Environmental, Economic and Psychophysical benefits of volcanic soil green roofs.

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ENVIRONMENTAL, ECONOMIC AND PSYCHOPHYSICAL BENEFITS OF VOLCANIC SOIL GREEN ROOFS.

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Abstract

Climate change will expose hundreds of millions of people to increasing environmental and social risks so adapting to the effects of climate change, the dramatic mass climate migrations expected in the coming decades, can be addressed with housing strategies suited to the characteristics of the environment. Greening the urban environment is a very important strategy to tackle the problems of urban densification, green infrastructures, like green roofs and green walls, have multiple associated environmental, social and economic benefits that improve buildings performance and the urban environment. Of course, it is a question of economic resources, but from this point of view, the perspective we propose in this study is to highlight the costs-benefits that infrastructures can bring, appropriately studied based on the climate of semi-arid geographical areas, and with the use of volcanic soil substrates. The benefits known from the various studies already conducted are explained here in terms of environmental improvements, with the capture of CO_2 by plants; economical, with the energy savings produced by thermal insulation and, finally, with the psychophysical well-being deriving from the relationship between inhabitants, the plant world and nature in general.

Keywords: Climate change, semi-arid landscapes, green roofs, volcanic soil, well-being.

1. Introduction

The concept behind this review of scientifically proven evidence finds its assumptions in the "biophilic approach" as a strategy to address climate change (Maggi 2023), as well as the increasingly pressing problems arising from climate migration. The most recent World Bank report reports that in 2023, about 184 million people (2.3 percent of the world's population) live outside their home country (Worl Bank, 2023). There is still no recognition of the legal figure of the environmental migrant; therefore, we cannot make a quantitative estimate, except to report the World Bank's Groundswell study, updated on 13 September 2021, according to which about 216 million people in the world will be forced to leave their territory by 2050 and migrate due to climate change. But how can men relate to hostile environments? It is not the theme of this paper to have to face causes, effects and proposals for a possible large-scale solution, where entire, or most of the populations, are migrating moved by the instinct of survival, for example in areas of the Sahel, affected by desertification, but to focus on the possibilities of improving housing conditions where climate change, especially the increase in temperature, makes living more and more challenging.

In the first part of this review, we address the issue of the benefits that can be obtained with the good practices of biophilic design. From biophilia to biophilic design: building and re-building an environment where man and nature return in harmony, passes through a necessary planning that overcomes political and economic barriers, putting the well-being of resident men at the centre of attention. A focus is made on

New Cairo, an example of design in line with biophilic principles. We mainly deal with volcanic soil green roofs (GRs), as a solution that has already proven its validity in the three benefit areas covered in this research.

The biophilic design is designed to ensure liability and well-being for man generated by homes with the peculiarities of being sustainable for the environment.

In the second part, dedicated to the economic benefits that can be obtained through the implementation of good practices of biophilic design, we report some experiences and scientific evidence, where it is possible to verify the reality of the facts, namely that good construction practices are also bearers of economic savings. Finally, the third part will highlight the psychophysical benefits that greenery and volcanic soil GRs, can produce on the inhabitants, and thus improve their quality of life, as well as create biodiversity and constructive interaction with the environment, which are the basis of the concept of biophilic design.

2. The environmental benefits of green roofs

The Plant Kingdom consists of approximately 350,000 species and represents at least 80% of the biomass present on Earth. Men account for 0.01% (Mancuso, 2019). The secret of the survival of humans and our planet is contained in plants. Plants absorb carbon dioxide and, by releasing oxygen, keep the earth's atmosphere breathable for humans. Maintaining vegetated territories, and reforesting environments that have not yet been urbanized, is a priority in land management. In this perspective, it is necessary to bear in mind the incidence of the urbanization of the territory, in particular the concentration of the world population in the large cities where they live. "Globally, more people live in urban areas than in rural areas, with 55 % of the world's population living in urban areas in 2018. In 1950, 30 % of the world's population was urban, and by 2050, 68 % of the world's population is projected to be urban (UN 2018). In the big cities, the Urban Heat Islands (UHI) is formed. "The deployment of green and blue infrastructures is one of the most effective measures to counteract the urban heat island effect" (JRC Publications Repository 2024). The temperature increases from 0, 4 °C and 11 °C in UHIs compared to rural areas, with consequences of greater exposure to heat stress of residents (Wong, Tan, Kolokotsa & Tekebayashi 2021). Among the good construction practices aimed at holding this phenomenon of anthropogenic origin are blue and green infrastructures. We point out GRs as one of the most effective. GRs are building roofing systems that allow the formation of real microclimates, where biodiversity can be set up that brings environmental benefits. Bringing vegetation and attracting living forms, such as butterflies, bees, beetles, which can find a hospitable habitat, means that the different environmental synergies find balance even in small spaces (Fig. 1). A clear demonstration of the effects on temperature mitigation can be seen in Peter Kuesters' contribution (Fig. 2).

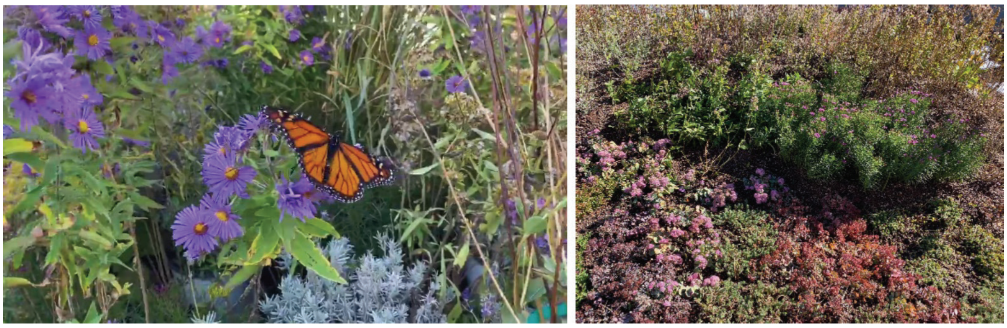


Fig.1 Biodiversity on the roof; Bedford Green House Creston Avenue, the Bronx, NYC. Credits: Substrates for Green Infrastructure, Grey to Green, Washington, DC / Oct 29-30, 2019 www.europomice.com

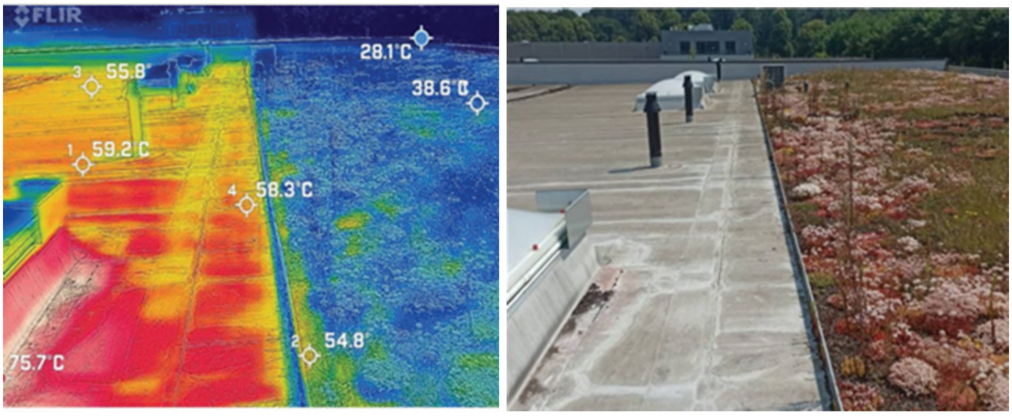


Fig. 2 Difference between temperatures between a partly green roof and partly without Credits: PeterKuesters. https://www.linkedin.com/in/peterkuesters/?lipi=urn%3Ali%3 page%3Ad_flagship3_detail_base%3BbXsp J3PfTkyTSORfGpdZcA%3D%3D

Other benefits of GRs are the capture of CO2 and the retention of rainwater. One of the strategies to reduce CO2 with a double benefit is the laying of GRs: the storage of charcoal in the roots of the plants (Kavehei et al., 2018; Velasco and Roth, 2010) and the reduction of the heat absorbed by the building (La Roche and Berardi, 2014; Santamouris, 2014; Shafique and Kim, 2017).

GRs are expanding around the world as an essential biophilic design framework for sustainable cities. The "heart" of these structures is the substrates, and we want to focus on the effectiveness of volcanic substrates. The composition of a substrate depends on the type of plants, the environment, and various other technical-constructive factors. Due to their characteristics, the volcanic aggregate (Pumice and Lapillus), used alone or in mixture, with simple and adequate construction systems may confer to the surface simultaneously drainage, bearing-durable, lightweight and fertility. Volcanic products as pumice and lapillus can be used in substrate for GRs. “These physical features suggest their applications a draining medium on green roofs. Low density is a key factor when choosing the drainage components in the layers”. Particle density of the lightweight aggregate’s composition analysed shows a density of 0.961 g/cm3 for a pumice lapillus and 1.277 g/cm3 for red clay. (Barbieri, Altimari, Andreola, Maggi and Lancellotti 2023). In (Fig. 3) we report two examples of Grs’ stratigraphy.

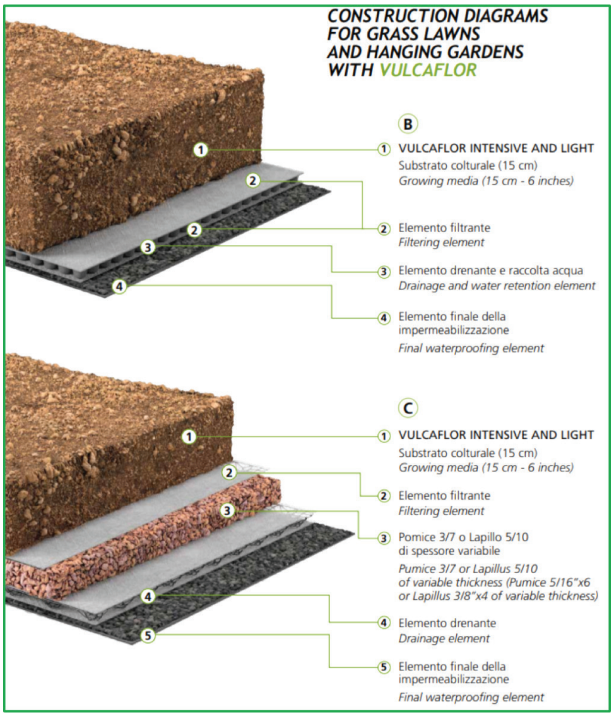


Fig. 3 Construction diagrams for grass lawns and hanging garden.
Credits: www.europomice,com.

We now want to have a look at the state of the art in Egypt with a focus on New Cairo. The 2023 UN Global Climate Awards reports in the winning projects "The future of green roofs in Egypt". The related activity is focused on mitigation and adaptation in Giza. Green roofs will be installed with the aim of mitigating UHI, implementing the energy efficiency of buildings and the other benefits already covered previously. A first GR at AUC (The American University in Cairo) provides vegetation and learning space. The aim is to evaluate through different technologies how a GR can work in Egypt. The construction of the New Administrative Capital began in 2016 on the 270 square miles are 30 miles east of Cairo, where one of the landscape's characteristics is the "Green River," a series of parks and waterways. Following the urban forestry building philosophy, Stefano Boeri Architetti has projected for New Cairo three Vertical Forest, with the aim of providing the inhabitants with an adequate amount of greenery, as well as providing all the benefits that urban greenery brings to the environment. (Fig.4)

Fig.4 Vertical Forest New Cairo. Credits: Stefano Boeri Architetti https://www.stefanoboeriarchitetti.net/project/cairo-vertical-forest/

3. Geomorphological and environmental aspects of New Cairo area.

In Egypt, soil-less agriculture is used to grow plants on the roofs of

buildings. No direct planting process on the roof itself, instead, plants are grown on wooden tables, providing a fresh and healthy source of food that is pesticides free. No obvious reasons why green-roofs didn't spread in a country like Egypt, despite, responsive climate conditions and high rate of pollution. Vegetables and fruits can be produced as self production for building users; moreover, many projects are running nowadays in schools as an introduction to this technology, Fig. 5 is an example for a national school that applied this idea .(Salam ,2012)

Fig. 5; Adapted from CLAC, Clockwise from above: Farid's kitchen garden; planting strawberries at Al-Orman School; the three-level tube system; Al-Zawya AlHamra green rooftops.(Salam ,2012)

Cairo is suitable place for study green roofs, since thousands of buildings do have large roof areas, that are totally accessible, these areas in itself is a an important resource that can be incorporated within the urban fabric, supplying the city with many thousands of square meters of green areas, social spaces and living spaces in a city that vitally still misses a lot of areas with such specifications, networks could be established to link rooftops of some buildings in Cairo, applying green roofs concept may lead to a more healthier city that lacks a lot of green areas.

More than 22 million inhabitants are living in Cairo and as per estimate it is the most densely populated and overcrowded cities in the Middle East along with the highest pollution rate as well. Cairo is facing serious shortage of open and green spaces in terms of both quantity and distribution. The average amount of green space which is available per inhabitant in Cairo is almost equal to 0.33 square meters. The green space per person in Cairo is one of the lowest most proportions in the world.

In a crowded metropolitan city like Cairo, and with this poor ratio of green area per person, green roofs concept is growing from being a luxury option, to a severe need to provide the city with more green areas, better air quality, & other benefits of green roofs. With the current increasingly urbanization rates, This need of green areas not only in the informal areas in Egypt but also in the majority of the city, could not be achieved easily through providing more green areas among the urban setting of these areas, due to many challenges and difficulties among them the increasing land value, people awareness, besides other legal, governmental and economic factors, considering the fact of having thousands meters of accessible areas represented in the roof tops, this could be a suitable solution for such an urban problem.

Although both types of inclusive and exclusive green roofs might not be this suitable solution for the informal areas, yet urban agriculture could be a good one, providing the environmental, socioeconomic benefits of the green roofs concept, supported by some successful experiences that took place in Egypt, and could encourage people for more trials and better expected outputs and results. Not only limited to green roofs and urban agriculture, rooftops could provide the buildings with many social spaces that could be utilized by the buildings inhabitants, talking on an urban scale, linking these rooftops could provide the city with a network of open spaces, accessible and considered as extension of spaces with different uses whether on the level of private or public buildings. Many attempts and project are currently ongoing in Egypt, that are applying the various concepts of utilizing the rooftops, which shows a good level of awareness towards the importance of such an issue. (Fig.6)(Radwan, 2017)

4. The economic benefits of green roofs

Economy and ecology interpenetrate in green infrastructure. The costs of a GR are largely amortized by the economic and environmental value that they return in a brief time. So, sustainability is the main paradigm of our belief in NbS (Nature base Solution, https://iucn.org/our-work/nature-based-solutions) which fully implements this principle. In a summary work on the economic benefits and costs of GRs (Feng and Kasun, 2018), the values converted into a net present value (NPV) and calculating a minimum duration of 40 years, show a benefit ranging from 42.3 to 978.8 $ m². (Tab.1)

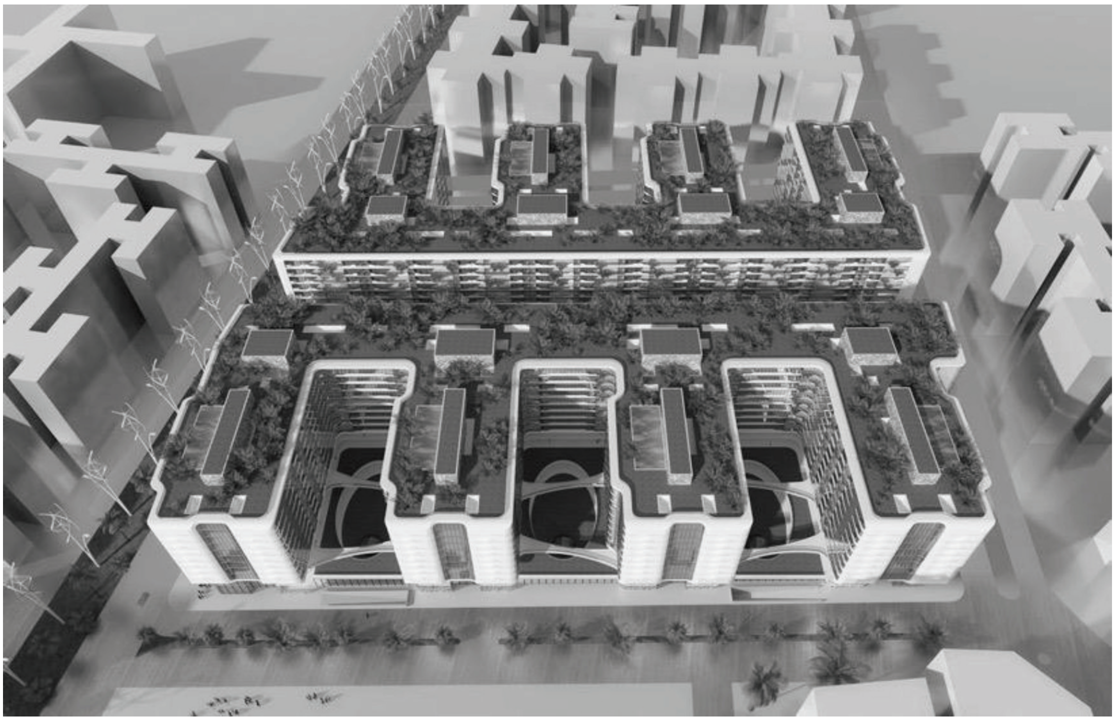


Fig. 6: Cairo Gate Residence - Proposed green roof, source: http://aasarchitecture.com/

TABLE 1 Economic Data Input and NPV Output ($ m^{-2}) for the Cost Benefit Assessment

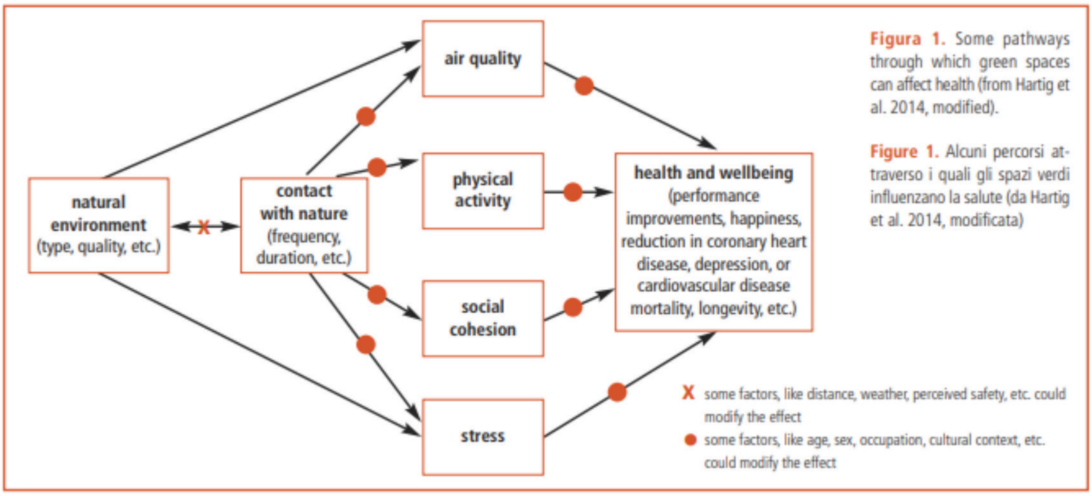
		Value	Time Frame (Year)	NPV ($ m^{-2})
Economic Factor	Lifespan (year)	\	40	\
	Discount rate (%)	3	\	\
Individual Benefits ($ m^{-2})	Reduction of energy	0.4–0.9	Annual	15.7–35
	Use in heating and cooling			
	Membrane longevity	160	At year 20	88.6
	Acoustic insulation	29	One time	29
	Aesthetic benefits	2.6–43.2	One time	2.6–43.2
	LEED certification bonus	n/a	n/a	n/a
Total NPV				135.9–195.8
Public Benefits ($ m^{-2})	Reduction in stormwater runoff	15 - 28	Annual	477.5–750.6
	Improvement of air quality	0.03	Annual	1.18
	Mitigation of urban heat island effect	n/a	n/a	n/a
	Increment of urban diversity	n/a	n/a	n/a
Total NPV				478.7–751.7
Lifecycle Costs ($ m^{-2})	Initial cost	15–540	One time	15–540
	Operation and maintenance cost	0.7–13.5	Annual	27.3–438.7
	Disposal cost	0.03–0.2	At year 40	0.01–0.06
Total NPV				42.3–978.8

Credits: Nature Based Strategies for Urban and Building Sustainability. Feng and Kasun, Nature Based Strategies for Urban and Building Sustainability, SECTION | IV, 2018.

The value of a single or a few GRs has an insignificant impact on urban heat island mitigation and biodiversity, compared to a wide diffusion that exponentially increases its collective benefits. However, the individual benefits that even a few square meters of GR can bring remain. Calculating the minimum NPV of 42.3 $ m², it will only take 13 years of the individual benefits to balance the cost of green roofs which as a life span of 40 years. Looking specifically at Cairo, a study has shown that there is a potential economic benefit ranging from 13 to 39% savings on electricity consumption, compared to traditional non-insulating roofs. (Salam, 2012).

5. The psychophysical benefits of green roofs

Green is the colour of well-being in all human cultures. Green is also the predominant colour of the plants which, with their presence, guarantee man life and, if correctly planted in constructive interaction with the city environment, promote the well-being of the inhabitants. Plants also have a positive influence on city microclimates. Using GRs limits the overheating of buildings by counteracting the "heat island" effect, as well as a positive effect on visual and psychophysical well-being, and on the better liveability of common spaces. (Signorelli, Capolongo, Buffoli, Capasso, Faggioli, Moscato, Petronio, D'Alessandro, 2016). If we imagine a walkable green roof, with substrates that allow intensive vegetation and, for example, the placement of activities such as communal gardens, or a simple walk among the greenery, we can well extend the benefits related to opportunities for relationships with others. Social cohesion, combating stress, and the physical activity possible in green spaces are positively correlated with physical and psychological health. The challenge is to make cities "just green enough" (Wolch, Byrne, Newell, 2014). In Table 2 we can see a clear representation of the benefits.



Tab. 2 Credits: Green areas and public health: improving wellbeing and physical activity in the urban context. D'Alessandro, Buffoli, Capasso, Fara, Rebecchi, Capolongo and the Hygiene on Built Environment Working Group on Healthy Buildings of the Italian Society of Hygiene, Preventive Medicine and Public Health (SItI), 2015.

The urbanization of many cities and megacities in the world has not been planned for green spaces. The intricate and contiguous network between roads and buildings does not allow the introduction of green corridors, except by demolishing houses. disused industrial and commercial buildings. The recovery of these buildings and roofs in a "green vision" can be a workable and sustainable way to forestation cities. We need to cool cities by covering them with trees. By removing 10% of the asphalt roofs in large cities and replacing them with green roofs, we would achieve an average reduction of 4-5 °C; a solution at hand, workable (Mancuso, 2024).

6. Discussion

Many topics of discussion appear from the three topics discussed. The evidence that we are in a historical period were turning points in favour of the well-being of man and the environment, closely related to each other, appears from the countless testimonies relating to climate change, the increasing concentration of population in large cities and the impact that the latter have on global warming, air quality, and the overall pollution of the planet. Can the creation of green spaces inserted in the city context, such as GRs, be a solution? Yes, if with scientific and sustainable programming at the same time. Are GRs suitable for all roofs? No, because it is necessary to design them according to environmental conditions and uses. There are different substrates that are the main part of GRs; Do they all have the same performance? No, volcanic mineral substrates allow balanced drainage, load bearing, durability, lightness and fertility at the same time and that they are easily available and workable. Are GRs a costs? Yes, but they lead to equally quantifiable benefits in energy savings, on the health and well-being of citizens.

7. Conclusion

Finally, looking at the set of information and direct experiences of the authors in the specific infrastructure of GRs, we can conclude that, especially in large urban realities, these roofs can offer significant advantages both at different environmental levels, where the well-being of the inhabitants is brought to the centre. It is therefore important to have urban planning that considers local realities, adequate construction stratigraphy including volcanic substrates and the recovery of potentially accessible areas, and usability at the level of all social classes. Without forgetting the already existing greenery, we take care of plants because plants cure us.

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