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Roof Garden as an Alternative to Balance Ecological Environment

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Abstract

Increasing urban physical development, population growth and various urban activities have reduced green open space and decreased environmental quality resulting in changes to natural ecosystems. Solutions that can be used by implementing a roof garden. This study aims to obtain economic, ecological and aesthetic data. The method used is inductive descriptive analysis method. In this research the priority is farming food crops. Therefore, efforts are needed to expand and improve the function of green open spaces to maintain the sustainability, harmony and balance of urban ecosystems. This roof garden can make the view more beautiful, as a heat insulator, absorbent of pollutant gases, preventing direct solar ultraviolet radiation from entering the house, and reducing noise. Roof gardens can also cool buildings and rooms below so they can save more energy by reducing the use of air conditioning. Roof gardens have ecological benefits, such as absorbing airborne contaminants and retaining rainwater. Roof gardens can increase rainwater intake to be absorbed and stored by up to 30%. In rooftop gardens, wastewater can be used to water plants.

Keyword: ecological environment, roof garden

1 INTRODUCTION

Vegetation, particularly forests, has been identified as an important component to reduce greenhouse gas emissions, through sequestering carbon in treewood biomass. Given the limited space available, especially in large urban areas, new adaptation strategies such as placing vegetation directly on rooftops are becoming very attractive. Rooftop gardens have been used in various countries, starting in countries with four seasons, arid and semi-arid areas, areas with tropical climates (Yuen & Hien, 2005), and coastal areas (Paraskevopoulou et al., 2021). In Canada, roof garden has been proven to reduce greenhouse gases by around 6% around 2008–2012. From this research, green roofs can be a solution to reducing the effect of greenhouse gases.

The global environmental crisis is caused by wrong and failed policies, low political commitment, and deviant behavior from state actors. Starting from transnational corporations, a culture of consumerism and individualism, which can damage the environment (Pudjiastuti: 2021). Regarding the climate change, humans are triggered to be able to make environmentally friendly technologies to prevent natural damage.

Concern of global warming is increasingly spreading and inspires us to be more aware of an environmentally friendly design. A green architecture can present a beautiful garden. The limited land for houses, especially in urban areas, often makes us unable to create a garden to the dwelling. In a crowded urban area, obtaining open space is not an easy matter. In particular, to meet the standard of 30 percent of green open space. Because urban land occupied with buildings, the target for obtaining green space has shifted to the flat roofs of buildings, which have more sunlight. As an oasis for this problem, we can create an alternative garden which is a rooftop garden.

Green roof installation provides several advantages in urban areas. Green roofs can improve the quality of the urban environment, can reduce heat energy in the process of cooling the room through roof covering, evapotranspiration and as a heat insulator. The green roof can collect rainwater during the rainy season. The effectiveness of green roofs is correlate with the thickness and nature of the green roof growing medium. Nature to some extent can be replicated on top of the building depending on how strong the roof construction is. Garden acts like an insulator absorbing and retaining energy from the sun's rays and releasing it when the surrounding air cools. With a green roof, the roof acts as a heat storage battery which slowly absorbs and retains sunlight and releases it as the surrounding air cools. Research in various countries proves that energy savings will be maximized in buildings during the dry season.

"This rooftop garden can be an alternative technology to answer the lack of land in urban areas for reforestation and water catchment areas," said Darmanto, in a seminar on the development of garden roofs, Thursday (8/10) at Wisma MM UGM. According to Darmanto, the purpose of developing a rooftop garden is to anticipate land shrinkage, especially in urban areas, and the shrinking of green open space which is replaced with residential and office buildings. The potential of this roof garden is in the development stage of using the technology as simply as possible so that it can be applied by the community. By combining the disciplines of agriculture and engineering with the challenges of very dense urban space, building construction, environmental and plant problems."

Dody Kastono, a member of the PSSL researcher, said that rooftop gardens absorb pollutant gases, reduce city heating and solar radiation by up to 80 percent, and reduce noise levels around the park location. "In addition to adding shade, the roof garden can absorb toxic gases." For example, bamboo or palm can absorb formaldehyde gas and gasoline. Meanwhile, lilies absorb both formaldehyde gas and gasoline. Lilies also absorb alcohol and acetone produced by paint. Furthermore, The vines function to absorb acetate gas, ammonia, and other gases. Because of this function, vines are planted at roof gardens. Making a garden on the roof is not cheap and requires a specific roof structure and construction. For optimal results, the roof construction for the garden is designed from the start, before the building is built. But this investment can return in a few years.

Research also shows that the use of green roofs has not been fully implemented in several developed countries, especially in developing countries due to high construction costs and long-term maintenance costs. However, several types of green roofs can be reviewed and adapted to the climate in the area as well as in terms of financing. Green roof installation is a solution that can be used to improve the quality of the urban environment and help improve rainwater management in urban environments. Some of the rain water is stored in the temporary growth medium and will absorb by plants and returned to the atmosphere through evapotranspiration. Green roofs prevent runoff water from flowing into city drains, which is a significant problem for many of the world's major cities. Plants and growing media can also filter air pollution.

Attitudes to the environment become the basis for behavior or concern for the environment (Pudjiastuti: 2020). There are various environmentally friendly technologies that can be utilized. A clean and pollution-free environment is needed by everyone. One of the factors is the use of fossil energy sources. This is because it would be bad for the survival of the earth's life if it continues to depend on fossil fuels and mining which brings many negative effects to the environment. Public knowledge of the existence of natural disaster warnings determines early preparedness for the impact of future disasters (Pudjiastuti: 2019).

Humans are the main factor causing a lot of environmental damage. Without realizing it, the activities of human life in daily life can damage the environment due to economic pressure and low public education (Maridi: 2012). Human interaction with the environment is not always harmonious. There are many negative impacts that occur due to human behavior towards the environment. According to Suparmini et al. (2013) this

interaction can cause negative effects that can be the cause of disasters and other losses. (Pudjiastuti, Iriansyah & Yuliwati:2021). Environmental care is not just aesthetics but rather the implementation of the objectives of the implementation of Islamic values. Furthermore, Pudjiastuti (2020) explained that behavior is closely related to the relationship between humans and their environment where the results of their actions can be a mirror of personal self, imitate other people's styles or ecological factors that naturally affect human behavior.

2 RESEARCH METHODS

This method uses descriptive-analytical methods, describes things that are analyzed and discussed comprehensively and integrally, providing explanations for problems related to roof gardens as an alternative to developing the ecological environment. This study focuses attention on the general principles that are the basis for realizing the symptoms contained in social life. Therefore, this study uses a qualitative approach, a research approach that has the aim of describing and providing an overview of certain matters. The technique used to collect data are observation, interviews and literature study. The research discussion was carried out through descriptive analysis supported by secondary data and literature studies (Pudjiastuti: 2019). This research is in the form of a case study that prioritizes research by investigating interrelated phenomena and contexts and utilizing a lot of evidence or information to find data.

3 RESULT AND DISCUSSION

Grass-covered roofs and vegetated gardens are now a common sight in many cities in the world. More private companies and municipal governments are greening their roofs because they are attracted to many benefits. The benefits are saving energy consumption, reducing flood risk, creating urban flora and fauna habitats, tackling urban air and heat pollution, and producing food. The rooftop garden utilizes building roofs as a space to apply agricultural micro-technology in urban areas. Bizzari (2014) explains that this application has some variations as a solution for more optimal use of buildings and land. Maximizing the function of the roof itself can support activities and have a positive impact on users. Frank Lloyd Wright has a principle that the quality of a building is expected to be in line with the quality of its users. It means that the designed building must be able to give a harmonious impression with a decent atmosphere that can be used comfortably by its occupants. Frank Lloyd Wright considers that the building is part of nature. It seems as if it emerged from nature or looks where the building stands. The theory put forward by Frank Lloyd Wright concluded that a building grows naturally along with its environment. (Lyall, Sutherland: 2006).

3.1 How to Build a Roof Garden

Before making a garden on a building, construction of the roof of the building need to be considered. It should be designed to support the load of the planting media in the form of soil and trees that will be planted. The roof garden must be supported by a strong roof structure and construction. "The existence of a roof garden will cause an additional burden. For example dead load, wind load, and additional water load on the roof of the building from soil and plant piles. The building must also have a proper functioning drainage system. If the roof garden planted by shrubs, the roof load would increase by about 650 kg/m². In addition, for the living load according to the activities on the roof garden. For example, 400 kg/m² for sports, 500 kg/m² for parties and dancing, and 250 kg/m² for restaurants.

For planting trees on the roof, the site floor slab must be supported by structural columns so that the concrete slab does not collapse. It is also necessary to build a

retaining wall because trees require sufficient soil thickness. Roof construction is prone to leakage, so it must be equipped with drainage channels. Drainage layers such as gravel, sand, and pumice need to be added to allow water to flow easily into the drain hole. The filter is made of geo textile or palm fiber which functions to drain water down but holds soil grains so as not to clog the drain hole. He also added that to prevent damage to the waterproof layer, a barrier layer must be added. Therefore, plant roots do not damage the waterproof layer and the concrete underneath. Because the plants on the roof are exposed to direct sunlight and the wind is stronger, watering should be done regularly. Therefore, it is necessary to spray water manually or automatically.

The formula of the planting medium must also be light but has the ability to provide nutrients and moisture, for example, by mixing sand with wood shavings plus a layer of pine bark and fertilizer. The depth of planting medium for grass and cover crops requires 20 to 30 centimeters, while shrubs and small trees require a depth of 60-105 centimeters. Meanwhile, large trees need a depth of almost 2 meters, designed with a flat roof in the form of no concrete. Usually, this area is more often used for service areas, such as a place to dry clothes. In the next few years, it is expected that the concrete roof area will be widely used as a garden. In addition to making the view more beautiful, the roof garden also functions as a heat insulator and prevents ultraviolet radiation from the sun directly entering the house. Moreover, this roof garden is able to cool the building and the room below it, so that we can save more energy by reducing the use of air conditioning (AC). It is undeniable that global warming has a negative impact on all aspects of life. Now it's just our effort to reduce the effects that are starting to feel very disturbing.

Roof garden is an alternative choice to balance the ecological environment with the building. Creating greenery despite having limited land at the base of the dwelling. In this case, we contribute to overcoming global warming by creating environmentally friendly housing by presenting a green environment. According to Emil Salim who was referred to by Budihardjo and Sudanti Hardjohubojo (1993) in his book "City with an Environmental perspective" on the pattern of development with an environmental perspective. According to him, there are some simple ways to make a roof garden: The first step in making a rooftop garden is to prepare all gardening equipment such as hoes, small shovels and plant sprinklers. Begin to prepare a place at the top of the house, such as a balcony so that it can accommodate all the plants that will be planted. Prepare various places to store plants such as small pots or square pots that are slightly large. Fill the pots with planting media or soil and plant the plants you like. Pots made of clay will create a more natural and attractive impression. Make sure that the size of the plant you choose is not too big so you can see and manage its development easily every day. Cut off any overgrown plants so they don't obscure the view. Don't forget to install sufficient lighting in the garden so you can still enjoy the view on the roof garden at night. in Pigure 1 examples of rooftop gardens.

Figure 1. Rooftop garden vegetables and flowers

3.2 The steps in the construction of a roof garden

The steps in the construction of a roof garden are as follows: (1) Good Protection on Roof and Structure. The load capacity supported by the roof can be planned so that it does not exceed the load-bearing capacity of the roof. In this case, it needs a good and careful structural calculation techniques. It is better to make a good roof design from the start in the construction of a house or other building. The design of the roof need to be water resistance to protect it from water seepage. The roof layer is sloping to drain water as a surface drainage system. The strength of the roof must be ensured in order to prevent repair costs in the event of a leak which will cause the entire garden on the roof to be dismantled to find the leak. Although the leak is very small, it can result in the creation of water openings that can be penetrated by plant roots. The roots of the plant in a long time will enlarge and result in more severe damage to the roof. (2) Good and Safe Drainage System. The drainage system on the roof garden shoule be integrated the system with the drainage system under the building. Drainage on the roof garden is intended to be able to collect water on the surface and sub-surface. To prevent soil media from clogging the drainage, planting media must be equipped with a filter made of polypropylene material. The planting media should not contain silt because it can clog the filter and result in closing the drainage channel. Every channel and drainage pipe in the lower layer of the roof garden must be properly recorded to make it easier to control and check in case of damage, as well as facilitate maintenance. (3) Light Planting Media. A good planting medium for a roof garden is a material that is lightweight, able to provide nutrients for plant growth and has a fixed structure but is still easy to drain. A mixture of soil, sand, gravel, and fertilizer is good enough to be a planting medium. Planting media can be replaced with other media such as styrofoam to reduce excess weight. The vegetation layer on the roof garden is a type of plant that spreads horizontally because the thin soil layer does not support vertical growth. (4) Adaptation to Weather. Roof gardens must be designed to be able to keep up with changing seasons, for example the largest rainfall that occurs in the rainy season must be predictable from the start so that the pipes and drainage channels can still accommodate the excess water. Tall plants and vertical structures such as fences, garden lights must be designed to withstand strong winds. The choice of plant species is also important because wind has a drought effect on plant material and soil media due to high evaporation. The plants chosen to be planted on the roof of the building are plants that can withstand excessive sunlight. Areas with excess sunlight require more water due to high evaporation rates. For this reason, it is necessary to add natural and artificial shade as a solution to reduce water loss. (5) Watering in the Roof Garden. Watering is intended to prevent dryness of the plant media and damage and even death of plants. In a large enough roof garden, watering should be done using an underground sprinkler that works automatically. In addition, it can also be done by manual watering which should be done at night so that the plant media does not dry out too quickly. In this case, the availability of water must be sufficient for the needs of watering plants, cleaning the roof surface and the possibility of fire. (6) Installation Method. Installation of all roof garden materials must be careful so it will not to damage the soil membrane layer or building construction. (7) Convenience and Security Due to the location of the roof garden which is on the roof of a building or house is generally high, it must be prioritized to pay attention to user safety. The outermost boundary of the roof garden should not reach the end of the roof, but should be spaced 2-3 meters apart. The outer boundary of the garden should also be given a strong and high railing or fence. (8) Maintenance. Maintenance of the roof garden includes watering, fertilizing, trimming trees and ornamental plants, replanting and checking and repairing the utilities in it. Apart from the occasional watering and fertilizing, a good roof garden is one that does not require much maintenance.

The layers of the green roof system from top to bottom are as follows: (1) Plants, usually selected plants specifically for a particular application (2) Irrigation and control systems Engineered growing media, not soil (3) Filter in the form of cloth, root holder, growth medium, allowing for water penetration (4) Special drainage layer, specially made

water reservoir (5) Waterproof membrane layer (6) Roof structure, with insulator. Special construction requirements and considerations in developing a roof garden. (7) Roof and Structure Protection. The most important element in the construction of a roof garden is to protect the integrity of the roof and structural components under the garden. (8) Load Bearing Capacity. Experts must verify the maximum load-bearing capacity that the existing structure can carry. Usually, the minimum additional dead load limit is 150psf between columns required to accommodate roof garden construction. (9) Coating Waterproof (Waterproofing). A waterproofing system must be installed to protect the building structure. A properly installed waterproofing system can last the entire life of a building, but small leaks can result in an overhaul of the entire park to find and repair the damage. (10) Provisions for Planting Green roof construction are made up of layers. Failure of plant components can cause significant damage and can be expensive to repair. (11) Drainage. Existing roof drains must be suitable for use in roof gardens. Some modifications are needed to accommodate the needs of the roof garden. (12) Climate Considerations. Climate and exposure can be major factors in the success of outdoor space. This is a consideration in the selection of plant materials, but also factors of human use and convenience. (13) Roof Slope In building a roof garden, it should not only be applied to flat roofs or not concrete, but can also be applied to gable roofs, shield roofs, pyramid roofs, and others. The recommended roof slope is above 10^0 and not more than 45^0.

3.3 Advantages of Building a Roof Garden

Creating green roofs yields many advantages, includes the macro-city-wide level and residential micro-building. Green roof systems store most of the annual rainfall and release it into the atmosphere by transpiration. Some of the benefits at the macro level are: (1)Reduces the effect of heat. Some of the open land in large cities has been covered by a waterproof layer, such as paved roads, city roofs absorb the sun's heat and reflect it back into the surrounding atmosphere. Plants add to the cooling factor by releasing water through a process called evapotranspiration. (2) Reduce pollution. Plants can reduce CO2 levels in big cities like Jakarta. With the number of vehicles that have CO2 levels, air pollution will increase along with economic growth in an area. (3) Reduce runoff. Rainwater which run off through the roofs of houses and directly flows into the city's drainage channels and then into the river body. Flowing runoff water directly into the city drainage will increase the discharge of rainwater and cause an increase in the burden on the city's rivers. (4) Building insulation. Like reducing the effect of heat, the roof garden also brings benefits as building insulation. The extra layer on top of the roof helps protect the building, which means lower heating and cooler air inside the building.

The existence of a rooftop garden can reduce rainwater runoff, reduce cooling loads, reduce urban heat islands (Bass & Baskaran, 2003), improve air quality, increase biodiversity, health, and beauty (Dam et al., 2000), reduce environmental temperature and wind speed thereby increasing climatic comfort for pedestrians (Bruse & Skinner, 1999), urban food security and ecosystem service providers (Orsini et al., 2014), stormwater retention by delaying water runoff for 45 minutes and absorbing at least 2 mm (0 .1 inch) before runoff occurs. This quality is important in rainwater management strategies in large cities (Liu, 2002). According to research in Canada (Michelle: 2004), the use of the rooftop garden technique can reduce heating usage by up to 25% in winter, and reduce air conditioning (cooling) usage in summer by 50-75%. The decrease in the temperature of the rooftop garden at Seoul National University ranges from 0.2 to 0.3℃ (Kim et al., 2020). (3) For a large capacity, it can update the air quality in an area, including the building area. A rooftop garden can be a filter for air pollution. It is up to 95% effective in reducing the content of heavy metals, such as copper and lead, as well as harmful particles in the open air. (4) Because it reduces energy consumption, it can also reduce gas emissions resulting from the greenhouse effect. In terms of energy saving, the recommended soil thickness is 0.3 m, and the leaf area index is 0.5, with an optimal plant height of 0.3 m (Zeng et al., 2017). Air conditioning energy savings range

from 8% to 20%, depending on the type of plant used (Ferrante et al., 2016). Installing a rooftop garden in 5 commercial buildings in Singapore can save 0.6-14.5% of annual energy. Bush-habitual plants have the most effective ability to reduce energy consumption from buildings. Soil thickness and soil moisture also substantially reduce the energy consumption of the building (Wong et al., 2003). (5) The technical advantage of the location on the roof of the building is that it can be free from disturbance of land pests, such as rats, frogs, and others which are usually obstacles to conventional technology. (6) Reducing waste because it uses organic waste from the surrounding area as a planting medium. To research by Grard et al. (2020), urban organic waste in Paris can be used as a model for rooftop garden planting media. The results show high crop productivity and very low levels of heavy metal pollutants in the vegetables consumed. Other rooftop garden functions are water purification, urban infrastructure improvement, roof life extension, sound insulation and noise reduction, recreation, property value enhancement, and job creation. (Zhang & He, 2021). Other functions are related to psychological benefits, such as increased concentration and aesthetic pleasure, but need to consider the Rooftop design and its uniqueness. Rooftop Garden can also be used for certain activities, such as sports, socialization, rest, and relaxation (Williams et al., 2021). Research Rahnema et al. (2019) regarding the Roof Garden found that 37.2% felt calm when they saw flowers, while 28.8% of the participants reported feelings of love. The types of flowering plants were more attractive to participants than leafy ornamental plants. Red was the most preferred flower color (52.1%) followed by purple (18.6%) and orange (11.4%) among ornamental species commonly used in green room designs, while tulip (Tulipa gesneriana) (29 %), rose (Rosa hybrida) (25%), and Easter lily (Lilium longiflorum) (19%) each ranked at the top of preference. Coleus (Solenostemon scutellarioides) and garden croton (Codiaeum variegatum) are also reported among the preferred species.

Research in various countries proves that maximum energy savings will be obtained in buildings during the dry season (Endah Lestari et al., 2017). Savings can reach 1.5kWh (5,100 BTU) with a reduced rate of 75% (Liu, 2002). The obligation to maintain and preserve the environment, in the view of all religions and beliefs, is a must for the community so that religious values and local wisdom of the community also become binding provisions to maintain and preserve the environment. The research of Sanye-Mengual et al. (2015) showed that lettuce was better at dealing with heating than other leafy vegetables. The use of floating hydroponics is 25% cheaper in the summer, while the use of soil media is 65% cheaper in the winter. Eggplant and tomato plants grown using soil on a rooftop showed the best performance at around 74 g CO2/kg, with the lowest soil production on eggplant at 0.13 € per Kg. Research by Orsini et al., (2014) stated that Rooftop gardens can be utilized as a city food security by providing 12,000 tons of vegetables per year to Bologna, meeting 77% of the population's needs. Research by Rufi-Salis et al. (2020) in Barcelona stated that the best type of agricultural crop with the lowest impact was tomato (0.49 kg CO2 eq./kg), while in autumn and winter the best crop was tomato combined with beans and lettuce with a market value of 0, 70 kg CO2 eq./€ and nutritional value 3.18.10-3 kg CO2/kcal.

4 CONCLUSION

A roof garden utilizes a building roof as a space to apply agricultural technology in urban areas. This technique has various variations as a solution for more optimal use of buildings and land. Maximizing the function of the roof itself is expected to support activities and have a positive impact on users.

Roof garden is a technique of using the roof of the building as a space to plant plants, in this study, mainly as land for producing food crops (vegetables and fruit). This technique has several advantages, first is to provide agricultural land in urban areas that can produce food crops. Then there are several benefits that can be obtained in terms of

the ecosystem and the building itself. One of them is maximum air conditioning of the building. Planting can cool the air temperature in buildings so that users have the desired thermal quality, by insulating and shading. From an economic point of view, it can reduce the costs incurred for the above air conditioning. Because air conditions tend to be stable, it can reduce the use of air conditioning or heating. The technical advantage of a roof garden is that it can be free from interference from land pests, such as rats, frogs which are usually obstacles in conventional techniques.

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