

## ROOFTOP FARMING AS A FORM OF URBAN AGRICULTURE FROM A SUSTAINABLE DEVELOPMENT PERSPECTIVE

Dr. Rania El Messeidy\*

### ABSTRACT

Rapid urbanization raises concerns about the sustainability of urban communities. Sustainability, which means “meeting the needs of current generations without affecting the future generations in meeting their needs” (WCED, 1987), has become one of the most important terms today and a major theme in our lives. Our world is loaded with ecological issues such as biodiversity loss, ecosystem degradation, landscape fragmentation, and climate change. Land use throughout history has transformed landscapes on many levels and reduced opportunities for wildlife and humans. Nowadays, the need for a multifunctional landscape that provides food security and livelihood opportunities, maintenance of species and ecological, cultural and aesthetic functions has become vital.

Urban agriculture; is a type of landscape that provides many benefits on the level of sustainability whether it is economic, social, environmental levels or nutrition and food security level. The core interest of this research is to highlight the importance of urban agriculture as a tool to achieve sustainable development. Moreover, the paper discusses the relevance of sustainable landscape to sustainable urbanism. It also focuses on the sustainable benefits of urban agriculture and its contributions to urban food security and nutrition. As this study is basically theoretical, it does not include a practical part but uses the analytical study of international cases that applied rooftop farming in different projects. It also highlights the experience of rooftop farming in Egypt. The paper, therefore, concludes the sustainable role that rooftop farming could play in the sustainable development process, as a top trend of urban agriculture, providing a set of recommendations on the level of municipalities and organizations.

**KEYWORDS:** Sustainable Urbanism, Sustainable Landscape, Urban Agriculture, Rooftop Farming.

### INTRODUCTION

Urban areas are areas of human settlement. As people increase and life continues, sustainability becomes a real demand. Environmental, economic and social problems are increasingly affecting the future of the world. Urban areas account for about 80% of carbon emissions, 60% of household water use, and nearly 80% of industrial timber. Activities undertaken by people in the built environment cause other problems such as biodiversity loss and system degradation, ecological fragmentation of landscapes and climate change. Furthermore, Urbanization influence the local climate by creating urban heating islands at multiple levels (Wu, J. 2010).

The presence of these problems in most cities is the evidence that they are unsustainable. In fact, if urbanization continues indiscriminately without intervening to achieve osmosis and reduce the environmental, socio-economic impacts, the problems will increase. There is an urgent need to design, build better cities, and deal with Urbani-

zation as part of the solution to regional and global sustainability. Former UN Secretary-General Kofi Annan said it well: "The future of humanity lies in the cities" (AA, Aliyu., L, Amadu., 2017).

The city provides diversity in the landscape. Sustainable urbanism is basically a sustainable urban landscape. Consequently, in order to develop a sustainable future; designers must acknowledge the landscapes they create. Urban agriculture is an agricultural activity that is produced at home or plots in urban or peri-urban areas. It positively affects food security, environment, and health and contributes to the reduction of poverty in the city. Its most essential characteristic, is its integration into the economic, social, and environmental systems of the city, and not just its location (Wu, J, 2010).

The core interest of this research is to highlight the significance of urban agriculture as a tool to achieve sustainable development. In this sense, the paper discusses the relevance of sustainable landscape to sustainable urbanism. It also focuses on the sustainable benefits of urban agriculture and

\*Lecturer, Department of Architecture, Faculty of Engineering, October University for Modern Sciences and Arts (MSA) University, 6<sup>th</sup> of October, Cairo, Egypt - [hamdi@msa.eun.eg](mailto:hamdi@msa.eun.eg) [rania\\_h2000@yahoo.com](mailto:rania_h2000@yahoo.com)

its contributions to urban food security and nutrition. As this study is basically theoretical, it does not include a practical part but uses the analytical study of international cases that applied rooftop farming in different projects. Additionally, it highlights the experience of rooftop farming in Egypt. The paper, therefore, concludes the sustainable role that rooftop farming could play in the sustainable development process, as a trend of urban agriculture, and provides a set of recommendations on the level of municipalities and organizations.

As mentioned before, this paper is mainly theoretical. It has the methodology of analytical study of some international cases that adopted the method of rooftop farming in different projects and successful experiences.

The paper also does not rely on the study of a particular case in Egypt, because of the limited spread out of this system in Egypt, so far, the study is limited to review and monitor what has been done in the past since the earlier trials in 1990s until today, and emphasize the importance and necessity of adopting this trend now and in the future.

As shown below in Fig. (1), the next diagram explains the methodology that this paper follows:

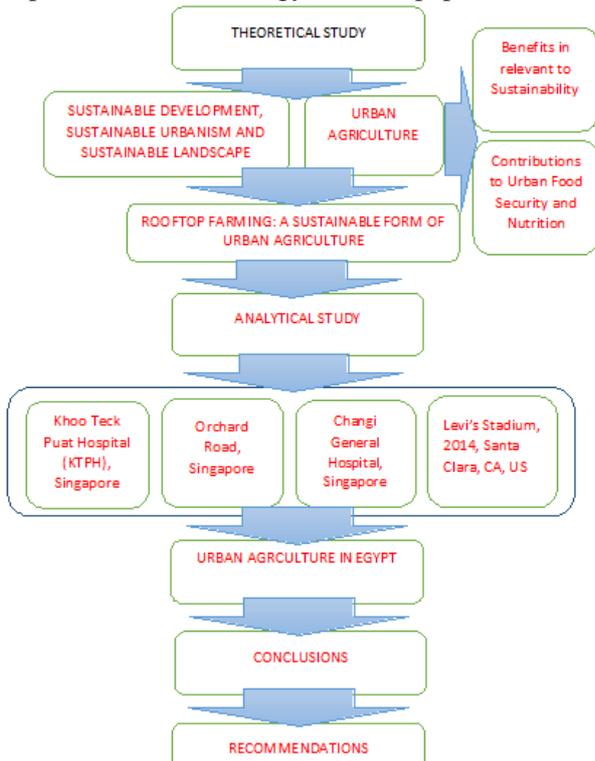


Fig. 1- Research Methodology, Source: Author

**1- SUSTAINABLE DEVELOPMENT, SUSTAINABLE URBANISM AND SUSTAINABLE LANDSCAPE**

The term sustainable development emerged in the 1970s and has been associated with terms such

as city sustainability and sustainable urbanism (S, Toofan. 2013). Sustainable development can be defined as “a development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs” according to the World Commission on Environment and Development (WCED, 1987; Wu, J. 2013). Sustainable development aims to integrate environmental management by protecting it from the effects of human activities that harm it. The United Nations Conference on Environment and Development (UNCED) - held in 1992 in Rio de Janeiro, which resulted in the signing of the Rio Declaration on Environment and Development - defines sustainable development as a process of social, economic and environmental change that balances the long-term balance between costs and benefits. Fig (2). In order to ensure its success, development must be maintained (Jasionkowski, J. Rafał., Anna, L., 2016).

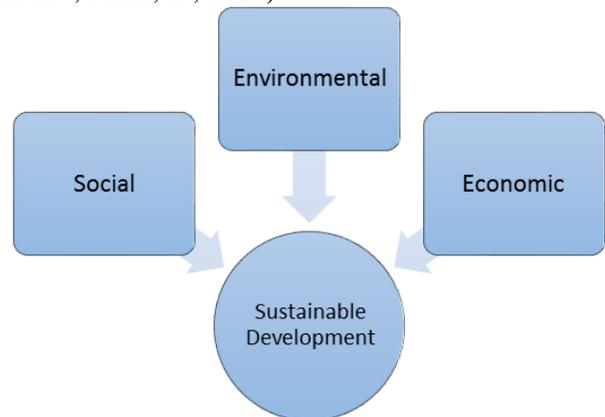


Fig. 2- Process of Sustainable Development, Source: (UNCED, 1992) edited by author

The city provides diversity in the landscape. Sustainable urbanism is basically a sustainable urban landscape. According to the most cited idea of "three basic sustainability", a sustainable city needs to strike a balance between environmental protection, economic development, and social wellbeing. This interpretation of urban sustainability is generally consistent with the sustainability of the six E's of landscape sustainability: environment, economy, justice, aesthetics, experience, and ethics (Wu, J., 2010; LR, Musacchio. 2009).

Landscapes are the right places for people's daily activities and arise from the differences between natural, cultural, social, cognitive and aesthetic components, such as soil, climate, plants, animals, land use, location, colors, patterns, shapes and interactions that people perceived. The results of these compositions create challenging landscapes and, therefore, are multifunctional and better understanding of context and history (Bohnet, Iris C., Beili, R., 2015). Sustainable Landscaping is a

category of sustainable design for space planning and design. Sustainable Landscaping creates environmental designs for the outdoor and urban environment. It is the incorporation of environmental, social, cultural and economic factors into landscape design, to promote the protection of habitats and contribute to rainwater management and water protection. The current trend in landscaping is to strike a balance between the "aesthetics and function" required for a successful sustainable design. There are many different ways to reach landscape sustainability. First, there is no right solution, each time leading to a sustainable landscape. Second, every proposal must be context-specific and responsive. After all, sustainable landscapes do not only refer to the creation of green spaces, but also to the implementation of a design from which both humans and ecosystems can benefit at the same time (S, Toofan., 2013; Knight, AT et al., 2008).

The emerging field of sustainable multifunctional landscapes offers a fairly important approach. It is a landscape that created and managed to integrate human production, and landscape use into the ecological fabric of landscape conservation, critical ecosystem function, service flows and protection of biodiversity. This is essential for the possibility of overcoming the end to reverse the declining patterns in most services of our ecosystem (El Messeidy, R., 2017). Many scientists believe that sustainable landscapes have many functions and values, including healthy eating, clean water, clean air, livelihoods and recreational opportunities, productive and healthy ecosystems, and thinking about aesthetic and cultural values (Bohnet, Iris C., Beili, R., 2015).

## **2- URBAN AGRICULTURE**

Agriculture is always related to the rural areas, and indeed the activities involved have often been confined to this context. As a result, it has long been assumed that it is sufficient for the nutrition of the population. Urban agriculture is by definition the production at home or on land in urban or per urban areas. Therefore, in most cases, it is an informal activity that is difficult to distinguish from precise information and patterns (F. Orsini, 2013). As result to its relation to urban areas; urban agriculture utilizes the water as a source from the city and the recycled organic wastes. Therefore, it has played a useful role in the management of natural resources to reach the environmental sustainability (FAO, 2017).

Urban Agriculture is incorporated into the economic urbanism and environmental system: it is an integral part and interacts with the urban

ecosystem. It includes the use of the urban population as workers, the use of urban resources, direct connections with urban shoppers and direct effects on the urban environment and part of the urban environment food system. Urban agriculture increases as the city develops and is not affected by rural migrants. It is a vital element of the urban framework and influence the urban policies and plans (Urban agriculture: what and why?). Moreover, urban agriculture can improve the quality of life by planting farms in different urban areas. The significant and specific value of urban agriculture isn't just its location, however, its incorporation inside the city's economic, social, and environmental system (H, Sam C. M., 2011). As a form of sustainable landscape; urban agriculture has many benefits on the sustainability level and by its contribution in the urban food security and nutrition process.

### **2-1-Benefits in relevant to Sustainability**

Most urban communities in developing countries have great difficulty managing this development and cannot create enough formal jobs for the poor. They additionally have expanding issues with urban waste and municipal wastewater, as well as with the maintenance of air quality and river water. Urban agriculture is an integral methodology to diminish urban poverty and food insecurity, as well as serving in managing the urban environment. The significance of urban agriculture is progressively being perceived by international organizations such as UN-Habitat and the Food and Agriculture Organization of the United Nations (FAO) (Urban agriculture: what and why?). Lately, urban agriculture production has become increasingly popular. It is useful in many ways: it empowers individuals to deliver vegetables without utilizing pesticides. In addition, urban fields affect the growth of biodiversity, improve the local climate and produce oxygen, which is very important and absorbs carbon dioxide (Jasionkowski, J. Rafał., Anna, L., 2016).; Bohnet, Iris C., Beili, R., 2015). Urban agriculture can likewise reflect different degrees of social and economic development, for example, urban food processing was a need during the wartime. However, in recent years, many societies have tried to create a new model of life that is more ecological and sustainable. At present, it is said that urban agriculture is a promising industry that can help developing countries to improve their social and economic levels (Iris C, B. Ruth., 2015).; Wilkin, J., et al., 2010).

### **2-2-Contributions to Urban Food Security and Nutrition**

It is likely that urban agriculture's contribution

to nutrition and food security is its main strength, as urban agricultural production provides poorer people with better access to food to cover a substantial part of their food needs (Zezza, A., Tasciotti, L., 2010). Food production in the city is often a reaction to the urban poor due to inadequate, unreliable and irregular food, and lack of purchasing power. Most cities in developing countries cannot produce enough income opportunities (formal or informal) for a quickly developing populace (Urban agriculture: what and why?). There are signs that individuals in small areas, such as where they live, have begun to produce food without chemical additives. From one point of view, this applies fundamentally to individuals with high earnings who can create herbs and zest plants as opposed to getting them in grocery stores, and thus, improving the status of their families. In addition, jobs will be created for people who are incidentally unemployed. On the other hand, commercial food production in cities must be based on new and rapidly evolving technologies adapted to small urban areas. With such procedures, the production of high yield crops used in urban production is more than 40 times higher than open-field production (Jasionkowski, J. Rafał., Anna, L., 2016).

### 3- ROOFTOP FARMING: A SUSTAINABLE FORM OF URBAN AGRICULTURE

One of the most important trends in urban agriculture is rooftop farming. It exploits in a smart way, the urban space that is not normally used. Roof farms additionally insulate buildings, lower temperatures in summer and keep heat in winter. These factors lead to lower consumption of heating and cooling systems, which saves a lot of energy and money (F. Orsini, 2013). Fig (3) shows Rooftop agriculture in Cairo, Egypt.

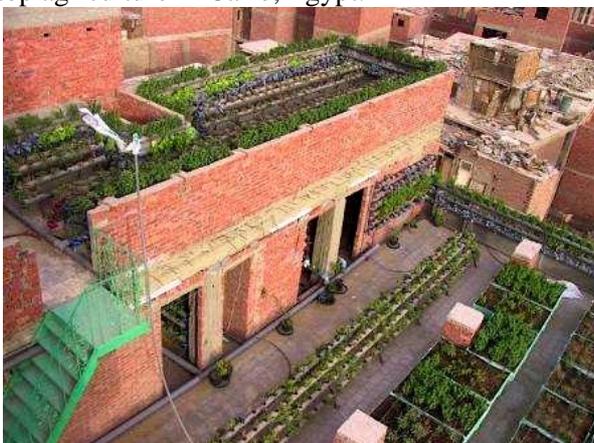


Fig. 3- Shows Rooftop agriculture in Cairo, Egypt  
Source: (Viney, S. Cattane, V., 2011)

Roof systems absorb moisture from the air, which means they also help reduce the flow of

rainwater that can contaminate waterways and sewage treatment plants. Green roof systems are attic units. You can make a positive contribution to improving the quality of life in cities by providing green space, reducing the risk of UCO, reducing air quality problems and improving the management of the city, rainwater and biodiversity. Indeed, green roofs offer various benefits, ranging from comfort and environmental and technical benefits to economic aspects. It is believed that cities can take advantage of green roofs to improve the visual, aesthetic and local climate of the inhabitants. Recently, the utilization and development of green roofs has increased in many countries as a useful feature of sustainable construction technology. Rooftop farms could provide “farmland” to produce vegetables and local (H, Sam C. M., 2011).

There are two widely recognized green roofs; intensive and extensive. The intense green surfaces can support complex plant communities with soil, small trees and shrubs in the depths of the substrate more than 20 cm deep. They are often designed as rooftop gardens for human use and usually require additional irrigation, maintenance and structural reinforcement for the roof (Gawad, Iman O., 2014) Extensive green roofs sometimes are referred to as ecological roofs that have a substrate depth of less than 20 cm, require minimal irrigation or are generally undeveloped, and are generally grown with low-growth juices and stress-resistant grasses (Dunnett, N., Kingsbury, N., 2004). Cities around the world make green roofs mandatory for new buildings. However, in the temperate regions of the northern hemisphere, this extent was extremely limited. In areas unfamiliar with green surfaces, such as Egypt, many obstacles prevent any wider application (Gawad, Iman O., 2014). Table (1) shows the benefits of Rooftop farming from a sustainable development perspective.

Table 1- The benefits of Rooftop farming from a sustainable development perspective (Source: H, Sam C. M., 2011)

Sustainable Development	Benefits
Environmental Level	<ul style="list-style-type: none"> <li>- Reducing food transportation</li> <li>- Reducing wastes</li> <li>- Recycling organic wastes</li> <li>- Mitigating urban heat island</li> <li>- Increasing ecological diversity</li> <li>- Improving air quality</li> <li>- Improving urban storm water management</li> <li>- Sound protection and clamor retention</li> </ul>
Social Level	<ul style="list-style-type: none"> <li>- Active involvement of communities</li> <li>- Social incorporation: provide fresh food to the poor</li> <li>- Educational approach</li> <li>- Local work</li> <li>- Amenity space for exercise and recreation</li> <li>- Aesthetic value</li> </ul>
Economic Level	<ul style="list-style-type: none"> <li>- Increasing nearby food production and sale</li> <li>- Increasing nearby food security</li> <li>- Selling organic vegetable and food</li> </ul>

<ul style="list-style-type: none"> <li>- Access to open space/views increases property value</li> <li>- Improving roof durability</li> <li>- Reducing building cooling load and energy costs</li> <li>- Increasing roof life span</li> </ul>
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**4- WORLDWIDE EXPERIENCES**

To emphasize the benefits of rooftop farming in particular and urban agriculture in general; the study is using an example from the U.S.A. As US cities have the potential to produce successful urban agriculture, they have built many pilot projects which have proved that urban agriculture is essential and profitable. Also, the study uses Singapore as an example of a highly developed country that suffers from limitation of availability of lands for agriculture. Singapore imports about 95% of the vegetables needed to consume. It has

been proposed to develop rooftop farming in social housing in Singapore to improve food security and reduce CO2 emissions. Today, about 25% of the vegetables consumed in Singapore can be produced thanks to this proposal (H, Sam C. M., 2011). These examples have been chosen because they represent successful attempts of varying scales between large projects such as the stadium in America, which is equipped with solar energy technology, and medium-sized examples such as hospitals in Singapore and others as small as the roofs of stores in Singapore too Table (2). Shows pilot projects of rooftop farming in the U.S.A and Singapore.

**Table 2- Pilot projects of rooftop farming in U.S.A and Singapore.**

Country/ Projects	Photos	
<p><b>Levi's Stadium, 2014, Santa Clara, CA, US</b>                      The project is a stadium with an area of 27,000 square meters. The stadium's landmark is designed by HNTB which is a huge five-story gabled wing on the west side, crowned by the green rooftop NRG Solar Terrace. Under the canopy, 1,186 solar panels were installed on the green roof and on three solar-powered pedestrian bridges connecting the parking lot to the park, generating 375 kilowatts of energy, which is the amount of renewable energy assumed to be consumed in the day game. The rooftop garden occupies an area of 4000 square meters. It contains 16 kind of native plants in the Bay area for traders who use agricultural bread products for the local table. About 85% of the irrigation in the playground is recycled water.</p>		<p><b>Levi's Stadium, 2014 Santa Clara, CA, USA</b></p>
<p><b>Changi General Hospital, Singapore</b>                      Utilization of hydroponics on the roof of Changi General Hospital in 1988. This project has been led by a group of hospital employees and the product is used by patients</p>		<p><b>Changi General Hospital</b></p>
<p><b>Orchard Road Singapore</b> is the main shopping street in the city. It has houses, shopping malls, modern supermarkets, numbered food courts, and a small farm. The Comcrop farmhouse on the roof of a shopping center uses lush vegetables and herbs for sale at nearby bars, restaurants, and shops, with its vertical shelves and hydroponics. The small size (600-square-foot) of the farm is its main objective: contribution to improve the food security of the city. Alan Lim of Comcorp, who founded a rooftop farm five years ago, has housed a 4,000-meter farm with a greenhouse on the outskirts of the city. High-tech urban plots are thought to have been grown in the city and there are no cultivars</p>		<p><b>Farms atop malls, at orchard road</b></p>
<p><b>Khoo Teck Puat Hospital (KTPH) certified LEAF</b>, derives the application of the concept of sustainability in KTPH gardens from: firstly, the creation of gardens in a practical and sustainable way; Second, the creation of parks with a view of nature and people; Third, the application of ecological landscape and energy-saving features</p>		<p><b>Khoo Teck Puat</b></p>

Sources: (Berman. S., 2014; H, Sam C. M., 2011; Changi General Hospital, 2018; Orchard Central Mall Greenroofs, 2018; Khoo Teck Puat Hospital, KTPH)

**5- URBAN AGRICULTURE IN EGYPT**

Rooftop agriculture offers many benefits, especially for plants growing in a hot, dry climate like Cairo. This can help a sector of inhabitants improve their quality of life and income and adds to its ecological and aesthetic role.

Cairo's Ain Shams University has revealed urban rooftop ambitions in the early 1990s when a group of agricultural professors launched an initiative to grow organic vegetables in densely populated cities in Egypt. The idea was implemented on a small scale. Until its formal adoption in 2001 by the Food and Agriculture Organization of the United Nations (FAO). A decade later, FAO, in coordination with the Egyptian government, launc-

hed the "Green Food from Green Roofs" project. This project was a policy-based tactic for the development of locally produced food production (Gawad, Iman O., 2014).

By working with the local population and marketing their harvest, several NGOs, public institutions, and initiatives of private citizens have been able to reach the community. They collaborated with several communities to start and developed roofs and hydroponics techniques. Among these organizations who work in Cairo, SHADUF; founded in 2011, this social institution transforms the rooftops of Dar-Elsalam and Elbasatin into thriving botanical gardens.

In 2013, the Desert Development Center (DDC) built the first large green roof for American Cairo in Cairo (AUC), with the support of Forest Service USA and DC Green. The location of the DDC office is where the DDC center is located. This global green roof was an experimental study of the different types of vertical plant cultivation, including wood producers, a vertical garden system and a system that involves a circular exchange of water with an aquarium (AUC, 2013). Fig. (4) shows Mechanical ventilation equipment. The roof of the American University in New Cairo.



Fig. 4- Shows Mechanical ventilation equipment. The roof of the American University in New Cairo. Source: (AUC, 2013)

In 2016, the government, in cooperation with several civil society organizations, launched a rooftop farming initiative providing an extensional coverage of the insufficiency of agricultural products due to the shortage of arable land. The initial target was the creation of two rooftop farming as a pilot model to interpret the idea of turning roofs into fertile gardens. The idea has been a success in many Egyptian cities and it has been reflected not only in the improvement of roofs, but also in the care of roofs in several schools, as the consideration was to make the students more aware of the environment by practicing creative activity (HABITAT III, Quito-2016).

Today there are many initiatives, including an initiative in Luxor, which is based on three levels. The first phase consists of 30 houses, mainly for female householders, to achieve self-sufficiency for their families with vegetables.

There is also a ministerial initiative that encourages Egyptians to plant roofs by offering them all the help and cleaning of the roofs in consultation with the Cairo Cleaning and Cosmetics Authority.

The Ministry also set up training for off-farm agriculture by hosting a large number of rooftop workshops and training sessions and explaining how to benefit from it. It also helped lower the cost of planting a meter from 3,000 pounds to 400 pounds, with the meter producing about 20 to 30 pounds of Kg per year.

## 6- CONCLUSIONS

In today's world, more and more roofs are being used to improve the quality of life. Urban agriculture is seen as a new approach for a sustainable efficient city. Urban agriculture includes different sectors of society, especially women. It provides communities of high-density cities with various economic, social and, environmental benefits. To sum up, it builds an environmentally friendly society. The use of urban areas and wastelands in urban agriculture will increase biodiversity and rainwater retention. Besides, it will also reduce urban heat islands, improve landscape aesthetics and, most importantly, raise possibility for production of organic food in the city. If we allow urban farms in the sustainable energy action plan, we will not only have the advantage of reducing CO<sub>2</sub> emissions, but also of using "wasted" land ecologically, aesthetically and functionally as well as developing the biologically active surface and improving the local climate for urban areas. The advantages of building urban farms, green roofs, vertical orchards, and small plantations with windows or balconies clearly show that these initiatives have a positive impact on urban areas, in accordance with the principle of sustainable development.

The study concluded that urban agriculture is a form of sustainable development and a mean to achieve it. Rooftop farming is the latest trend for sustainable multifunctional landscape. Rooftop farming is an urban agriculture that exploits the built roofs of cities, especially the overpopulated to provide not only a green surface of aesthetic form and environmental benefit, but also social benefit through the participation of a segment of the population themselves in this activity, especially women and the good spirit of integration and community participation. This activity also provides many benefits on the economic level, especially for the poor in the city by providing them with job opportunities by selling agricultural products. It is also a source of income, whether basic or additional, as it provides a source of fresh food. This last feature itself represents a sustainable source of food for the population. Fig. (5) shows the relationship between rooftop farming benefits and sustainable development.

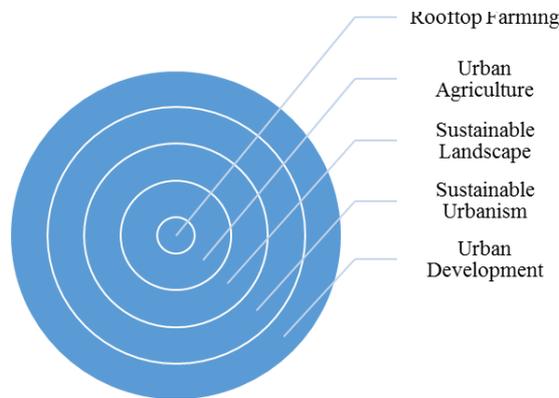


Fig. 5- The Relationship between rooftop farming benefits and Sustainable Development. Source: Author

## 7- RECOMMENDATIONS

The research recommends, in general, paying attention to this kind of urban agriculture from the developing countries' side for its nutritional benefit, which helps secure food as well as, giving additional income, and reducing poverty. The research as well proposes some recommendations for Egypt as follows:

1- Establish guidelines for planting roofs in Egypt; through a framework of Egypt's conditions and challenges.

2- Requirement for governmental support for companies and serious initiatives.

3- Apply the researches' results that are directed to the Egyptian climate and related to the types of plants suitable for green surfaces in Egypt.

4- The usage of economic studies to determine the types of plants and methods of agriculture that are economically feasible.

5- The usage of geographic information programs such as GIS to identify zones and buildings suitable for the implementation of this kind of project.

6- The government could adopt the idea and consider it a national project because of its benefits for the Egyptian society.

7- Increase awareness and training programs for this activity at the provincial level.

8- Follow up on emerging projects and overcome obstacles.

9- Provide good seeds, especially useful seeds for the growth of children as they are sustainable human wealth.

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