PAPER • **OPEN ACCESS**

Green roof awareness, opportunities, and challenges in Egypt

To cite this article: Zainab Faisal and A.S. Elsaadany 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1113** 012006

Green roof awareness, opportunities, and challenges in Egypt

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Abstract. Many Egyptian cities are influenced by environmental stress from air pollution, noise, traffic jams, and the scarcity of green spaces. Green roofs represent one of the ways to achieve sustainability as a result of the environmental, social and economic benefits they provide. The research aims to identify the most important roles that green roof technology can provide and to identify the challenges it faces in the Egyptian market. This research deals with the study of the awareness of Egyptian professionals in the various fields of the built environment with green roof technology, its capabilities and difficulties. The research concludes with a set of recommendations aimed at trying to overcome these difficulties in order to maximize the use of green roof technology.

Keywords: green roof, urban agriculture, multifunction, green infrastructure.

1. Introduction

Urbanization increases in many countries because of the rapid growth, leading to the deterioration of physical geography and the surrounding environment. Green roof strategies can be one of the solutions to these problems and contribute to improving the built environment (Khan, S., and Asif, M.2017) Green roofs are general roofs that are grown distinctively from plants on roofs in suitable soil. The idea is to encourage the creation of green spaces above buildings to obtain multiple environmental and socio-economic benefits (Feisal Z. Haron A., 2017). The green roof consists of several elements. (Ismail et. al, 2012). The green roof is an integrative process in which all its elements combine for the best results. Each element has special importance and an essential role in improving the overall performance of green roofs.

Roof cultivation is a technology that provides a wide range of tangible and intangible benefits to communities (Feisal Z. Haron A., 2017). Green roofs also reduce pollution because they act as a filter for air purification. from the benefits of green roofs playing an important role in reducing noise, which is one of the modern era problems of, especially in cities (Osmundson, 1999). Rooftop gardening is not limited to achieving aesthetic benefits but extends to psychological, functional, economic, and environmental achievements (Feisal Z. Haron A., 2020). Benefits such as protecting the building from climatic changes, in addition to saving energy consumed in the building and reducing air pollution, the idea of a roof garden is to provide a good natural environment for users and help them to achieve psychological balance and connectivity to the land from which it was separated due to housing in the city, including population density The first of which is the lack of green spaces. (Köhler, 2001).

The roof garden is an open urban space that is directly connected to nature and is distinguished from external spaces by its specificity (Feisal Z. Haron A., 2017). From an economic perspective, they are an alternative to open spaces and green spaces that are currently difficult to provide either for economic reasons – such as the price of land or for lack of spaces that can be exploited to provide green spaces (Mentens, 2006; Stovin et. al, 2012), From a social perspective, it is the only outlet close to the family – away from concrete walls and closed spaces – as well as a place for gatherings and social relationships. As a result, day-to-day green roof technologies are created and designed around the world due to multiple advantages (Ismail et. al, 2012).

2. Research Methodology

To achieve the objectives of the research, the study began with a theoretical part that deals with the types of green roofs, their benefits and challenges so that the researcher can prepare a questionnaire that targets

professionals to know the extent of their awareness of the importance of green roofs and the most important roles and obstacles .
The next part of the research reviews the statistical analysis of the survey results, leading to the conclusion of the research and recommendations.

3. History of green roofs

Green roofs represent one of the green infrastructure applications at the level of buildings (Feisal Z. Haron A., 2017). Some believe that roof gardens are a modern idea but on the contrary, the technology of roof gardens began in the seventh century BC in Babylon. At that time, it was known as the Hanging Gardens of Babylon, built by King Nebuchadnezzar II (2009, Salam Abdel M,) to compensate her for the green hills of Persia in which she used to live. Thus came the idea of the hanging gardens of Babylon to restore the appearance of green spaces, which we desperately need now, especially with the decrease in the per capita share of green spaces in Greater Cairo to reach 0.33 m2 per capita (2009, Attia).

4. Green roofs (types and benefits):

The prevalence of green roofs in many countries has been increasing recently not only because of their aesthetic value but also because of their positive impact on the environment. Green roofs can be divided in more than one way, According to European standards, 'green roofs' divide into three types (Getter* Rowe, 2006);

4.1. Extensive green roofs:

The thickness of the vegetation layer in this type of surface varies between 3" and 8" inches. It is suitable for young plants such as desert herbs, succulent plants, etc. Due to its lightweight. It is suitable for light and heavy structures. The cost of building and maintaining this green roof is very low compared with the other types. Such a roof looks unattractive during the winter. It is suitable for flat surfaces as well as for inclined surfaces (up to 45 degrees).

Pic (1) refers to Extensive green roofs
(https://www.ecomena.org/green-roofs-ar/)

4.2. Intensive green roofs:

The thickness of the vegetation layer on this surface varies between 8 and 12 inches. Plants and trees variety can be planted. Large-rooted plants should be avoided. This roof has a large weight and is suitable for heavy structures. The cost of construction, maintenance and irrigation system is high in this species. The construction process is more complex compared to the previous type. It looks very attractive and can be used as a park, playground, and botanical garden. And suitable for flat surfaces only.

Pic (2) refers to Extensive green roofs
(https://ar.greening-solution.com/three-types-of-green-roof%EF%BB%BF/)

4.3. Semi-intensive green roofs:

It is a hybrid roof. Combines the characteristics of an intensive and extensive green roof.

Pic (3) refers to semi-intensive green roofs
(https://ar.greening-solution.com/three-types-of-green-roof%EF%BB%BF/)

The systems used to grow rooftops should be a lightweight system that does not cause overload on the building, as well as water leakage from the system to the roof of the building, should not occur until the building is well maintained and for a long time (Khan, S., and Asif, M.2017). It has been found that soilless agriculture with its different systems and diverse forms is the best way to grow the surface. Green roofs can consist of trees, plants, or shrubs (Feisal Z. Haron A., 2020). The depth and density of the germinated layer of cultivation are divided into two different types according to some specialists intensive and extensive (Osmundson, 1999). Thus, the purpose of having a green roof must be determined and understood before choosing the type to achieve of the design purpose.

The green roof is a method to achieve sustainability. Previous studies conducted on green roofs have proven that green roofs have numerous economic, environmental, and social benefits and the economic benefits include accelerating the marketability by classifying them as green buildings (Rahman et.al., 2012).

The benefits of green roofs are divided into three mains environmental, social (including psychological, health, and aesthetic) and economic benefits, each of which contains a range of diverse and important benefits for humans and the city, its vitality, and sustainability.

5. Ecological Impacts of Green Roofs:

Urban land cover is dominated by an impregnable surface that leads to the degradation of both terrestrial and submarine ecosystems compared to pre-development conditions (Feisal Z. Haron A., 2017). There are opportunities for architecture to use additional land coverings that have multiple functions, serving the human and inhuman elements of the urban ecosystem. green roofs are an indispensable form of land cover that has shown the ability to give a variety of ecosystem benefits in urban spaces (Mentens etal. 2005). Green roofs provide urban ecosystem services, including improved rainwater management, increased urban wildlife habitats, better regulation of building temperatures, and reduced impacts of urban heat islands.

5.1. Stormwater Management:

Usually, the roof garden can be a primary reason for the exploitation of rainwater, as the plants and soil of the roofs collect and filter rainwater, which constitutes a natural process of managing this water, and without these plants, the water collects above the buildings and sidewalks, not absorbed into the ground, so the roof garden prevents the flow of contaminated water from entering the drainage systems, as it collects in normally. They are used to feed plants grown in the roof garden. (Moran etal. 2005).

5.2. Energy conservation:

Green roofs have the potential to reduce energy requirements through the following:

- Absorbing heat and considering it as thermal insulation for the building. Adding a layer of soil and plants to the roofs increase the thermal insulation layer on the surface. Roofs are the most likely to lose internal heat in winter and make the building hotter in summer. Green roofs can reduce the amount of energy needed to soften the heat inside the building and thus reduce the energy requirements which has a positive impact on air quality and reduce pollution. (Porsche and Köhler 2003).

- Green roofs can reduce greenhouse gas emissions and air pollution associated with an increase in carbon dioxide in the atmosphere. Power plants, which are known to cause carbon dioxide emissions, are considered green roofs are a positive solution to reduce these emissions by converting them into oxygen, which helps to improve air quality in the surrounding environment. (Frazer 2005).

5.3. Urban habitat provision:

Green roofs constitute a promising environment to contribute to the preservation of the environment. Through biodiversity, which appears in the formation of green roofs as a suitable environment for the growth and coexistence of cultivated plants and some species of insects, invertebrates, and birds, studies and research have proven that rare plants that arise spontaneously often on ancient surfaces help maximize biodiversity, and then green roofs can be exploited in helping to integrate bio-ecology and biodiversity. (Brenneisen 2006, Grant 2006).

5.4. Aesthetic and psychological benefits

Green roofs are a living environment with aesthetic and psychological advantages for people in urban places. Whether by living with them and exploiting them if possible or in the case of seeing them only and not being able to exploit them, (Ismail et al., 2012) which helps to relax and mental health of the human being, green roofs can bring economic and educational feasibility through urban agriculture (Feisal Z. Haron A., 2017) . Green roofs help reduce noise by absorbing the output sound and preventing its transmission (Donnet and Kingsbury 2004).

5.5. Relaxation and restoration can improve human health .

During the summer, green roofs perform their role as heat insulators, reducing energy consumption - used to cool the building (Feisal Z. Haron A., 2020). Research in Singapore has proven heat transfer through the green roof during a normal day less than 10 reference surfaces. Japanese research identifies a decrease in heat flow of about 50 per year, and works in Ottawa determine a 95 percent reduction in natural heat gain (Leo 2004). green roofs reduce the flow of heat in the summer by enhancing evaporation, physically shading the ceiling, and increasing isolation (Onmura etal. 2001).

5.6. Urban agriculture:

Many economic and educational benefits can be provided to urban dwellers by producing food from green roofs (Feisal Z. Haron A., 2017). The initial cost of green roofs is more expensive to build than traditional roofs, but they are more economical in the long run by providing energy, surface conservation, and food products than urban agriculture. Although green roofs represent a different type of urban habitat, they have been treated entirely as an engineering or horticultural challenge, not as ecosystems. Green roofs reduce sound pollution (Porsche and Köhler 2003).

6. Challenges of green roofs:

Although green roofs are a potential opportunity to combat pollution and an attempt to restore natural hydrology in urban areas, difficult situations that restrict their use remain. Although many of the results of the study show that green roofs are management best practices due to several benefits, some factors include (high initial cost, lack of awareness of green roof implementation mechanisms and maintenance costs, etc.) Still hindering green roofs in some countries (Ismail et al., 2012). One of the challenges is the design of a perfect green roof that can be applied to all places and weather conditions. Since most of the research has been conducted in cold regions, choosing the right green roof plants needs careful study to be compatible with different environments as in hot environments. The challenges and issues related with green roof research are linked and need more research to successfully implement green roofs everywhere (Porsche and Köhler 2003). Economic challenges in dealing with the green roof issue have a great importance by considering the high initial construction cost, the technical aspects of reducing polymer materials, maintenance costs, roof leakage problems, and limited local research.

7. Green roof technology in Egypt:

Green spaces are essential to environmental and urban quality of cities. Most of Egyptian cities suffers from a serious shortage of green spaces, in allocation and area (Abdel Kader Z., Shedid M., 2017). Consequently, it’s urgent to search for possibility of expanding green spaces in urban communities with

different techniques such as green roofs and green walls. Despite the positive effects of green roofs, they are limited in spread in Egypt, and their application is limited to some individual experiences. The research in the following section attempts to reach the most important challenges faced by green roofs in the Egyptian market from the point of view of professionals.

8. Materials and methods:

The research focuses on the issue of the green roofs and the opinion of specialists in this technology and its mechanisms and obstacles to its spread in Egypt despite the environmental, economic, and social advantages of this idea, and the questionnaire discusses the opinions and suggestions that help in spreading the idea.

The questionnaire was conducted as part of a workshop organized at Benha Faculty of Engineering in April 2021 under the title "Green roofs between Theory and Practice" for the participants, and the final number of the sample after excluding the incomplete forms reached 76 participants from different construction disciplines comprising of landscape architect, architect, developer, urban planner, project executive, academics, as well as architecture students.

8.1. Survey Questionnaire development

The first part of the survey deals with basic information about the participants, then their background in green roofs. The second part asks about the advantages and disadvantages of green roofs from the specialist's point of view. Then, the questionnaire shifted to obstacles to the spread of green roof technology in Egypt from the perspective of experts.

8.2. Data analysis

The collected data were recorded and coordinated using Microsoft Excel, before conducting the statistical analysis. Furthermore, the irregular data were refined, and unfinished surveys were excluded.

9. Results and discussion:

9.1. Demographics:

Regarding demographic characteristics a questionnaire was used to obtain this information, such as age, gender, and profession. The following table illustrates some demographic characteristics of the sample participating in the survey, which consists of 76. The average age of the people surveyed was 35 years old. The percentage of female respondents was 52%, while the percentage of males was 48%. Regarding profession, most respondents were academics, 41%.

Gender	(%)	Age	(%)	Profession	(%)
Male	48	18-25	25	Academician	41
		26-35	20	Architect	22
Female	52	36-45	43	Site Engineer	13
		>45	12	Architecture student	24

Table 1: Characteristics of the sample (Sample size, 76)

9.2. Experts' perceptions toward their knowledge of green roof technology:

The 2nd part of the questionnaire with experts was dealing with the green roof technology, the first finding was that the majority know well about green roofs (43.8%) of the sample have good knowledge and (31.1%) have fair knowledge.

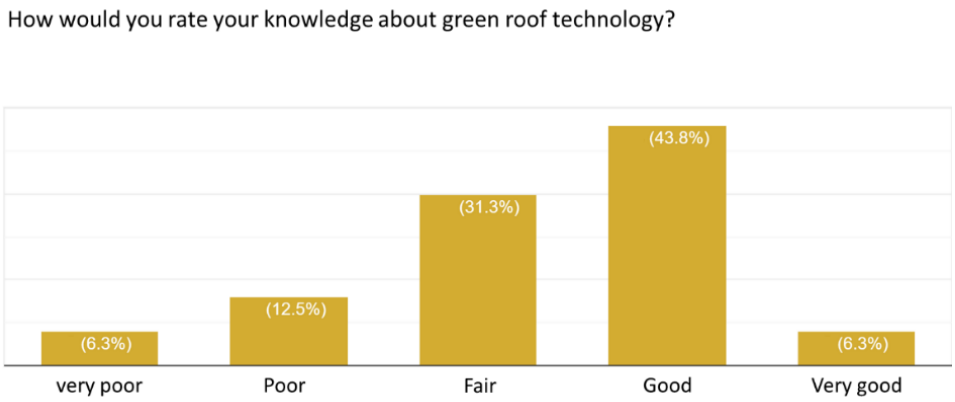

Fig. 1 the awareness of green roofs (authors)

In addition, they had to choose from among a set of points representing the advantages of green roofs, which were identified through previous studies (Bass and Baskaran, 2003; Cory and Bess, 2005), to know the specialists' perceptions and opinions on the benefit of installing green roofs.

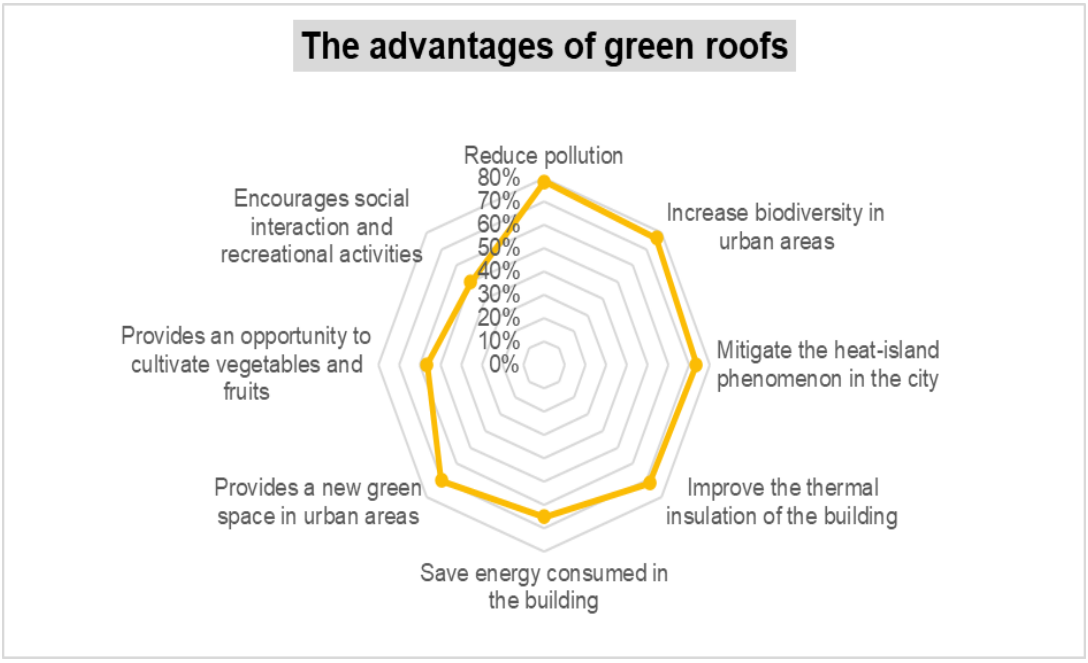

Fig. 2 the advantages of green roof (authors)

As shown in the figure, the highest potential benefits selected by the sample were the reduction of air pollution, followed by the increase in urban biodiversity. On the other hand, the advantages of green roofs that were less valued by the respondents were that they encourage social interaction and recreational activities, and then they provide an opportunity to cultivate vegetables and fruits, and the reason for this may be due to the difficulty of urban agriculture and that it needs greater care and follow-up.

Regarding the disadvantages, as shown in the figure, the problems most chosen by professionals were the high cost of maintenance, followed by the high cost of insulation.

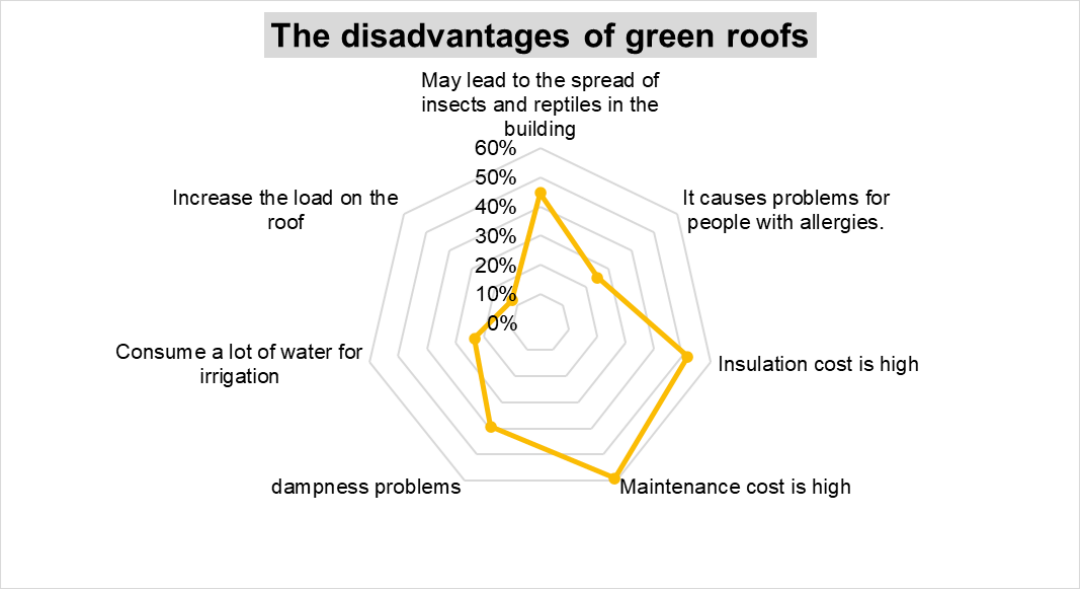

Fig. 3 the disadvantages of green roofs (authors)

It is interesting to note that the high water consumption for green roof irrigation was a drawback that did not meet the expectations. Considering that Egypt enjoys an arid climate as well as water poverty, it is strange that they didn't choose water consumption as a potential defect.

Although specialists are aware of the advantages of the green roof, their participation in the application of this technology is still limited, as only less than a third of the sample (28.6%) have used this technology in the design or implementation projects.

Despite the advantages of green roofs, their application is still very limited in Egypt, and there may be several reasons behind this. It is clear from the figure that specialists think that one of the most important reasons is the Insufficient awareness of green roof technology and its implementation methods, and the lack of experience with this type of project.

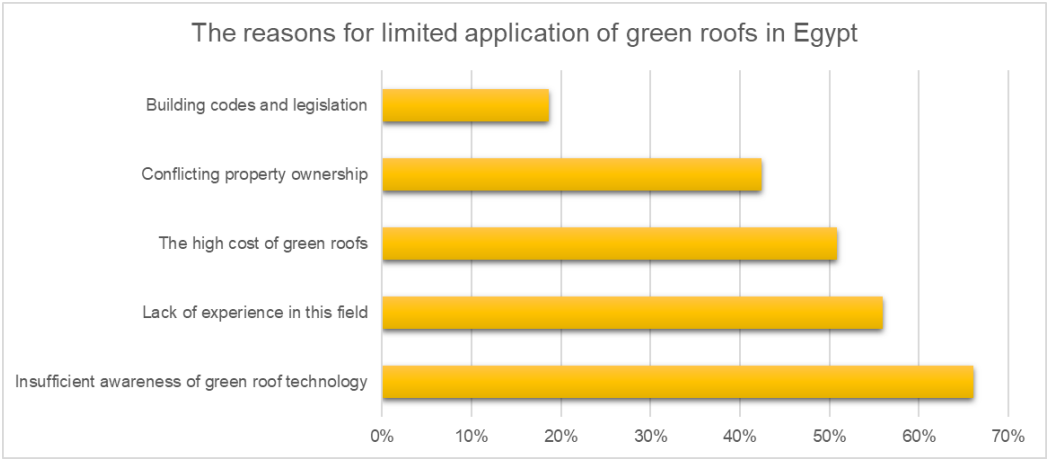

Fig. 4 the reasons for limited application of green roofs in Egypt (authors)

The last part of the questionnaire was related to the architects' desire to develop their idea and information about green roofs, and most of the answers were positive, reflecting their awareness of the importance of this field. (89%) agree to spend time and money learning the latest techniques and methods of green roofs and (84.6%) would like to take more courses and training to practice green roofs.

10. Discussion:

This study examined Experts' perceptions and preferences toward green roof technology and its application in Egypt. Results have shown that:

- The majority of the sample know well about green roofs.
- The highest selected benefit of green roofs was the reduction of air pollution.
- Regarding the disadvantages, the problems most chosen by professionals were the high cost of maintenance, followed by the high cost of insulation.
- Although specialists are aware of the advantages of green roofs, their participation in the application of this technology is still limited.
- Despite the advantages of green roofs, their application is still very limited in Egypt. One of the most important reasons is the Insufficient awareness of green roof technology and its implementation methods.
- Most of the sample would like to develop their idea and information about green roofs application.
- The government should encourage green roof technology by applying the concept in the government buildings, such as schools, hospitals, etc…
- The government should encourage real estate developers to apply technology through licensing rules and requirements.
- Green roof technologies should be incorporated into architectural education materials.

11. Conclusion and recommendations:

There are several technical impediments related to the widespread application of green roofs in Egypt that must be considered:

• The difficulty of costing some intangible issues such as air quality, noise, temperature reduction, and environmental improvement to analyse the cost of the life cycle of green roofs, so more studies are needed regarding the cost analysis of the life cycle of green roofs.
• More studies are needed to find a better local substrate that can reduce the water quality problems experienced by green roofs.
• Stakeholders should be attracted to the application of green roofs by advertising the quality of water and air and the thermal performance of green roofs.
• Finding environmentally friendly materials that can preserve the environment and reduce polymer materials used in green surface components.
• The need for a great deal of cooperation between various agricultural and engineering fields for the application and management of green roofs.

The application of roof gardens has many motives from the point of view of specialists: the environmental value as it reduces thermal emissions and limits the use of heat-insulating materials in addition to reducing pollution and dust and increasing the proportion of oxygen in the atmosphere, as well as the social and aesthetic value, in addition to the economic value as it is considered a garden The roof is an added area to the areas used in the building, in addition to increasing the value of the building and in some cases urban agriculture.

The opinion of specialists that the problem with applying the idea of roof gardens in residential buildings is that the roof is in the public domain, especially in light of the current building law that prohibits building or using the roofs of residential buildings except for services, so to implement the idea of gardens.
The roof in the buildings must be amended by law to allow the roof to be an independent unit or the possibility that the roof is attached to one of the units of the last floor. This amendment in the law can achieve a direct return to the state, but the main goal is to determine the identity of the beneficiary of the surface.

The application of the idea of roof gardens in public buildings, especially schools, is considered an added value or space to the school yard, especially in small schools.
The roof garden can be used as an economic project: for urban agriculture (vegetable and fruit growing) which may contribute to good productivity.
The reuse of water resulting from the drainage of basins in residential units should be studied. And the design of irrigation networks or water treatment units at the level (building, neighbourhood, city) to achieve sustainability in light of Egypt's suffering from water poverty, according to the reports of the Egyptian government and the United Nations.
The tendency to use modern irrigation methods and irrigation technology to achieve the highest rate of efficiency with the lowest rate of water use.
Establish incentive factors for unit owners and facility owners to encourage them to establish roof gardens to achieve environmental benefits for the whole community. And such incentives that the research monitored from international experiences (reducing the electricity and water bill for the building - exempting the last floor from the irrigation water bill - reducing licensing fees - reducing the real estate tax for the building).
Increasing environmental and urban awareness in schools and introducing green education curricula to increase children's collective awareness of the value of green roofs (Rafael Fernandez & others 2013). In addition to paying attention to green applied projects for students of engineering faculties.
Authors believe that further studies with application to selected case studies are recommended.

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