



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 10, October 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

The Effectiveness of Green Infrastructure in Reducing Urban Air Pollution: A Study of Cities with and Without Green Roofs and Walls

¹DR. SHEESH RAM YADAV & ²DR. LALITA YADAV

¹PROFESSOR, CHEMISTRY, L.B.S. GOVT. COLLEGE, KOTPUTLI, JAIPUR, RAJASTHAN, INDIA

²PROFESSOR, ECONOMICS, L.B.S. GOVT. COLLEGE, KOTPUTLI, JAIPUR, RAJASTHAN, INDIA

ABSTRACT

Urban green spaces can provide habitat and resources for urban dwelling fauna. Suburban green spaces occur most commonly as parks and roadside vegetation, but as human populations grow and space in cities becomes increasingly limited, space-efficient green solutions like green roofs and walls in metropolitan areas are becoming increasingly common. However, the efficacy of these forms of green infrastructure in attracting and promoting biodiversity remains limited. To address this, we compared arthropod, gastropod, and avian species richness and diversity between green and conventional roofs on neighbouring and identical buildings in metropolitan Sydney, Australia. By monitoring local biodiversity using motion sensing camera traps and regular insect surveys, we found that the green roof supported four times the avian, over seven times the arthropod, and twice the gastropod diversity of the conventional roof. Only the green roof attracted locally rare species including blue banded bees (*Amegilla Cingulata*) and metallic shield bugs (*Scutiphora pedicellata*). Our results suggest that green roofs, like other urban green spaces, can have ecological significance by attracting and supporting urban fauna that may then add important functional capacities to previously depauperate spaces. This study demonstrates the potential for the widespread adoption of green roofs to create more biologically diverse cities.

KEYWORDS-green infrastructure, air pollution, green roofs, green walls, cities

INTRODUCTION

In recent years, designing and displaying green elements such as roofs and walls have become important in urban landscapes. These elements can increase the city's environmental value. Greenery in the built environment is an important element of sustainable development and, therefore, sustainable, and healthy city. For many years, progressive urbanization has harmed the city environment. For this reason, architects and city planners have begun to introduce new concepts and projects that are more environmentally friendly and can improve the quality of life of city residents. Overcoming the existing environmental problems has become the key to achieving sustainability in cities. The definition of sustainable development assumes that the needs of the current sustainable city residents must be met without reducing the opportunities of the city's future residents. Consequently, many challenges need to be overcome for cities to continue to provide the right conditions for living and working. Another important element is also the energy efficiency and promotion of the development of energy-saving technologies enabling energy recovery, improving air quality, supporting the recovery of building materials, and limiting materials damaging the natural environment and enabling the protection of the ecological zone. This paper aims to present examples of the implementation of green building solutions in cities and their environmental benefits in terms of sustainable development. When creating sustainable cities, we think about the future. At the same time, society is paying more and more attention to the problems of our planet. Green solutions in buildings become an important element and a rescue for regaining balance in the environment. Through the ultimate potential of green roofs and walls to promote sustainable development, they are very important. A huge number of buildings are being built around the world, and the challenge is to build them intelligently with minimum consumption of non-renewable energy, minimum pollution production, and minimum energy costs. Other important issues are increasing the comfort, health, and safety of people living and working in these constructions. 2. The genesis of green roofs and walls The tradition of creating green roofs derives from the distant times of antiquity, as it existed already five thousand years ago in Egypt, where the population planted the roofs of their houses. Due to the dense development of cities that could not grow beyond their existing walls, the construction of private roof gardens was popular [1]. Even then, attention was paid to creating a harmonious,

natural surroundings of buildings. The first commonly known example of the use of greenery in architecture from the Mesopotamian area is the so-called Hanging Gardens of Babylon. This was the result of the Babylonians' excellent ability to irrigate land and construct engineering structures. It is known that from the 3rd century BC, the Romans grew grapevines that climbed walls and special trellises. They used supports that allowed the plants to form the shape of a wall, a system called "palmette". The industrial development in the 20th century, and in particular the emergence of reinforced concrete, contributed to the popularization of the idea of flat roofs. In the 1920s, architect Le Corbusier recognized the roof garden as an important point in the program promoting new architecture. On the other hand, the first steps to promote structures in which plants could develop freely creating vertical surfaces took place in the first half of the 20th century. Thus, various methods of turning roofs and facades green, which are more and more popular all over the world (and recently also in Poland), are not a new idea. Later, until the mid-1970s, intensive green roofs, i.e., usable roofs, were built. To further popularize green roofs, more economically viable construction systems were developed. Thus, at the beginning of the 1980s, the first extensive (light, inexpensive, ecological) green roofs were created, where the focus was not so much on usability, but on ecology and economy. More intensive implementation of green roofs started in German-speaking countries in the 1970s [2]. Around the same time, green roofs gained popularity also in France and Switzerland. Vertical gardens began to appear in the 1970s. In turn, the trend for the first vertical green walls was spread by a French botanist Patrick Blanc in the 1990s.[1,2,3]

Green walls are found most often in urban environments where the plants reduce overall temperatures of the building. "The primary cause of heat build-up in cities is insolation, the absorption of solar radiation by roads and buildings in the city and the storage of this heat in the building material and its subsequent re-radiation. Plant surfaces however, as a result of transpiration, do not rise more than 4–5 °C above the ambient and are sometimes cooler."^[18]

Living walls may also be a means for water reuse. The plants may purify slightly polluted water (such as greywater) by absorbing the dissolved nutrients. Bacteria mineralize the organic components to make them available to the plants. A study is underway at the Bertschi School in Seattle, Washington, using a GSky Pro Wall system, however, no publicly available data on this is available at this time.

Living walls are particularly suitable for cities, as they allow good use of available vertical surface areas. They are also suitable in arid areas, as the circulating water on a vertical wall is less likely to evaporate than in horizontal gardens.

The living wall could also function for urban agriculture, urban gardening, or for its beauty as art. It is sometimes built indoors to help alleviate sick building syndrome.[4,5,6]

Living walls are also acknowledged for remediation of poor air quality, both to internal and external areas.

Green walls provide an additional layer of insulation that can protect buildings from heavy rainwater which leads to management of heavy storm water and provides thermal mass. They also help reduce the temperature of a building because vegetation absorbs large amounts of solar radiation. This can reduce energy demands and cleanse the air from VOC's (Volatile Organic Compounds) released by paints, furniture, and adhesives. Off-gassing from VOCs can cause headaches, eye irritation, and airway irritation and internal air pollution. Green walls can also purify the air from mould growth in building interiors that can cause asthma and allergies. Vegetation in green walls can help with the mitigation of the heat island effect and contribute to urban biodiversity.^[2]

Indoor green walls can have a therapeutic effect from exposure to vegetation. The aesthetic feel and visual appearance of green walls are other examples of the benefits - but also affects the indoor climate with reduced CO₂ level, noise level and air pollution abatement.^{[19][3]} However, to have the optimal effect on the indoor climate it is important that the plants in the green wall has the best conditions for growth, both when talking about watering, fertilizing and the right amount of light. To have the best result on all of the aforementioned, some green wall systems has special and patented technologies that is developed to the benefit of the plants.^[20]

Another example in urban areas is green walls provide acoustic protection and reduces the noise through sound absorption.

Thomas Pugh, a biogeochemist at the Karlsruhe Institute of Technology in Germany, created a computer model of a green wall with a broad selection of vegetation. The study showed results of the green wall absorbing nitrogen dioxide and particulate matter. In street canyons where polluted air is trapped, green walls can absorb the polluted air and purify the streets.

DISCUSSION

In Europe, the European Commission set in motion a Renovation Wave to improve the energy performance of buildings across Europe. Aiming at reducing our emissions significantly until 2030, 35 million buildings are set to be renovated to be more energy-efficient and to use renewable energy. In the USA, a broad initiative of states, cities, and businesses (“America’s pledge”) prioritises building retrofitting.

This is a once-in-a-lifetime opportunity to build the houses we need based on entirely new standards of construction or renovation, as opposed to the no-limits mindset that ended up giving way to the sprawling wasteful towns and cities of the 20th century.

So what kind of world will our children get to see, say, in 30 years?

In Europe, the movement ‘New Bauhaus’ is precisely an attempt to come up with a new architectural language for the Low-Carbon Age. It calls for a diverse range of professionals and citizens to propose the buildings of tomorrow. “Beautiful, sustainable, together” is its motto.

Hopefully, they will be inspired by some examples of sustainable buildings we had in the past across the world.

The Hanging Gardens of Babylon were one of the Seven Wonders of the Ancient World. They were built by the Babylonian king Nebuchadnezzar II (V Century BCE) and described as “self-watering planes of exotic flora and fauna reaching a height of over 23 metres through a series of climbing terraces”. They must have felt like an oasis of freshness in the midst of the harsh climate of what is now Iraq.

Centuries later, in the Faroe Islands, the Vikings were building longhouses covered by a roof of turf, stone, and driftwood under heavy grass roofs. In the Islands, it rains 300 days during the year, so the settlers’ introduction of grass roofs was seen as an obvious solution for humidity and thermal insulation. The awareness of the benefits of these nature-based solutions had been lost in time. That is until recently, when a number of developments began to present them in a positive light. As the understanding of their function re-emerges, more towns and cities around the world experiment with this green infrastructure. A Green Roof is a roof that is partially or completely covered with vegetation planted in a growing medium, separated from the building by a waterproof membrane.

There are mainly two categories: Intensive and extensive.[7,8,9]

- Intensive Roofs look like gardens. Soils are deep (more than 20 cm), so they can sustain lush vegetation, which sometimes can include vegetable gardens and even orchards. They require considerable care as well as consideration of their potential weight.

- Extensive Roofs are usually vegetated with low-growing, drought-tolerant vegetation such as sedum species and dry meadows. The soils are shallow (less than 15 cm) and require low maintenance.

A Green Wall is a structure attached to a building’s wall, where vegetation can grow. Textiles, plastics, and metal (boxes) are used to provide pockets that support the plants. Green Walls are usually irrigated, often with the use of sensors and timers that are activated when moisture levels are too low.

According to research, although installation does involve higher upfront costs than a traditional roof, there are economic benefits that can make up for it. The University of Michigan performed a valuation study comparing a 2,000 square meter conventional roof and a green roof [i]. The study looked at the range of benefits that could be estimated, including energy savings, rainwater management, and direct health benefits. Over an estimated lifespan of 40 years, the green roof saved about \$200,000, including energy savings.

Of course, these cost analyses are dependent on the local climate and the type of roof or wall, but it is undeniable that in specific cases there is a business case. Also, scale can play a key factor in their profitability.

Contrary to economic valuations, the range of services and benefits provided by green roofs or walls are well understood:

- Control stormwater run-off and retention.
- Reduce the Urban Heat Island effect and improve air quality. The temperature in a large city is on average a few degrees higher than in surrounding rural areas. Green roofs and walls not only cover the surface, but also use solar radiation to evaporate water and transpire, which reduces temperature.
- Insulate a building. The extra layers of greenery decrease the amount of heat reaching the building façade, reducing energy needs for cooling.

- Provide urban amenities to building occupants. Green roofs can incorporate gardens or urban agriculture.
- Provide habitats for biodiversity. A green roof or wall provides refuge for insects and birds in the midst of a large city.
- Provide psychological and physiological health benefits, as it does offer respite from the grey urban environment and a visual connection with the natural world. This has been demonstrated in some studies to provide positive emotions.
- An undeniable aesthetic appeal. Various solutions are available with different texture and colours that can be skilfully arranged to decorate the building façade.

RESULTS

In the Chinese city of Chengdu, a housing estate was constructed with vertical vegetation in every open space and balcony. The visual effect was stunning, but the occupants had to deal with a new-found biodiversity in the building — scores of mosquitoes and other bugs colonised the vertical forests and made life quite difficult. It did not of course help that Chengdu is located in Sichuan, China, where the climate is humid sub-tropical. Other green infrastructure projects across the globe were more careful. Milan's Bosco Verticale is one of these examples. Architect Stefano Boeri and botanist Laura Gatti reportedly spent long hours selecting adequate vegetation to fit the local climate. The result is quite stunning, and probably not far off from the Gardens of Babylon

Environmental benefits

Thermal reduction and energy conservation

Green roofs improve and reduce energy consumption.^[9] They can reduce heating by adding mass and thermal resistance value, also can reduce the heat island by increasing evapotranspiration.^[10] A 2005 study by Brad Bass of the University of Toronto showed that green roofs can also reduce heat loss and energy consumption in winter conditions.^[11] A modeling study found that adding green roofs to 50 percent of the available surfaces in downtown Toronto would cool the entire city by 0.1 to 0.8 °C (0.2 to 1.4 °F).^[12]

A green roof reduces cooling (by evaporative cooling) loads on a building by fifty to ninety percent,^[13] especially if it is glassed-in so as to act as a terrarium and passive solar heat reservoir.^[10]

A concentration of green roofs in an urban area can even reduce the city's average temperatures during the summer, combating the urban heat island effect.^[14] Traditional building materials soak up the sun's radiation and re-emit it as heat, making cities at least 4 °C (7.2 °F) hotter than surrounding areas. On Chicago's City Hall, by contrast, which features a green roof, roof temperatures on a hot day are typically 1.4–4.4 °C (2.5–7.9 °F) cooler than they are on traditionally roofed buildings nearby.^[15] Green roofs are becoming common in Chicago, as well as in Atlanta, Portland, and other United States cities, where their use is encouraged by regulations to combat the urban heat-island effect. Green roofs are a type of low impact development.^[16] In the case of Chicago, the city has passed codes offering incentives to builders who put green roofs on their buildings. The Chicago City Hall green roof is one of the earliest and most well-known examples of green roofs in the United States; it was planted as an experiment to determine the effects a green roof would have on the microclimate of the roof. Following this and other studies, it has now been estimated that if all the roofs in a major city were greened, urban temperatures could be reduced by as much as 7 °C (13 °F).^[17]

Water management

Green roofs can reduce stormwater runoff^[18] via water-wise gardening techniques. Green roofs play a significant role in retrofitting the Low Impact Development (LID) practices in urban areas.^[19] A study presented at the Green Roofs for Healthy Cities Conference in June 2004, cited by the EPA, found water runoff was reduced by over 75% during rainstorms.^[20] Water is stored by the roof's substrate and then taken up by the plants, from which it is returned to the atmosphere through transpiration and evaporation.

Green roofs decrease the total amount of runoff and slow the rate of runoff from the roof. It has been found that they can retain up to 75% of rainwater, gradually releasing it back into the atmosphere via condensation and transpiration, while retaining pollutants in their soil.^[20] Many green roofs are installed to comply with local regulations and

government fees, often regarding stormwater runoff management.^[21] In areas with combined sewer-stormwater systems, heavy storms can overload the wastewater system and cause it to flood, dumping raw sewage into the local waterways. Often, phosphorus and nitrogen are in this category of environmentally harmful substances even though they are stimulating to the growth of plant life and agriculture. When these substances are added to a system, it can create mass biological activity since they are considered limiting factors of plant growth and by adding more of them to a system, it allows for more plant growth.^[22]

Ecological benefits

Green roofs create natural habitat as part of an urban wilderness.^[23] Even in high-rise urban settings as tall as 19 stories, it has been found that green roofs can attract beneficial insects, birds, bees and butterflies. A recent list of the bee species recorded from green roofs (worldwide) highlights both the diversity of species, but also the (expected) bias towards small ground-nesting species (Hofmann and Renner, 2017). Rooftop greenery complements wild areas by providing stepping stones for songbirds, migratory birds and other wildlife facing shortages of natural habitat.^[2,3,4]

Green roofs also serve as a green wall, filtering pollutants and carbon dioxide out of the air, helping to lower rates of diseases such as asthma.^[24] They can also filter pollutants and heavy metals out of rainwater.

Carbon sequestration

An additional environmental benefit of a green roof is the ability to sequester carbon. Carbon is the main component of plant matter and is naturally absorbed by plant tissue. The carbon is stored in the plant tissue and the soil substrate through plant litter and root exudates.^[25] A study on green roofs in Michigan and Maryland found the above ground biomass and below ground substrate stored on average between 168 g C m⁻² and 107 g C m⁻². Variations occurred among the different species of plant used. Substrate carbon content averaged 913 g C m⁻² and after the subtraction of the original carbon content the total sequestration was 378 g C m⁻².^[26] The sequestration can be improved by changing plant species, increasing substrate depth, substrate composition, and management practices. In a study done in Michigan above ground sequestration ranged from 64 g C m⁻² to 239 g C m⁻² for *S. acre* and *S. album*.^[26] Also, by increasing the substrate depth would allow for more area of carbon storage and diversify the types of plants with greater potential of carbon storage. The direct carbon sequestration techniques and methods can be measured and accounted for. Green roofs also indirectly reduce CO₂ given off by power plants through their ability to insulate buildings.^[25] Buildings in the US account for 38% of the total carbon dioxide emissions.^[27] A model supported by the U.S. Department of Energy found a 2 percent reduction in electricity consumption and 9-11% reduction in natural gas when implementing green roofs.

Other

Help to insulate a building for sound; the soil helps to block lower frequencies and the plants block higher frequencies.^[28]

- If installed correctly many living roofs can contribute to LEED points
- Increase agricultural space
- Green roofs not only retain rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to run off.

Costs and financial benefits

A properly designed and installed extensive green-roof system can cost \$108–\$248/m² (\$10–\$23/sq ft) while an intensive green roof costs \$355–\$2,368/m² (\$33–\$220/sq ft) However, since most of the materials used to build the green roof can be salvaged, it is estimated that the cost of replacing a green roof is generally one third of the initial installation costs.^[29]

With the initial cost of installing a green roof in mind, there are many financial benefits that accompany green roofing.^[3,4,5]

- Green roofing can extend the lifespan of a roof by over 200% by covering the waterproofing membrane with growing medium and vegetation, this shields the membrane from ultra-violet radiation and physical damage.^[30] Further, Penn State University's Green Roof Research Center expects the lifespan of a roof to increase by as much as three times after greening the roof.^[31]
- It is estimated that the installation of a green roof could increase the real estate value of an average house by about 7%.^[32]
- Reduction in energy use is an important property of green roofing. By improving the thermal performance of a roof, green roofing allows buildings to better retain their heat during the cooler winter months while reflecting and absorbing solar radiation during the hotter summer months, allowing buildings to remain cooler. A study conducted by Environment Canada found a 26% reduction in summer cooling needs and a 26% reduction in winter heat losses when a green roof is used.^[33] With respect to hotter summer weather, green roofing is able to reduce the solar heating of a building by reflecting 27% of solar radiation, absorbing 60% by the vegetation through photosynthesis and evapotranspiration, and absorbing the remaining 13% into the growing medium. Such mitigation of solar radiation has been found to reduce building temperatures by up to 20 °C (36 °F) and reduce energy needs for air-conditioning by 25% to 80%. This reduction in energy required to cool a building in the summer is accompanied by a reduction in energy required to heat a building in the winter, thus reducing the energy requirements of the building year-round which allows the building temperature to be controlled at a lower cost.^[34]
- Depending on the region in which a green roof is installed, incentives may be available in the form of stormwater tax reduction, grants, or rebates. The regions where these incentives will most likely be found are areas where failing storm water management infrastructure is in place, urban heat island effect has significantly increased the local air temperature, or areas where environmental contaminants in the storm water runoff is of great concern.^[35] An example of such an incentive is a one-year property tax credit is available in New York City, since 2009, for property owners who green at least 50% of their roof area

CONCLUSION

Green roofs, or vegetated roofs, or eco-roofs are roof surfaces covered with vegetation planted over a waterproofing membrane. These systems typically comprise several layers, including a root barrier, drainage layer, and soil or growing medium.

Green roofs can be classified into two main types: extensive and intensive. Extensive eco-roofs have a shallow growing medium, supporting hardy, low-maintenance plants. In contrast, intensive green roofs have a deeper growing medium, accommodating various plant species and trees.

Living walls, also known as vertical gardens or green walls, are structures covered with plants, either attached directly to the wall or installed using modular systems.

These walls can be built indoors and outdoors and are designed to accommodate a variety of plant species, including flowers, ferns, and even edible plants. Living walls can be hydroponic, with plants growing in nutrient-rich water, or use soil or other growing media.

The Multifaceted Benefits of Green Roofs and Living Walls[5,6,7]

Improved Air Quality

Green roofs and living walls act as natural air filters, with plants absorbing pollutants and CO₂ while releasing oxygen through photosynthesis. In urban environments, where air pollution is often a major concern, these features can significantly contribute to healthier air and improved quality of life.

Reduced Energy Costs

Natural insulation, green roofs, and living walls help regulate building temperatures, reducing the need for air conditioning in summer and heating in winter. This results in lower energy consumption and costs and reduced greenhouse gas emissions.

Enhanced Biodiversity

Green roofs and living walls offer a much-needed refuge for birds, insects, and other wildlife in densely populated urban areas. These features can serve as stepping stones for species to move between green spaces, promoting ecological connectivity and fostering city biodiversity.

Stormwater Management

Green roofs and living walls can absorb, filter, and store rainwater, reducing the volume and velocity of stormwater runoff. This mitigates the risk of flooding and decreases the load on urban sewer systems, ultimately reducing the need for costly infrastructure upgrades.

Noise Reduction

The vegetation and growing medium in green roofs and living walls act as natural sound barriers, absorbing and deflecting noise. This can lead to a quieter and more pleasant environment for building occupants and the surrounding community.

Aesthetics and Well-being[7,8,9]

Green roofs and living walls can transform bland urban landscapes into visually appealing, vibrant spaces. The presence of greenery can significantly improve the aesthetics of a building, increasing its market value and appeal. Furthermore, numerous studies have demonstrated the positive impact of exposure to nature on human well-being, including reduced stress, improved mental health, and increased productivity.[10]

REFERENCES

1. Rodriguez Droguett, Barbara (2011). Sustainability assessment of green infrastructure practices for stormwater management: A comparative energy analysis (Thesis). ProQuest 900864997.
2. ^ Özyavuz, Murat, B. Karakaya, and D. G. Ertin. "The Effects of Green Roofs on Urban Ecosystems." GreenAge Symposium 2015.
3. ^ EPA (2017) Green Roofs. U.S. EPA. Available from: <http://www.epa.gov/heatisland/strategies/greenroofs.html>
4. ^ "Benefits of Green Roofs". www.greenroof.hrt.msu.edu. Archived from the original on 4 July 2018. Retrieved 1 November 2018.
5. ^ Vandermeulen, Valerie; Verspecht, Ann; Vermeire, Bert; Van Huylenbroeck, Guido; Gellynck, Xavier (November 2011). "The use of economic valuation to create public support for green infrastructure investments in urban areas". *Landscape and Urban Planning*. 103 (2): 198–206. doi:10.1016/j.landurbplan.2011.07.010.
6. ^ "System Overview : Planted Roof : GSA Sustainable Facilities Tool". sftool.gov.
7. ^ Volder, Astrid; Dvorak, Bruce (February 2014). "Event size, substrate water content and vegetation affect storm water retention efficiency of an un-irrigated extensive green roof system in Central Texas". *Sustainable Cities and Society*. 10: 59–64. doi:10.1016/j.scs.2013.05.005.
8. ^ "Aurélien P. JEAN". Archived from the original on 24 August 2011. Retrieved 19 May 2011.
9. ^ Li, W. (2013). A scenario planning approach for school green roofs to achieve stormwater management benefits: A case study of Brier's Mill Run Subwatershed
10. ^ Santamouris, M. (2014). Cooling the cities – A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar Energy*, 103(Supplement C), 682–703.



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.423



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 6381 907 438 ijirset@gmail.com



www.ijirset.com

Scan to save the contact details