Sustainability Through Green Roofs and Walls in Urban Areas

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ABSTRACT

This paper discusses the sustainability benefits through the installation of living green roofs and walls in urban areas. A brief history of these living systems is provided to give context to the reader. Different kinds of green roofs and walls, how they are maintained, and their many benefits will be discussed. The many public and private benefits for cities that implement these systems will be examined. Then two case studies in different locations will be looked at that examine different benefits of green roofs in two different climates.

INTRODUCTION

Charles Elton a zoologist and animal ecologist stated, "Unless one merely thinks man was intended to be an all-conquering and sterilizin-g power in the world, there must be… some wise principle of coexistence between man and nature, even if it has to be a modified kind of man and a modified kind of nature. This is what I understand by conservation" (Francis & Lorimer, 2016). Green roofs and walls are a modified kind of nature that can be designed to coexist with humans in urban environments to increase the sustainability of an area. In his essay, *Sustainability as a Project of History,* Clive Dilnot discusses how a human's relationship with nature must be re-constructed in order to reach a sustainable world. "Of course, there will be no sustainability, or nothing even close to a more sustainable world, without pacified and reconstrued relations with nature" states Dilnot (2011). The world cannot return back to before there was artifice, we must work with the artificial world we have created and make a new form of sustainability.

Throughout this essay, I will discuss the history of green architecture, what green roofs and walls are, their benefits, and how they can be implemented. I will relate green roofs and walls to the United Nations Sustainable Development Goals, and analyze two case studies of current roof and wall systems and their successes. The use of living green roofs and walls in urban areas is imperative for environmental, ecological, and health improvements for cities and their people.

THE HISTORY OF GREEN ROOFS

The Hanging Gardens of Babylon from 600 BC in Mesopotamia were the first documented green roofs and walls (Hopkins & Goodwin, 2011). These gardens provided a cooling effect in the arid Middle Eastern climate. In Europe during the Viking era of 800-1000AD sod roofs, turf, and seaweed-lined walls were used as insulation for the colder temperatures (Hopkins & Goodwin, 2011). Today in North America there are green roofs and walls being largely implemented in Toronto, Vancouver, Chicago, Boston, Portland, Phoenix, Washington DC, and New York (Hopkins & Goodwin, 2011). Singapore and Japan and other Asian cities are the most innovative with scale and unique design in the world with their creation of green roofs and walls today (Hopkins & Goodwin, 2011).

GREEN ROOFS

Green roofs function and survive better in cooler climates, because there is not only a need for cooling but also for heating from the green roofs (Berardi, 2016). Hotter or tropical climates do not need the heating effect of green roofs because of the lack of cold weather. Warmer climates benefit more from cooling roofs, which are made of reflective materials to prevent heat absorption (Berardi, 2016). Green roofs can be built at different depths, however, the deeper the soil is for a green roof the more effective it is in heating and cooling a building (Berardi, 2016).

Maintenance of green roofs must be considered in the design plan for the system before they are implemented, as this is necessary for the system's success (Hopkins & Goodwin, 2011). Water and fertilizer systems for the roofs need to be monitored and devices can be installed to alert maintenance or contractors if a problem occurs (Hopkins & Goodwin, 2011). Watering, airborne seed germination, and access to the roof are all necessary for maintenance, and green roofs also need protection from general building maintenance (Hopkins & Goodwin, 2011).

There are three types of green roofs: intensive, extensive, and biodiverse (Hopkins & Goodwin, 2011). Intensive green roofs are manicured, weeded, sprayed, and the plant species are generally chosen for aesthetic reasons (Appendix A, Fig.1). They are planted in engineered substrates with organic matter and are 150 millimeters or less deep (Hopkins & Goodwin, 2011). Extensive green roofs are planted and need no further maintenance (Appendix A, Fig. 2). The plant selection for extensive green roofs must be native to the area in order for survival in certain climates without maintenance. They are planted in engineered substrates with organic matter and are 150 millimeters or more deep (Hopkins & Goodwin, 2011). Finally, biodiverse and elevated green roofs, also known as "brown roofs", consist of natural soil, are the lowest maintenance, and are highly biodiverse (Appendix A, Fig. 3). Their plants are native to the area and are allowed to germinate and grow without human interaction, and these roofs are 600 millimeters or more deep (Hopkins & Goodwin, 2011). Different green roofs have different benefits and effects that will be further analyzed in the two case studies.

GREEN WALLS

Many plants can easily grow on a walled environment. Larger walls and bigger plants need crevices, fractures, and intersects to trap mineral and organic sediment and to allow trapping of germination and seeds (Hopkins & Goodwin, 2011). Maintenance of green walls consists of watering (especially initially) airborne seed germination, and access to the wall for maintenance and equipment (Hopkins & Goodwin, 2011).

There are five types of green walls: green façades, green walls, hybrid system walls, spontaneous living walls, and landscape walls. The first is a green façade that uses plants grown from the ground or in raised planters. Self-clinging plants have been used consistently in green walls, but this often damages the structure of the wall (Fig. 4). More recently trellises, modular panels, and cable wires and ropes have been installed for the plants to grow onto (Hopkins & Goodwin, 2011). The next type is a green wall, which is built from already vegetated panels or planted fabric pockets that are then attached to the wall. (Fig. 5) (Hopkins & Goodwin, 2011). Next, hybrid system walls are when plant walls are placed on wall space between the windows on buildings. This allows the wall to shade the building while still allowing light into the windows (Fig.6) (Hopkins & Goodwin, 2011). Spontaneous living walls occur unexpectedly where seeds germinate on buildings, meaning they are not planned or planted and are usually very biodiverse (Fig.7) (Hopkins & Goodwin, 2011). Finally, landscape walls use already existing vegetation around engineered structures built out of concrete or plastic blocks for the plants to begin to grow on (Fig.8) (Hopkins & Goodwin, 2011).

BENEFITS OF LIVING GREEN ROOFS AND WALLS

There are many benefits to green roofs and walls that can be categorized into private and public categories. The private benefits for people who own or use the building are temperature control, noise reduction, improved indoor air quality, energy cost savings, market value increase of the building, and an overall increase in the sustainability of the building (Hopkins & Goodwin, 2011). The public benefits of these systems for everyone who interacts with or is near the building are: an urban heat reduction, air pollution reduction, stormwater management, improved water quality, improved public health and wellbeing, an urban agriculture increase, improved biomass and biodiversity, and an aesthetic improvement of the area (Hopkins & Goodwin, 2011).

The environmental benefits of green roofs and walls are very extensive. Air quality improvement is an environmental benefit as 109 hectares of green roofs contributes to around 7.87 metric tons of air pollution removal per year (Berardi, Ghaffarian Hoseini, & Ghaffarian Hoseini, 2014). Green Roofs and walls reflect between twenty and thirty percent of solar radiation, and absorb up to sixty percent through photosynthesis which reduces urban temperatures (Berardi et al., 2014). Storm water control is seen as one of the most important parts of a green roof function by many researchers. Sixty percent runoff mitigation can be achieved with some extensive roofs and up to one hundred percent for intensive roofs (Berardi et al., 2014). The quality of stormwater is also improved when passed through a green roof system; this will be further analyzed in the Adelaide case study.

Along with the environmental benefits of these living systems, many ecological benefits can be achieved. Deeper green roofs and green roofs that resemble ground environments from the local area are most successful in building and maintaining ecological systems. Green roofs and walls support many insect, animal, and plant species. These include mycorrhizal fungi, which assist soil life, flying insects such as bees and butterflies, spiders, snails, beetles, bats and birds (Thuring & Grant, 2016). A study of a green roof in Switzerland found seventy-eight species of spiders on a green roof with many being a conservation concern and potentially endangered (Thuring & Grant, 2016). Furthermore, a London study found 136 species of invertebrates on a green roof with many being nationally scarce, or rare (Thuring & Grant, 2016). Green roofs and walls are imperative to the existence of ecological systems if urban areas are going to continue to grow and destroy ecological systems and plant species.

Psychological and health improvements for citizens in the areas are a key benefit of these systems. There are many health benefits because of increased air quality through the increase of oxygen and reduction of carbon dioxide, and reduction of air pollution and airborne particles. Access to outdoor space for people in hospitals, clinics, and other health facilities has been studied and shown to improve recovery and have direct links to better health (Hopkins & Goodwin, 2011). Green roofs and walls can also reduce heat strokes and heat related deaths by managing and lowering urban temperatures (Hopkins & Goodwin, 2011). Better health, more oxygen, and better moods all lead to improved productivity of people which can be achieved with these systems.

Along with people's physical interaction with green areas, the visual interaction of people with nature reduces stress and improves illness recovery (Hopkins & Goodwin, 2011). In the long term, these benefits could have a large effect on the health of people in urban areas and create monetary savings for the health care system.

The final benefit of these systems that will be analyzed is the aesthetic benefit. Public roofs and walls can be viewed and interacted with by all types of people who live in the city. These aesthetic benefits can improve moods and overall well-being of people which can, in turn, be a health benefit as well. Better health, more oxygen, and better moods all lead to improved productivity of people which can be achieved with these systems. (Hopkins & Goodwin, 2011). Green roofs and walls can be considered urban art by adding color, texture, and beauty to urban areas. All of these aesthetic benefits give green roofs and walls a dual purpose of increasing sustainability while adding beauty to cities (Hopkins & Goodwin, 2011).

IMPLEMENTING GREEN ROOFS AND WALLS

There are many steps to implementing a green roof. Proper waterproofing and materials are crucial to a green roofs success. Waterproofing lasts about ten to twenty years, but most green roofs can be maintained for up to fifty years (Berardi et al., 2014). This long life helps ensure the economic feasibility of green roofs because of cost savings over time. Properly built green roofs can be less expensive than a regular roof when energy savings are incorporated, as conventional roofs need to be replaced every fifteen years (Architek, n.d.). Costs vary greatly, but an extensive green roof with 100mm of growing medium is commonly in the range of $13 to $16 per square foot, including installation and plants (Architek, n.d.). Implementing a green wall requires similar considerations as a green roof. When implemented properly they also have up to a fifty-year life span. Initial installation, maintenance, and final disposal are the main costs. While different forms of green walls have different costs, it is about $95 to $125 per square foot for material and installation (Architek,n.d.). While the initial cost of these systems is quite high, the energy savings and other benefits over time can compensate for the initial cost (Architek, n.d.). These savings will be analyzed in the later case studies.

THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

The United Nations Sustainable Development Goals relate well to this topic and many of the goals can be better and faster achieved if these systems are properly and extensively implemented. Goal 3 aims to "ensure healthy lives and promote well-being for all at all ages" (United Nations, 2016). The Goal states, "in 2012, household and ambient air pollution resulted in some 6.5 million deaths" (United Nations, 2016). The implementation of living architecture can greatly reduce household and ambient air pollution to reduce annual deaths.

Goal 11 aims "to make cities and human settlements inclusive, safe, resilient, and sustainable" (United Nations, 2016). This goal states "For every 10 percent increase in sprawl, there is a 5.7 percent increase in per capita carbon dioxide emissions and a 9.6 percent increase in per capita hazardous pollution" (United Nations, 2016). Furthermore, more the goal states, "In 2014, around half the global urban population was exposed to air pollution levels at least 2.5 times higher than maximum standards set by the World Health Organization" (United Nations, 2016). Green roofs and walls can greatly decrease carbon dioxide emissions and increase oxygen in cities and lower air pollution" (United Nations, 2016). They can also make cities and human settlements inclusive, safe, resilient, sustainable, and reduce the impact of increasing urban sprawl.

Goal 13 aims "to take urgent action to combat climate change and minimize its disruptions" (United Nations, 2016). It seeks to reduce carbon and greenhouse gas emissions through the implementation of sustainable passageways. Green roofs and walls reduce these emissions and release oxygen into urban areas reducing climate change.

Finally, Goal 15 aims "to take urgent action to combat climate change and its impacts" (United Nations, 2016). This goal looks at maintaining and improving forests sustainability and reducing desertification and degradation of natural habitats and of biodiversity. Green roofs and walls lower urban temperatures and sustain and grow urban ecosystems. They preserve natural diversity and ecosystems, manage forest sustainability, restore degraded natural land, and halt biodiversity loss of species that are sliding towards extinction, assisting in achieving many of these goals. All of these goals can be better and more efficiently achieved if green roofs and walls are extensively implemented in urban areas.

CASE STUDIES

Two case studies will be analyzed in this paper. First, a case study in Toronto, Canada will be examined followed by a case study from Adelaide, Australia. These two studies were chosen to analyze the success of these systems in very different climates and to discuss different functions of green roofs. The Toronto study analyzes the energy savings for a building and which type of green roof best achieves these savings, and the Adelaide study focuses on how stormwater can be managed through different types of green roofs.

Case Study: Toronto, Canada

Toronto is a unique city in Canada with regards to green roofs. In 2009 the City of Toronto adopted the Green Roof By-Law, which requires every building that has a floor area greater than 2000 square meters to build a green roof (Berardi, 2016). Since this was implemented in 2010, 196,000 square meters of green roofs have been built. The cities green roof surface is around 232,000 square meters and another 200,000 square meters of roofs were approved at the end of 2015 (Berardi, 2016). The Toronto Eco-Roof Program guarantees a $75 cash incentive for each square meter of green roof built for existing roofs and new roofs (Berardi, 2016). Toronto has extremely cold temperatures but also rising heat in the summer months. There are 120 heat related deaths estimated in Toronto each year and that number has been expected to double by 2050 (Berardi, 2016). Green roofs can lower urban temperatures and reduce these fatalities. The case study done at Ryerson University study found that there are 50 million square meters of roofs available for green roof installation. If this area was covered it could save the city $37 million dollars each year in energy cost savings. Furthermore, there would be energy savings of 4.15 kilowatt hours per square meter which would result in another twenty-one million dollars in savings for building owners (Berardi, 2016). These savings would be a result of better thermal insulation but also the mitigation of local microclimate temperatures.

The Toronto study that will be discussed was done at Kerr Hall at Ryerson University, where four green roofs were installed on the building. Two were built with 15cm deep soil and two with 30cm deep soil (Berardi, 2016). The green roofs on this building decreased the energy use intensity or EUI by 5.8 kilowatt hours per square meter, and there were heating savings of 9 percent and cooling savings of 4 percent. The overall energy savings of 3 percent resulted in $20,000 dollars each year (Berardi, 2016). The greatest benefits and the lowest need for heating and cooling were seen on the top level of the building and little benefits were seen on the pedestrian level. There were greater heating and cooling savings from the deeper green roofs and these benefits were seen year round (Berardi, 2016). This study further shows how green roofs are extremely successful in colder climates and can have great cost and energy savings for buildings.

Case Study: Adelaide, Australia

Green spaces in Australia have greatly reduced because of construction of roads, highways, paving, and roofs. There has been widespread urban construction in Australia that absorbs heat and not water, and this has greatly changed the water absorption of the land (Razzaghmanesh, Beecham, and Kazemi, 2014). Adelaide is the capital of the driest state in Australia and has a Mediterranean climate; this gives it mild wet winters, and hot dry summers (Razzaghmanesh et al., 2014). Adelaide is dealing with urban heat increases and water scarcity (Razzaghmanesh et al., 2014). Green roofs and walls can help these issues.

This study looked at the improvement of the quality of water runoff. It used intensive and extensive green roofs similar to the previous study. Four large-scale green roofs were built on the top of a twenty-two story building that was monitored from September 2011 to June 2012 (Razzaghmanesh et al., 2014). They were all designed with a free drainage system, which allows the fastest drainage of water with the implementation of pipes in the ground. The green roofs were all 14.4 square meters with two intensive and two extensive that were built with different materials One of each depth was built with crushed brick, scoria (a volcanic rock), and coir fiber, combined with composted organic, and the other two with scoria, pine bark, and hydro cell flakes (Razzaghmanesh et al., 2014). Through the entire study sixty water samples from all the rainfall were collected (Razzaghmanesh et al., 2014). The first combination of materials with the brick, scoria, and organic matter showed higher turbidity making the water a darker color and with more solids dissolved in it. The total amount of solids dissolved in the water was greatly lessened over time in the deeper extensive roofs because the water had a greater filter time (Razzaghmanesh et al., 2014). Overall, the extensive green roofs were better at removing pollutants than the intensive roofs. The water, in the end, was not up to the standards for human consumption, but it was suitable for urban irrigation and non-potable purposes such as toilet flushing. However, the water was cleaner and less polluted than collected rainwater that is not filtered (Razzaghmanesh et al., 2014). These systems can be used to reduce pollutants, metals, and solids dissolved in urban water runoff, which overall can lead to less pollution in urban environments.

CONCLUSION

There are many environmental, ecological, health, and aesthetic benefits of green roofs and walls. These health, psychological, ecological, and environmental benefits can be achieved in cities all over the world especially in cooler climates. Multiple of the United Nations Sustainable Development Goals can be more rapidly met with the implementation of these systems. As discussed in the two case studies, pollution can be reduced and energy can be saved with these systems creating more sustainable cities. Sustainable design innovation is essential for the continued growth and development of the world while caring for the environment, health, and natural resources.

REFERENCES

Arch Daily. (Photograph). (2011). *Concrete Wall Block – Vedura.* [Digital Image]. Retrieved from: http://www.archdaily.com/catalog/us/products/944/concrete-wall-block-verdura-soil-retention (Accessed Dec 4, 2016)

Architek (n.d.). Green Roofs. Retrieved on December 22, 2016 from http://architek.com/products/green-roofs.

Berardi, U. (2016). The outdoor microclimate benefits and energy saving resulting from green roofs retrofits. *Energy & Buildings*, 121, 217-229. doi:10.1016/j.enbuild.2016.03.021

Berardi, U., Ghaffarian Hoseini, A., & Ghaffarian Hoseini, A. (2014). State-of-the-art analysis of the environmental benefits of green roofs. *Applied Energy*, 115, 411-428. doi:10.1016/j.apenergy.2013.10.047

Dilnot, C. (2011). Sustainability as a project of history. *Design Philosophy Papers*, (2).

Dusty Gedge. (Photograph) *Biodiverse Green Roof.* [Digital Image]. Bug Life. Retrieved from: https://www.buglife.org.uk/campaigns-and-our-work/habitat-projects/living-roofs

Francis, R. (2011). Wall ecology: a frontier for urban biodiversity and ecological engineering (English). *Progress In Physical Geography*, 35(1), 43-63.

Francis, R., & Lorimer, J. (2016). Urban reconciliation ecology: The potential of living roofs and walls. *Journal Of Environmental Management*, 92(6), 1429-1437.

Green Roof Technology. (Photograph). (2013). *Extensive Green Roof.* [Digital Image]. Green Roof Technology. Retrieved from: http://www.greenrooftechnology.com/green-roof blog/extensive_verses_intensive_-_what_would_you_choose

Green Screen. (Photograph). (2015). *Green Façade/Green Wall.* [Digital Image]. Green Screen. Retrieved from: http://greenscreen.com/how-to-prune-a-wall-mounted-green-facadegreen-wall/

Green Screen. (Photograph). (2015). *Green Façade/Green Wall.* [Digital Image]. Green Screen. Retrieved from: http://greenscreen.com/how-to-prune-a-wall-mounted-green-facadegreen-wall/

High View Creations. (Photograph). (2015). *Intensive Green Roof.* [Digital Image]. Green Roof Technology. Retrieved from: http://www.greenrooftechnology.com/green-roof-blog/extensive_verses_intensive_-_what_would_you_choose

Hopkins, G., & Goodwin, C. (2011). *Living Architecture: Green Roofs and Walls*. Collingwood, Vic.: CSIRO Pub.

Madre, F., Vergnes, A., Machon, N., & Clergeau, P. (2014). Green roofs as habitats for wild plant species in urban landscapes: first insights from a large-scale sampling. *Landscape and urban Planning*, *122*, 100-107.

Perini, K., & Rosasco, P. (2013). Cost–benefit analysis for green façades and living wall systems. *Building & Environment*, 70, 110-121. doi:10.1016/j.buildenv.2013.08.012

Razzaghmanesh, M., Beecham, S., & Kazemi, F. (2014). Impact of green roofs on stormwater quality in a South Australian urban environment. *Science Of The Total Environment*, 470-471, 651-659. doi:10.1016/j.scitotenv.2013.10.047

Thomas Jefferson School of Law. (Photograph). (2011). *The Living Wall.* [Digital Image]. Thomas Jefferson School of Law. Retrieved from: http://www.tjsl.edu/news-media.edu

Thuring, C., & Grant, G. (2016). The biodiversity of temperate extensive green roofs – a review of research and practice. *Israel Journal Of Ecology & Evolution*, 62(1/2), 44-57. doi:10.1080/15659801.2015.1091190

UK Company National Grid's Car Park. (Photograph) (2011). *Europe's Largest Green Wall.* [Digital Image]. ABC. Available from: http://www.abc.net.au/radionational/programs/blueprintforliving/segment/6417820

United Nations. (2016). Sustainable Development Goals. Retrieved on December 22, 2016 from https://sustainabledevelopment.un.org/sdgs.

World Green Infrastructure Network. (Photograph) (2011). *Green Walls/Living Walls Archive.* [Digital Image]. WGIN. Retrieved from: http://www.worldgreenroof.org/Photos-Images-Green-walls-archive-2011.html

APPENDIX A

Figure 1: Intensive Roof

Figure 2: Extensive Roof

Figure 3: Biodiverse Roof

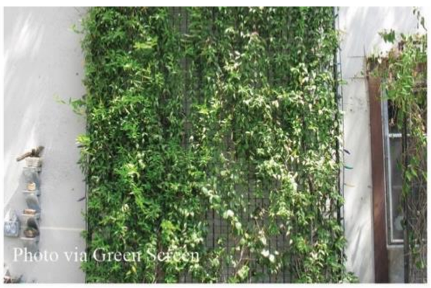

Figure 4: Green Facade

Figure 6: Hybrid Green Wall

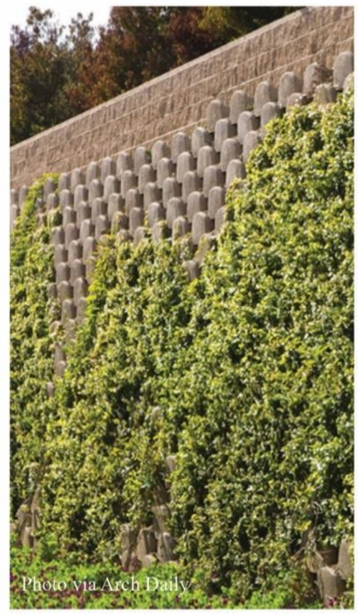

Figure 8: Landscape Green Wall

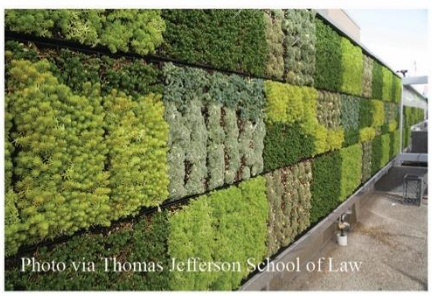

Figure 5: Green Wall

Figure 7: Spontaneous Green Wall