residents by cooling the temperature of the interior of the building makes them super valuable outdoor space[24].

A Portland survey found that the most popular leisure activities on green rooftops, were exercising, lounging or even barbecuing[25].

Green rooftops could be a perfect multifunctional garden if it has been designed with the landscaping elements like patios, stones…etc.

[24] Snodgrass, E. C., & McIntyre, L. (2010). *The Green Roof Manual A Professional Guide to Design, Installation, and Maintenance*. Portland, Oregon: Timber Press, Inc. According to study by (Srivastava, 2011),'' Green Roof Design and Practices: A Case of Delhi". From: https://etd.ohiolink.edu/!etd.send_file?accession=kent1311004642&disposition=inline. Accessed: (May,28,2017)

[25] According to study by (Srivastava, 2011),'' GREEN ROOF DESIGN AND PRACTICES : A CASE OD DELHI'. From: https://etd.ohiolink.edu/!etd.send_file?accession=kent1311004642&disposition=inline. Accessed: (May,28,2017)

According to Michel Foucault, power is not something exercised in a dominant class (highbrow culture) over a subservient class (lowbrow culture) but rather is a whole complex of forces that work together to produce what transpires (Murfin, 1996, p. 26).

The idea of the green roof as a substantial structure and more complex composition can lead one to believe that it is more highbrow than the rooftop garden.

And many professionals are needed to be involved in such a project. Landscape architects and architects are responsible for the overall design of the roof, and roofing contractor is a necessity for the construction of the structure, which includes technical knowledge of waterproofing, drainage, and planting materials.

Since knowledge is generally considered highbrow and the green roof requires technical knowledge to construct it, the green roof could be considered a part of highbrow culture.

The funding and investment in green roofs also leads to particular highbrow cultural beliefs.

Regarding accessibility, it carries a Marxist element into the realm of green roofs in that accessibility is power which is under the control of the upper class as this is the class which has the money to construct such a project.

There are important questions to be asked about the accessibility of green roofs:

-Who is able to gain access to these "gardens on the top"?

-Are green roofs generally privatized or are they open to the community as a whole?

The term green roof automatically conjures up images of lush gardens located on top of tall buildings that are not easily accessible to the public. Because entrances to these green roofs are usually restricted to building maintenance employees or, if the building is privately owned, employees of the company that

owns the green roof. Even public buildings such as libraries and city halls may not allow citizens to gain entry to the green roof.

Also we could say that there are rooftops located at street level because they cover underground buildings such as parking garages. These rooftops are highly visible and accessible yet not recognized as rooftops because our cultural beliefs tell us that rooftops are located above our heads.

The green roof could be considered a highbrow structure for a variety of reasons such as basic roof structure, professionals involved and knowledge needed to complete the design and construction, amount of economic investment needed to produce the green roof, accessibility to the green roof, and visibility and location.

Nonetheless, the rooftop garden can be just as intricate in its design and components as a green roof.

For instance, deep in the heart of Manhattan an elaborate rooftop garden based on Japanese tea ceremony garden contains detailed elements such as statues, marble paths, meditation pools, and small trees (Dooley, 1996, p. 222-226).

Therefore, mere structure alone should not elevate the green root into highbrow culture.

3. Economic Value:[26]

Green roofs do require expenditure in the beginning; however we could say that is an investment if we think about the long term benefits. (Wong *et al*., 2003, p. 38).

Meanwhile for the future, the building which has a successful green roof would attract not only residents, people from the neighborhood but also tourists. So it would become a landmark in the city. (Oberndorfer et al., 2007, p. 823).

[26] According to study by Syumi Rafida Abdul Rahman, and Hamidah Ahmad ," Green Roofs as Urban Antidote: A Review on Aesthetic, Environmental, Economic and Social Benefits" From: http://www.academia.edu/2283321/Green_roofs_as_urban_antidote_A_review_on_aesthetic_environmental_economic_and_social_benefits. Accessed :(May,27,2017)

As compared to a conventional building roof, the green roof has more upfront costs for its installation due to more technical infrastructure as well as the addition of planting materials.

This may seem like highbrow culture at first but when one considers long-term costs as well as a cost-benefit analysis of the green roof is far more economical than a conventional rooftop. For example, many hotels have utilized green roofs to help with storm-water management, growing fresh produce for in-house use in restaurants, and for cutting costs because self-sustaining roofs require little to no maintenance.[27]

There are some thoughts about the damage for the roof if it is a green roof and at the same time there are opposite thoughts which prove the role of the vegetation on the green rooftops increase the longevity, so as an example and according to an article by (Cannarsa A., 2008) In Germany, "Porche and Köhler found some green roofs in Berlin lasted 90 years with no big damage to it".

Another example in Singapore, green roofs decrease the cooling load by 10% of the usual building compared with a conventional roof (Wong *et al*., 2003, p. 261)[28].

A green roof lasts up to twenty years longer than a conventional roof.

This is due to the fact that on a conventional roof, the roofing infrastructure is exposed to various weather elements such as acid rain, snow, and ultraviolet sunlight that quickly depreciate and degrade the roofing materials.

As discussed earlier the green roof has many ecological benefits, but it also has economic benefits as well.

The vegetation on the green roof has an insulating effect on the building where it is built.

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[27] Cannarsa, Andrew (2008). "Hilton hotel to sport area's largest green roof". The Examiner. http://www.examiner.com/a-1341059~Hilton_hotel_to_sport_area_s_largest_green_roof.html. Accessed:(October 9, 2017, 5:16:02 PM)

[28] Wong, N. H., Chen, Y., Ong, C. L., & Sia, A. (2003). *Building and Environment, 38*,261.According to study by (Srivastava, 2011),'' Green Roof Design and Practices: A Case of Delhi. From: https://etd.ohiolink.edu/!etd.send_file?accession=kent1311004642&disposition=inline. Accessed: (May,28,2017)

A building equipped with a green roof uses less energy in the winter for heating and also less cooling energy in the summer, therefore greatly reducing energy costs.

Therefore, green roofs have benefits not only for the environment but also for the owner himself because they help to save both energy resources and money (Griswold, 1999, p. 22).

To look at the green roof on these economical terms, it would be considered a cost-effective, which is not generally, consistent with highbrow culture beliefs that prefer to spend money extravagantly.

Another idea is to have food production as an economical kitchen garden integrated in green rooftop gardens projects because that would save money and time as the vegetables would be fresher and cheaper and people wouldn't need to spend time going to the supermarket to buy less quality fruit and vegetables due to the lower carbon footprint which normally affects them due to the shipment from the place of production to the market place. Furthermore, citizens of roof gardening will learn to appreciate the nature and maybe help to maintain or take care of their green rooftop.

Until now research is still in progress regarding planting on the rooftop to make sure of its usefulness.

4. Urban Aesthetical Value:

Aesthetics are shaped by cultural beliefs and values.

“An aesthetic of urban design must therefore be rooted in the normal processes of nature and of living. It should link function, feeling, and meaning and should merge the senses of the mind”. (Spirn, 1988, p. 108).

Because the city is a highly cultural entity, it is important to have an aesthetic that includes both nature and culture.

Spirn proposes an aesthetic that "recognizes both natural and cultural processes and reveals the rhythms and the patterns created by their discourse". (Spirn, 1988, p. 108)

Function can occur on a variety of levels - social, ecological, and economic to name a few. Therefore, a design that is ecologically functional is not always seen as being aesthetically pleasing.

But with that aesthetic theory in mind, the green roof is a perfect example of an urban aesthetic because its functions are both natural and cultural and can also be experienced on a multi-sensory level. So the green roof's environmental functions include reducing dust and air pollution, providing wildlife habitat, decreasing storm water runoff (therefore reducing flooding), and decreasing the urban heat island effect (Griswold , 1999, p. 21).

Green roof design that promotes and reveals this environmental function is also aesthetic because it creates unity - one on the fundamental principles to aesthetics (Bartuska and Gerald, 1995, p. 80).

According to study[29] a roof is not the last part of the building's facade. And the reason is: the green roofs transformed the visual aesthetic of its concrete structure to a living green space.

And as the green roof could be a landmark in the city, so it encourages the designer to create more in this field and by that it softens the rough gray urban areas and adds color, natural spaces for relaxation and as a recreational spaces in a

[29] According to study by Syumi Rafida Abdul Rahman, and Hamidah Ahmad ," Green Roofs as Urban Antidote: A Review on Aesthetic, Environmental, Economic and Social Benefits". From: http://www.academia.edu/2283321/Green_roofs_as_urban_antidote_A_review_on_aesthetic_environmental_economic_and_social_benefits. Accessed :(May,27,2017)

beautiful places provided by aesthetic and psychological benefits for people who lives there, the thing which can improve their health and behaviors.

Recreational spaces on the green roofs are controlled so they are safer from social problems which are common in the public green spaces at the ground level (Weiler & Barth, 2009)[30].

Green roofs which are accessible add a kind of colored texture, enjoyment, interests and value for the building itself, its residents/workers or even for the owner of it (Getter & Rowe, 2006, p. 41).

V. Green Rooftops case of Arab Area

1. Current Situation:

In Scandinavian countries green roof technology and products have been known, used and installed since a long time while it is more recent in the US, as for Europe it is very well supported and established due to the government support in many European countries.

But currently, installation of green roofs in the Middle East and North Africa (MENA) region (figure.24) is very rare.

[30] Weiler, S. K., & Barth, K. S. (2009). *Green Roof Systems*. New Jersey: John Wiley and Sons.

Figure 24. Arab area

Source: http://fr.academic.ru/dic.nsf/frwiki/122985

Accessed: (September 24, 2017, 7:51:21 PM)

However, the concrete architecture structure which is followed in most of countries in the Middle East is perfect for a green roof installation, as it has the ability to carry the weight of the different types of green roofs.

But also, some facts regarding Arab Region represent challenges facing the idea of applying green rooftops such as when governments want to start any project they would prefer building a school or a hospital instead of making a budget for such a thing as green rooftops projects.

Adding to that most of people in the developing countries are busy focusing on the basics needs of living, according to Maslow's pyramid of human needs, be it food, looking for a safe place and house to live …etc. so the priorities in thinking are different due to living conditions in that region and the problems which people have been facing.

Neveen Metwally[31] gave an explanation, to make people satisfied with urban horticulture; we must focus on their needs and try to explain the benefits which

[31]Neveen Metwally a researcher at the Central Laboratory for Agriculture Climate in Cairo, Egypt spoke to Integrated Regional Information Networks (IRIN) about urban gardening in the region.

they might have. “I can say to someone, ‘A rooftop garden will help the environment’, and they’ll say, ‘No, thank you – I just want to feed my family’. So I must identify and communicate benefits that are of interest to that person.” (Aburawa, 2010).

Many countries in Middle East have suffered from the problem of air pollution, for example, Egypt and Tehran have recently shown high air pollution rates in region, in Tehran, reportedly 27 persons die per day. As Metwally stated, the green roofs will help to reduce the pollution and bring other advantages to the environment.

Something else to mention is that in most Arabic cities, roofs are accessible to residents who for example use it to dry laundry and in some areas the roofs hold events for social activities like celebration or even weddings. So application of green roofs might be a problem as it will occupy the space so prevent them from continuing their daily activities, but at the same time it could be an ideal place for other festive occasions.

And while the industry of green roofs has become more popular in this area, it still needs effort and research to prove its worth.

2. The Problems and the Possible Solutions:[32]

According to a study and tests by (R.Fioretti, Palla, Lanza, & Principi, 2010) which were conducted in the Mediterranean, regarding water management and daily energy demands, it is been confirmed in the results that green rooftops could have this contribution even in Mediterranean climate.

[32] According to a study had been made in Department of Energetics, Marche Polytechnic University, Ancona, Italy and Department of Civil, Environmental and Architectural Engineering, University of Genova, Genova, Italy in 2009.

Most of the cities in developing countries including most of the Arab Region have many environmental problems, from pollution to the rapid growth of urbanization with low care and disappearance of green spaces in addition to many economic problems which are basically due to the environmental ones, so for instance cooling systems are used for the whole summer season and most of the winter, one of the things which leads to a huge loss in energy which result in the high prices of electricity bills and so on. (Attia, Green Roof Potential in Arab Cities, 2010)

Arab cities are facing problems regarding food production and distribution, food prices and toxic contaminants. In addition to that, the high shipping cost - regarding the petrol, the vehicles or the workers - of the vegetables, fruits and so on from the place of production to the markets or consumption areas in the cities. Adding to that, population growth and the failing spatial planning policies contributed to the growth off randomly in and around the center. Cairo is a great example of that. That's why investments of roof farming can help to address the lack of green space in the urban areas and can have a remarkable contribution for the previous problems.

According to renewable energy status report (Hansen, 2016) : In 2013, Middle East and North Africa (MENA), the Total Primary Energy Supply (TPES) in Middle East and North Africa reached about 800 million tons of oil which means a 15% increase in energy demands since 2007. Which is basically due to population growth and the more use of domestic electricity for the devices and other things. So the green roof investments are solutions to help in reducing those demands of energy in Middle East Region.

2.1. Regarding Environmental Issues:[33]

a) Reduce environmental pollution resulting from increased areas of buildings and facilities which has low vegetation space.
b) Reduce the chance of respiratory diseases and malignant diseases because if we plant 1.5 square meters, it would provide a person needs for one whole year of oxygen according to Dr. Usama El-Behairy.[34]
c) Disposal of the waste that is stored on the surfaces, which cause deformation of the environment and increase the chance of fire, and exploitation of these surfaces instead of being a store for waste and old things that result in environmental damage and health.
d) Reduce the presence of various harmful organisms that invade different homes and establishments as a result of living on neglected surfaces.
e) Purification of urban air pollutants where the green plant is a candidate, where it was found that each square meter of the green surface removes 0.5 kilograms of air pollutants every year.
f) Reducing the percentage of carbon dioxide in urban air through its consumption in plant photosynthesis and oxygen production.
g) Produce safe food through control of fertilizers and non-use of chemical pesticides, as well as the possibility of using organic fertilizers in the fertilization of surface farms systems to ensure the production of safe food from chemicals.
h) Protection of the residents of the top floors from high temperature during the summer, where the plants receive sunlight, which reduces the impact on the

[33] (Ali, 2010) Ali, K. (2010, September 20). "Green surfaces break the rigidity of the concrete and create a healthy and aesthetic environment". Retrieved May 3, 2017, from www.alittihad.ae: http://www.alittihad.ae/details.php?id=60294&y=2010&article=full#ixzz1yplhsbky

[34] Dr.Usama El-Behairy who wrote in a study under the name of *Green Rooftop Project* in Arab area for the foundation of Hanns Seidel Foundation Cairo 2009, p4-5.

roofs, where it was found that by planting the surface temperature in August in the last roles by approximately 7 degrees.

2.2. Regarding Social Issues[35]

a. The possibility of anyone producing some of the types of vegetables they need, which increases self-confidence, especially for older pensioners who are used to having an active and important role in society.
b. Increase the quality of vegetables produced.
c. Provide employment opportunities for young graduates, which will generate a financial return, thus raising household income.
d. Produce fresh food for residents of remote areas, which suffer from the scarcity of fresh vegetables and high prices due to high shipping prices.
e. Cultivation of surfaces could work as a social system for the inhabitants of the same building as well as the neighborhood, which leads to increasing the interdependence of the population on each other, which leads to the solution of their problems, and return to the spirit of familiarity and love that used to exist among people since ancient times and was one of its most important features.

2.3. Storm Water Management

Storm water can carry the dirt, chemicals, garbage, bacteria and pollutants into the sewer system which is dangerous especially in MENA region as it has not been treated and it will just end up nearby the water which we drink, swim or fish from or it might cause flooding of the sanitary systems because in developing countries the management of storm water is deficient. Therefore, green roofs help in reducing hazardous runoff and contamination of water supplies.

[35] (Attia & Hegazi, *Green Roofs in Cairo: A Holistic Approach for Healthy Productive Cities*, 2009)

According to an US Environment Protection Agency (EPA) study (Berghage, Beattie , Jarrett , Thuring , & Razaei , 2009), green roofs are able to remove 50% of annually rainfall by evapo transpiration and absorbing water, the thing which decreases the pressure on the sewer systems.

2.4. Urban Heat Island Effect

Urban heat island is a phenomenon in the urban areas due to the fact that the buildings absorb the sun's radiation and release it as heat, which makes the urban area very hot and that increases a loss of energy in the use of air conditioning for the internal space which leads to the harmful greenhouse gas emissions.

UHI is something to worry about in areas such as the Middle East and North Africa, due to the huge population in urban areas. Furthermore, according to UN projections the MENA population will rise to 430 million in 2020 (Hansen, 2016), so more urban areas are expected to exist, therefore more UHI effects must be considered. In order to control that, communities could utilize green roofs to absorb the radiation and release water vapor instead to help cool the temperature and provide shade at the same time.

2.5. Roof Lifespan

Vegetation of green roofs protect the roof from ultra violet, extreme heat and wind which damage it, so as a result they are actually extending its life (Alsalam, 2009) by more than twenty years according to a German study (which has been mentioned before) and reduces the waste of landfill.

2.6. *Habitats* for Species

In most of the cities *habitats* are rare or even destroyed so having an urban *habitat* is very important to support biodiversity in the city (Sadeghian, 2016) and green roofs offers food, breeding place, water and nests for many species.

So creation of *habitats* in a living space like green roofs for modern cities like Jeddah or Tahran in the Middle East is a very valuable aspect.

2.7. Building Resilient Cities

Rooftop gardens can also help absorb heat and act as insulators, reducing the energy needed for cooling or heating; provide low-cost food and also a refuge for bird, bees and insects as it has been mentioned previously. These benefits are clearly transferable across the Middle East region and agriculture in urban areas can play an important role to have resilience cities and their populations against the impacts of climate change. According to the UN Population Fund, about half the world population already lives in urban areas with the number expected to reach some five billion by 2030. (Aburawa, 2010).

Being able to supply fruit and vegetables is clearly an advantage in a time of food scarcity and rising prices. And it's also not impossible. Hong Kong and Singapore, for instance, both produce more than 20% of their meat and vegetables within the city limits. (Aburawa, 2010).

As well as the environmental and economic benefits, rooftop gardens also bring a much needed splash of color to our rather grey concrete jungles.

3. Challenges Faced in MENA Climates

In the Middle East and North Africa the problem is water resources and conservation.

The climate challenges from the heat to the wind or the humidity in some places adding to that the sandy or salty soils in so many areas in that region such as United Arab Emirates (UAE) and most of Arabic Gulf countries. According to the president of Green Living Technologies International (GLTI)[36], George Irwin, speaking after experiences in MENA, it is very important to add a mixture of growing media as the type of soil in this region doesn't have the ability to hold the nutrients. In addition to that, it is necessary to have a capacity for water retention inherent in the materials of the system itself to keep the irrigation water for the vegetation. (Velazquez, 2014).

George continued his explanation "there are hundreds of native and adaptive ground covers and grasses applicable to extensive roofs". And he added an important thing regarding materials which his company used in their projects in UAE that because of the high temperature, the plastic components which normally been used in green roofs were replaced by stainless steel to adapt with the weather where we are planning as it has resistance for melting and also keeping in mind a high quality water proofing is very important as the system will always have water for irrigation.

Finally, we should think always regarding the potential of renewable solar and wind energy to power the irrigation of the sustainable building integrated greenery.

[36] Green Living Technologies International (GLTI) is an American company and institute who care about living rooftops and walls.

There has been an important spotlight on green rooftops projects in the Middle Eastern and North African countries such as Morocco, Egypt, Palestine, United Arab Emirates (UAE), Kingdom of Saudi Arabia (KSA) and Kuwait.

Grow in Cairo, Egypt[37]

Green rooftops farming is largely touted to reduce citizens' reliance on poorly regulated commercial farming and the general industrial food machine. But getting the seeds of urban agriculture programs to grow in a vast city like Cairo needs tender loving care.

So *Grow* is a simple idea by a group of friends Sumaya Holdijk, Dalia Abu Fotouh, Bassem Khalifa and Pamela Labib, who started the Food Sovereignty Project out of concern about Egypt's food security (see figure.25).

Figure 25. Food Sovereignty Project, Cairo, Egypt

Source: https://www.greenprophet.com/2011/07/urban-agriculture-egypt/

Accessed: (July 17, 2017, 7:04:09 PM)

[37] (Laylin, 2011) Laylin, T. (2011, July 15)." Egypt's Urban Agriculture Movement is Growing". Retrieved August 15, 2017, from www.greenprophet.com: https://www.greenprophet.com/2011/07/urban-agriculture-egypt/

They have developed an online platform where would-be and ongoing urban farmers can share their experiences, tips, challenges, and in general foster a community that would try to maintain a city farming movement that is clearly on the rise.

After its full launch in August 2011, their website will be known as *Ezraa*, or in English (Grow).

This move comes in response to the failure of many excellent farming projects to reach completion. Labib and friends discovered this usually occurred because community members were unable to communicate with and lend each other their expertise and support. Knowledge, they discovered, is only half the battle.

"For two years I desired to start my own private urban agriculture in my garden," says Mariam Ali, who was a user involved in this initiative. "When I heard about the site, it really inspired me to start and get on with it because I felt I wasn't alone. It also just makes life so much easier because there is so much uncertainty concerning what to do during the early stages of construction."[38]

While the group hopes to advocate organic agriculture, they will not alienate users who are not ready for this approach. They also have the support and interest of South African permaculture expert Dominique De Bruin, who advocates a holistic design approach to urban agriculture.

[38] According to a report by Laylin, T. (2011, July 15)." Egypt's Urban Agriculture Movement is Growing". Retrieved August 15, 2017, from www.greenprophet.com: https://www.greenprophet.com/2011/07/urban-agriculture-egypt/

Farming on Rooftops to Resist Blockade in Gaza, Palestine

People of Gaza Strip, after they had been under the siege for long time, used rooftops farming as a kind of resistance economy to provide their families with nutritional needs as it was a very necessary step.

According to what was written in a report for Tasnim News Agency blog in (July, 10, 2017)[39] one of the persons who had launched a green rooftop project said

"Using rooftop agriculture was essential to provide people's food needs in the region that has little land for agriculture. Most of the agriculture lands in the region have been destroyed by the Zionist occupiers. We are now training 360 Palestinian to promote modern ways of agriculture here. In this way, we can both provide food for the people and create jobs."

One student from there told Tasnim that on the rooftop of his school they have agriculture. "At the break time and also during science class, we go to the rooftop farm and practice farming. We learned how to cultivate, fertilize, look after and irrigate vegetables."

Aquaponic Gardening Technique

In Gaza, agriculture on the roofs produces summer and winter crops without soil and without chemical fertilizers.

And according to a report by Aljazeera blog (Gadzo, 2017)[40] with shrinking cultivable land and polluted water system, Palestinians in Gaza Strip have been looking for ways of finding fresh food and water as an alternative solution.

[39] Tasnim. (2017). "Besieged Gaza People Farming on Rooftops to Resist Blockade". From: Gaza: www.tasnimnews.com.

https://www.tasnimnews.com/en/news/2017/07/10/1460504/besieged-gaza-people-farming-on-rooftops-to-resist-blockade-video. Accessed: (September 30, 2017, 7:00:21 PM)

At sunset, Said Salim Abu Nasser's[41] grandsons crouched on the ground, using bricks to crush chalk into powder for calcium to help grow vegetables in water.

Abu Nasser, has grown 3,500 kgs of organic produce without using soil, (figure.26). He plants many types of vegetables and herbs, Abu Nasser could double the number of products if we compare it with the traditional techniques. Besides that, he is saving 90% of water by recycling.

“For six months, I don't need to change the water,” Abu Nasser said.

The water has excrement from fish swimming in a barrel to be used for growing crops.

Figure 26. Said Salim’s cultivation rooftop [Mersiha Gadzo/Al Jazeera]

Source: http://www.aljazeera.com/indepth/features/2017/01/alternative-farming-rise-besieged-gaza-170120074544620.html

Accessed: ((September 30, 2017, 7:59:40 PM)

He depends on solar system to produce energy to pump oxygen in the water to be available for the crops.

[40] Gadzo, M. (2017). “Alternative farming on the rise in besieged Gaza”. Gaza: Al Jazeera. http://www.aljazeera.com/indepth/features/2017/01/alternative-farming-rise-besieged-gaza-170120074544620.html. Accessed: (September 30, 2017, 7:20:21 PM)

[41] Said Salim Abu Nasser's a 53 years old man from Gaza , who started green rooftops farming

And by these experiments, this man proves that we could grow vegetables even in salinity water by following those techniques.

The King Abdulaziz Center for World Culture, Dahran , Saudi Arabia[42]

King Abdulaziz Center for World Culture[43] in Dhahran, Saudi Arabia (figures.27-28-29). It has 38,000 SQM green roofs which completely cover occupied space.

Figure 27. The King Abdulaziz Center for World Culture

Source: http://www.gulfconstructiononline.com/news/161030_Culture-Club.html

Accessed: (September 27, 2017, 7:11:20 PM)

Because of critical space under the green roof, they had a suspicion about a water leak under the roof. Multi waterproofing systems have been considered to make the insulation such as (EPDM/PVC)[44]. The sandy wind was the reason that fluid applied systems could no longer be considered, due to adhesion problems.
For that, to make the system works perfectly, a large amount of elaboration was needed to make EPDM/PVC to avoid pockets under the velum.

[42] (CETCO, 2015) CETCO. (2015, April).” King Abduaziz Center For World Culture”. Retrieved September 25, 2017, from www.CETCO.com: http://www.cetco.co.uk/Portals/0/01_PDFs/CS/CS_King_Abdullah_Center_EMEA_EN_201504_V2.pdf

[43] The King Abdulaziz Center for World Culture is by the Saudi Aramco Oil Company to promote cultural development in Kingdom of Saudi Arabia. The project contains cultural facilities, cinema, library, a hall for exhibitions, museum. The Cultural Center was been completed in 2015.

[44] EPDM is a type of synthetic rubber as roof installing and PVC is a type of synthetic plastic.

Figure 28.**The King Abdulaziz Center, Dahran , Saudi Arabia**

Figure 29. **The King Abdulaziz Center, KSA**

Sources: http://metecnolatinoamerica.com/blog/2013/11/page/8/

Accessed :(July 17, 2017, 6:55:30 PM)

http://www.greenroofs.com/content/articles/129-Exclusives-The-MENA-Regions-Drive-towards-Green-Possible-with-the-Living-Architecture-of-Greenroofs-and-Greenwalls.htm#.WWz4S1GQz3g

Accessed: (September 27, 2017, 7:14:29 PM)

COREFLEX®[45] waterproof system was selected because it was one product that provided a solution to several problems. It allowed the use of products where the traditional insulation system not effective and on the other hand, COREFLEX® does not rely on adhesion.

So COREFLEX is an active polymer core (APC). Because when the APC hydrates, it would be able to fill voids under the membrane.

Kuwait University Shuwaikh, Kuwait City, Kuwait[46]

The Kuwait University Model School (figures.30-31-32) by Perkins+Will[47] provides education for the community's 700 kindergartens through to the 12th school grade and some of Kuwait University's own students.

[45] COREFLEX consists of a thermoplastic membrane integrally bonded to a proprietary Active Polymer Core (APC) layer. Combined with fully welded seams, this provides the ultimate waterproofing protection.

[46] According to (Meinhold, 2012)

Figure 300. **The Kuwait University Model School Rooftop**

Figure 311. **The Kuwait University Model School's Green**

Source: http://inhabitat.com/perkinswills-kuwait-university-model-school-will-be-a-living-green-laboratory/kuwait-university-model-school-perkins-will-4/

Accessed: (September 27, 2017, 7:34:12

The school's missions are to research, test and advance teaching modalities as well as educate students on sustainability, especially with regards to agriculture and the landscape. One of the core principles of the school is to extend learning into outdoor classrooms to provide more hands-on experiences. The school currently works to educate future stewards of the land and the re-fertilization the desert land.

[47] Perkins+Will is an interdisciplinary, research-based architecture and design firm established in 1935.

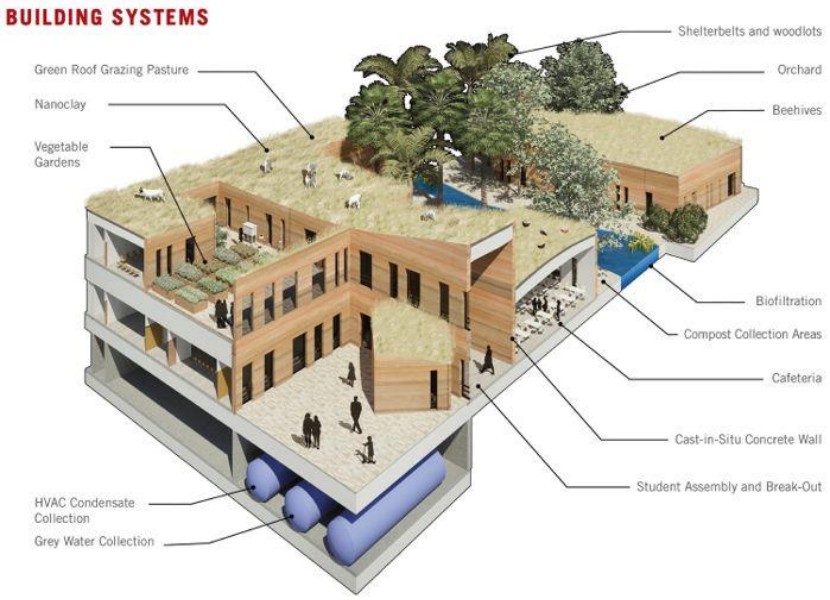

Figure 32. Kuwait University Shuwaikh, Kuwait City, Kuwait

Source: http://www.greenroofs.com/content/articles/129-Exclusives-The-MENA-Regions-Drive-towards-Green-Possible-with-the-Living-Architecture-of-Greenroofs-and-Greenwalls.htm

Accessed: (September 27, 2017, 7:30:08 PM)

The school features strategies to create micro climates through the use of vegetation, shade, and natural ventilation. A series of green roofs extend green spaces and provide insulation while Nano clays work to retain soil moisture. Gray and black-water recycling irrigates the land and carefully selected vegetation work to enrich the land and reintroduce native species. Shelter beds and woodlots provide both shade and shield the school against desert winds. And active gardens, hands-on laboratories, reading terraces and weather stations have been incorporated to create engaging learning spaces for the students.

VI. Conclusions

This Thesis presents a foundation upon which to build. This study is just the beginning of a larger exploration into the issues surrounding the green roof. It is important to take this first step towards a greater knowledge of the role that culture plays in landscape architecture in the Arab Region.

This thesis is a call to action to look deeper into green roofs by critically inquiring about their meaning in order to understand the insights they can provide concerning culture. This critical analysis is a spark to invest more in the application of the technique of green rooftops despite the difficulties which might be faced.

“Criticism is not only interpretive and evaluative, it is also creative. It not only assesses the way things are, but also speculates, at least implicitly, about how things could and should be.” (McAvin, 1991, p. 156).

The history of green roofs in this study shows how our ancestors used them to regulate the temperature of their environments. Structures with green roofs are cooler in the summer heat and warmer in the winter compared to others. While difficult to measure, green spaces revitalize people. Green spaces improve our lives.

Therefore, many rooftop gardens and green roofs from the past and present, from the east to the west have been described and documented in this study.

Green roofs are highly recommended in many countries due to their positive benefits. Therefore, this review encourages more local research for the future to make it possible for them to be installed in Arab region.

This includes viewing green roof design on a larger city scale, to the continued integration of environmental and social functions on a small scale in green roof design. It is important to note that progress can be a slow process; it will not and should not be expected immediately. That is why; the evolution of green roof

design should be in steps or stages to create the ideal vegetative rooftop structure by further integrating social and environmental functions within an ecological system.

As for the future of the ideal vegetative rooftop structure, it transcends the present-day vegetative rooftop structures discussed in this thesis. Ideal vegetative rooftop structures exhibit an extreme integration of social and environmental functions so that rooftops are utilized as social spaces that also enhance the environment in which we live. The ideal vegetative rooftop structure should be designed with both social and environmental objectives rather than just one or the other.

The ideal rooftop structure is seen as an entity that integrates both social and environmental functions to the highest potential rather than either a rooftop garden or a green roof.

By applying the fundamentals of landscape ecology through expanding singular islands of green roofs into larger systems of corridors and matrices, viable wildlife habitat can be formed and these large systems can also have a significant effect on urban temperature regulation and storm water management. A systems approach based on the principles of landscape ecology adds a new function to the current vegetative rooftop structure *continuum* an ecological function.

A new rooftop structure *continuum* should be established to show the addition of ecological function of vegetative rooftop structures.

Crop production on green roofs, including vegetables, is an emerging method to return agriculture to the urban environment. From wasted grey spaces we can create useful green spaces. Local food requires less energy to transport to the consumer due to less distance being involved.

The benefit of all green roof technology is to utilize wasted space that we can no longer afford to ignore.

Green roofs play roles in low impact development (LID), by increasing green areas in the cities. Besides that, green roofs are an aesthetic print which has economic profits by saving cost for maintaining roofs of the buildings, reduce the energy consuming. (Velazquez, 2014).

There are several obstacles in Middle East to green roofs, some of them due to the lack of awareness and knowledge about these technologies and, in most Arab countries, the absence of strategies and government support. However, with the proper groundwork and a good strategy we still have a hope to develop this industry.

The future success of vegetative rooftop practices depends on education and acceptance by the general public. It is important to the vitality of the green roof to publicize the benefits that they can provide. The more the general public learns about the green roof, the more they will accept and promote this sustainable practice.

As the popularity and acceptance of green roofs grow, there will be a need to continue to expand research and critical exploration in order to assess and promote the progress of green roof design especially with MENA.
Further research opportunities include studying the aesthetic components and performing visual assessments of the green roof. Expanding the boundaries of critical inquiry outside of the urban environment to examine green roof design in both suburban and rural areas, analyzing the economic impacts of green roof systems on an individual [residential] level and on a citywide scale, and assessing the effectiveness of a large-scale planning approach, to name a few.

In order to accept and promote environmentally, aesthetically, and economically sustainable design practices, we need to further discuss and disclose the cultural issues of green roof design.

It is also an imperative to push the limits of current green roof design by creating citywide systems of green roofs while looking at the cultural implications of this development. Green roof design and assessment is not only relevant to the field of landscape architecture but also to fields such as planning, architecture, ecology, art, design, and environmental studies since everyone will benefit from it and should be working together to achieve the best results.

This is possible of course with integrated projects, with the right materials and practices.

This thesis is a call to action, everyone must work together to promote green roof design. It is imperative that this thesis reflects the issues regarding the case of green, the fact that not only are the professionals responsible for designing and building green roofs but also the private and public agencies that can invest in and fund the green roofs and the citizens who will interact with and learn from the green roofs.

The fact is that many countries in the Middle East are in a need of solutions such as these due to the current situations and difficulties due to circumstances of war which have destroyed huge agricultural and green areas. The doubling of the cost of shipping vegetables has added to the economic problems and the fact that most of the cities are grey right now with so many people out of work, these people want to do something positive and advantageous to save their land and their cities.

Arabic people (in general) were avid gardeners, they cultivated kitchen gardens or grew medicinal or perfumed plants whether it be in the courtyard or patio which

they had in their houses as the old Arabic architecture design incorporated these areas in every house or building and this attitude was inherited by generation after generation until the architectural system changed and made this less possible to be cultivated.

However I believe that the horizontal structure of the rooftops of the building which are constructed currently in most of Arabic cities would be ideal for green rooftops in Arab regions, adding to that the availability of high percentage of young people who have the energy, retired persons who are dreaming to do something useful to feel that they are still alive, unemployed people and besieged people- all of those factors would help to revive the initiative of farming, food production and creating green spaces in the cities again, participating in saving the environment and seeking the sustainability using green rooftops gardens technology as one of the tools that under suitable supervision, support and co-operation depending and using research which should be made for that area having in mind the fact that green rooftops idea began and was realized in the middle east so this is a spotlight that it might be designed in the area again in spite of the climate changes and the current situation but by being inspired by the successful designs and how challenges might be faced and the difficulties possible solution …. it is absolutely possible but first we need to increase the technical rigor and to put more weight on the most important categories related to green rooftops mainly water, pollution , energy …etc. to extend green rooftops technology in the Middle East and North Africa.

Now I am passing on this work to be continued, to promote the social, environmental, aesthetic, and economic benefits that green roof systems could provide and develop harmonized green rooftops for the long-term sustainability in the MENA which is a part of the world's urban environments.

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