IMPROVING TEXAS WITH GREEN ROOF GARDENS:

A REVIEW OF GREEN ROOF GARDEN SYSTEMS

AND EVIDENCE-BASED DESIGN PROPOSAL

FOR THE CAPPA BUILDING, UTA

by

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ABSTRACT

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The University of Texas at Arlington, 2022

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Texas is home to some of the hottest summers, often reaching over 100º during the day. A few countries, like Canada and Germany, have created policies that mandated green roof garden systems for new and renovated buildings. Studies conducted by the American Society of Landscape Architects shows that green roofs can lower the temperature of a city as a whole anywhere between 0.2º and 1.4º F. The implementation of green roof gardens in Texas can aid in lowering heat islands, excessive rainwater run-off, and increase energy efficiency in buildings. With the research conducted, this project was a creative design proposal for the construction of a green roof garden for the CAPPA Building at the University of Texas at Arlington, in hopes of beginning a more sustainable change.

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CHAPTER 1

INTRODUCTION

Rapid urbanization has depended on an unprecedented amount of concrete, asphalt, and tar to create our cityscapes. These materials, used for buildings, roadways, and other infrastructure, cause extreme elevations of temperature, an excess amount of energy use, and pollution in our water and air. As an aspiring architect, who is concerned about the future and climate change, sustainable design is a central factor in the curriculum and understanding of the profession. On a personal level, Raul's sister's passion for environmental sustainability influenced him to pursue his own Environmental and Sustainability Studies minor. Her work for the city of Pflugerville, Texas helps the city become cleaner and more environmentally friendly. In the spring of 2021, Professor Ed Nelson taught the Architecture & Environment course at UTA, in which, truly opened up Raul's eyes in how sustainable design can benefit the people, the planet, and even have economic benefits for those who implement the designs in their buildings. Finally, the American Institute of Architects (AIA) recognizes "Four Ways that Architects Can Fight Climate Change," stating that "Buildings are a major contributor to global warming, and we can make a huge impact by changing how we practice architecture" (Melton, 2018). The senior project is therefore dedicated to understanding the potential benefit of retrofitting existing buildings with green roofs to reduce excess heat, eliminate unnecessary run off, and reduce emissions by reducing power consumption. Raul will pursue this study by looking specifically at one building on the UTA campus, the CAPPA building, as a case study that will let him understand the retrofitting process, as well as the benefits and challenges of green roof retrofits as a solution to climate change. Ultimately through his design proposal he hopes to raise awareness of green roofs and to make the case that they can begin to solve the climate crisis one small step at a time.

CHAPTER 2

LITERATURE REVIEW

2.1 Green Roof Retrofit

Sara Wilkinson and Tim Dixon state there are three layers that contribute to urban heat islands in their book, *Green Roof Retrofit: Building Urban Resilience.* The boundary layer and canopy layer both refer the rising temperature of the urban atmosphere, whereas the urban canopy layer refers to the ground level up to the mean height of the surrounding buildings. It has been anticipated that with the rate of which global warming is occurring, the intensity and frequency of heat waves will only increase. The elderly, young, and ill can be at a serious risk to these high temperatures in urban areas. Meteorological records for Shanghai, China show the high urban temperatures in their megacities to directly correlate together with the mortality rate and shows an increase mortality rate when compared to the suburban/ rural areas. The hot and impervious surfaces draw up polluted city air, which can lead to either discomfort or death. The drawn up air is then referred to as an "urban dust-dome", which then traps even more heat within its parameter. There are four main geometric properties that affect the solar radiation exposure of a building, length, width, height and orientation. Each component affects the wind speed, pollution dispersion, and the intensity levels. (Wilkinson/ Dixon, 2016). Based on studies of current green roof garden systems, the lowered temperatures led to a lower heat transfer rate when compared to that of a conventional roof. In Chicago, IL, a green roof building with non-vegetated neighboring buildings had a drastic difference in temperatures. The conventional roofing systems reached 165° F, compared to that of 91° to 118° F from the green roof surface. A similar study was conducted in Florida, and it was observed to have a temperature difference of 80° F. (EPA, 2014). While heat reduction is important, storm water retention also plays an important role in green roof gardens. Researchers have concluded based on a sample of several roof garden systems that the average retention of storm water ranges from 30% to 100%. Performance of these green roofs rely on 3 actions: absorption by the garden, storage of the water, and evapotranspiration. (Wilkinson/ Dixon, 2016). With these actions in place, there are several sub-factors that can control each outcome, for example, the type of vegetation can affect water retention between 40-60%.

2.2 Heat Islands

The EPA states that structures such as buildings, roads, and infrastructural materials absorb and reflect the sun's heat at a much higher percentage than natural or sustainable landscapes. Highly concentrated areas (cities) become "islands" of intensely heated areas compared to the outlying areas. The heat islands can emerge at any time of the day and any time of the year in all sized areas. ("Heat Island Effect" – EPA, 2021). These heat islands are mainly caused through artificially constructed environments. The rapid sprawl of large cities have altered the natural landscape, removing natural vegetation, bodies of water, and trees in preparation for new subdivisions, highways, strip malls, residential units, and business developments that pave the land and create a high proportion of hardscape. (Norton et. al, 2013).

Hardscapes, such as roofs, sidewalks, parking structures and roads all are dry and impervious, providing little to no shade or have the moisture retention like that of natural landscape features, i.e., grass, trees, ponds, etc. Conventional asphalt roofing and pavement materials absorb more of the sun's heat than any other material. (Norton et. al, 2013). These man-made materials, while convenient and easy to use, absorb much more heat, and at night, the structures retain the heat and expel it at a much lower rate, thus continuing the heat island effect much after the sun has set. (Norton et. al, 2013).

Urban geometry and layout of the city as a whole also play a role in creating heat islands. According to the EPA, "the dimensions and spacing of buildings within a city influence wind flow and urban materials' ability to absorb and release solar energy" ("Heat Island Effect" – EPA, 2021). The density of various structures create an unavoidable thermal massing which cannot release the heat at a steady pace. Narrow streets and tall buildings create "urban canyons" that block the wind flow that could bring needed cooling effects. Not only does the city itself retain the solar energy, but the heat generated by human activities (i.e., vehicles, air-conditioning units, etc.) contributes to the mass heat island effects ("Heat Island Effect" – EPA, 2021). With the continuous population growth, global warming, and urban sprawl, human interaction within a city will only increase. Heat islands affect the community as a whole, causing several health problems. The increased temperatures can lead to respiratory difficulties, rapid heat exhaustion, and general discomfort.

According to researcher Muhammad Shafique in an article published in the *Review of Renewable and Sustainable Energy Reviews*, the implementation of green roof systems can reduce surface temperature and improve overall thermal comfort. The additional thermal resistance allows for the building to cool and release heat at a much faster and efficient pace. (Shafique, 2018). A modeling study conducted by the American Society of Landscape Architects showed that if 50% of the buildings in downtown Toronto, Canada added a green roof system, the entire city could cool off by 0.2 to 1.4º F. (Professional Practice, 2009). While retrofitting a single building would seem only a drop in the bucket, this study shows that collective action, if continued across multiple buildings and in every city, could have an effect on decreasing global temperature, thus aiding in the fight against climate change.

Additional studies support the idea of retrofitting existing buildings to combat the heat island effect locally, producing global change. The University of Central Florida found that the average traditional roof can heat up to 130F, but a green roof will have a maximum average temperature of 91F. A green roof costing near $460,000 can save the building $200,000 in its lifetime; two-thirds of which, come from the reduced energy usage. (Professional Practice, 2009).

2.3 Roof Run Off and Water Quality

You The use of impervious or non-porous materials for rooves, not only heats up cities but also contributes to a polluted water supply. Standard roofing, whether it is commercial or residential, does not absorb any rainwater runoff, rather it redirects it either to the lawn, storm drains, or the streets. Minor pollutants accumulate in the water supply, leading to poor water quality. Pollutants mainly include anti-freeze, oils, grease, fertilizers, pesticides, and other chemicals people have leaked into the environment. Improper rainwater runoff prevention can potentially lead to costly harm to the people and the environment. (DOEE, 2022)

In Figure 1, the down pour overwhelms the capacity of the sewer system, causing untreated water to be dumped into the river. Sediment from run off can lead to clogs in the waterway and cause aquatic species to get sick or die. The polluted water will impair any recreational use that may be a valuable asset to the city. Water cleanliness may seem like a simple problem, with the solution of “let’s just clean and filter the water”, however with several known and unknown sources of pollution, prevention or reducing the problem becomes very difficult. The Department of Energy and Environment states that nonpoint source pollution cannot be traced back to a singular source, but it is a diffusion of multiple sources. (DOEE, 2022).

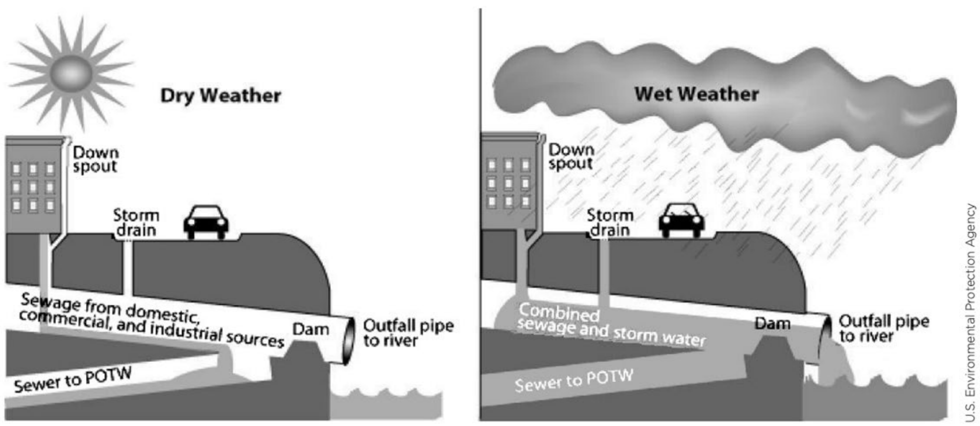

Figure 2.1: Sewage Overflow Diagram (Odefey, 2012)

While complete prevention of roof run off is nearly impossible, reducing the problems of traditional roofing is possible with a simple installation of a green roof garden. Shafique states that green roof systems are the best solution for storm water run-off. The vegetation and absorbent substrate layering allow for more water to be collected and utilized for the vegetation/ plants. The high volume of water stored drastically decreases the chances of flash floods occurring in urban areas. Water retention varies on several factors, such as soil type, depth, and location. Table 1 below demonstrates the average water retention (%) in different cities/ countries. (Shafique, 2018).

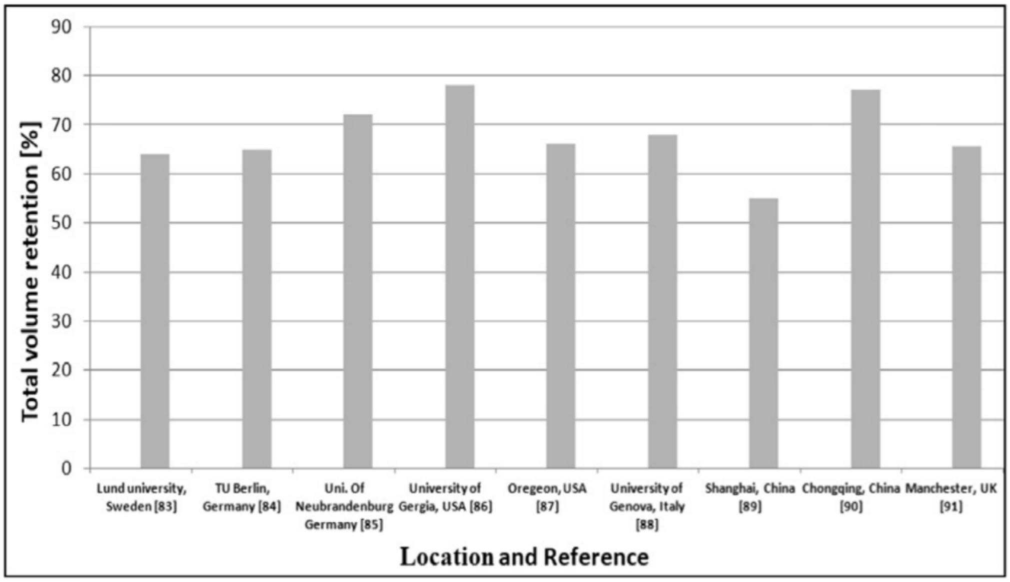

Table 2.1: Average Water Retention in Different Cities, Countries (Shafique, 2018)

A published study in 2000 by the Journal of Climate found that the cost of flood damage has been increasing rapidly, from $1 billion in the 1940s to well over $5 billion in the 1990s. By 2001, damages rose up to $7.1 billion nationally. Cities initially thought that the solution of reducing storm water run-off was to increase the rate of which water ran off from the properties into the rivers, storm drains or streets. However, that became an issue when the water reached its "destination" and flooding inevitably occurred. Scientists have concluded, for example, that impervious cover, including sidewalks, streets, and rooves, was the major contributor to extreme flooding in Houston during Hurricane Harvey in 2017 and recommend that "The effect of urbanization on storm-induced extreme precipitation and flooding should be more explicitly included in global climate models" (Zhang et al, 2018).

The implementation of green roof systems can reduce localized flooding and significantly reduce negative downstream impacts. (Odefey, 2012). Alexandra Rice stated in her journal the reduction of flooding damages also means the cost of repairs will be significantly less, as well as overall water treatments. (Rice, 2012). The cost of conventional storm water systems averages between $40 to $50 per linear foot, but with green infrastructure, savings can go up to $230,000. The American Society of Landscape Architects conducted 479 case studies of various project types and green infrastructure types; they found that green infrastructure, whether it is retrofitted, new development, or redeveloped, can be less costly. A properly built/ designed green roof system with functional components can reduce built capital costs (equipment), external costs, operation costs, and infrastructural replacement costs. A case study conducted at Episcopal High School in Baton Rouge, LA, showed that they had a severe flooding issue, with an estimated repair cost of $500,000. BROWN+DANOS Land Design, Inc. designed and constructed a few bio swales and a rain garden for the 5 acre land with the capacity to absorb 1 inch of water. The total cost of the project was $110,000, drastically cheaper than the alternative non-sustainable solution, plus flooding in the area was completely eliminated. (Odefey, 2012).

2.4 Increasing Overall Building Efficiency

National Research Council of Canada found that with the increased insulation of the green roof, overall energy needed to keep the warmth in during the winter, and the heat out during the summer is vastly less than a traditional roof. (Figure 3) The daily energy demand can be reduced by 75% with an extensive green roof garden. Green roofs can provide an extensive list of benefits, in which, the people, the planet and even the economy can gain from.

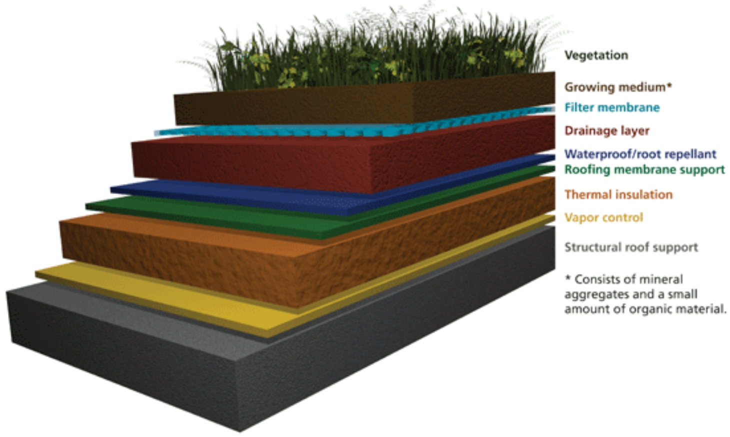

Figure 2.2: Green Roof Garden Section (NPS, 2018)

2.5 Additional Benefits

Whether it is the increased fire retardation, reduction of electromagnetic radiation, noise reduction, and even marketing benefits (i.e., sales, lease outs, property value, etc.), by increasing the roof's efficiency, its lifespan can double or even triple in length. (Malik, 2004). Sustainable South Bronx conducted a study with black tar roofs on a 90º F day, in which, they can reach up to temperatures as high as 175º F, causing damage. (Professional Practice, 2009).

With the extensive list of why green roofs should be implemented on every eligible building, there are many push factors that investors fear, and thus deny the opportunity to become sustainable and efficient. Shafique's reviews state that the initial costs of designing and construction a green roof garden add a high additional cost to a building. (Shafique, 2018). A cost average of green roof gardens conducted by Green Roofs for Healthy Cities says that based on the extent and functional ability can cost anywhere between $10 to $24 per square foot. (Malik, 2004). Maintenance costs range drastically varying on which level of green roof system a building designer opts for; and the limited research does not help on determining costs. If properly designed, a green roof can act as a self-sustaining ecosystem, in which, will require little human interaction, but then there are green roofs who’s purpose, whilst still for its sustainable benefits, act as an aesthetic relief for the hardscape city life.

CHAPTER 3

EVIDENCE-BASED DESIGN PROPOSAL

The proposed green roof garden will take place in the northern section of the CAPPA roof. The main goal is to create a more sustainable roofing system for the university, as well as build a calming, stress relief environment for the students and faculty. While there is a garden on the ground level, this will be a more intimate space, away from passerby's and traffic. The aesthetics will allow guests to be surrounded by native Texas plant species and a hardscape zone for either leisure use or classroom use. The CAPPA roof is a solid flat roof with no elevation changes. During the design process, the CAPPA building was going under a new roof construction, in which a thermoplastic polyolefin membrane (cool roof) was placed, as seen in figure 6 & 7. The design is under the presumption of the pre-existing roof being still gravel based. Research conducted by Professor Hopman showed the best plants to use and which to stay away from. Based on his findings, plants were chosen with the highest benefits and most aesthetically pleasing; based on either colors or growth patterns. Plants included the following species.

Figure 3.1: Chosen Garden Plants for CAPPA, Four Nerve Daisy: Blooms yellow flowers 12 months of the year and has survived all tests.

Figure 3.2: Chosen Garden Plants for CAPPA, Russian Sage: Semi-large bushy perennial with long purple flowers can withstand the hottest Texas summers.

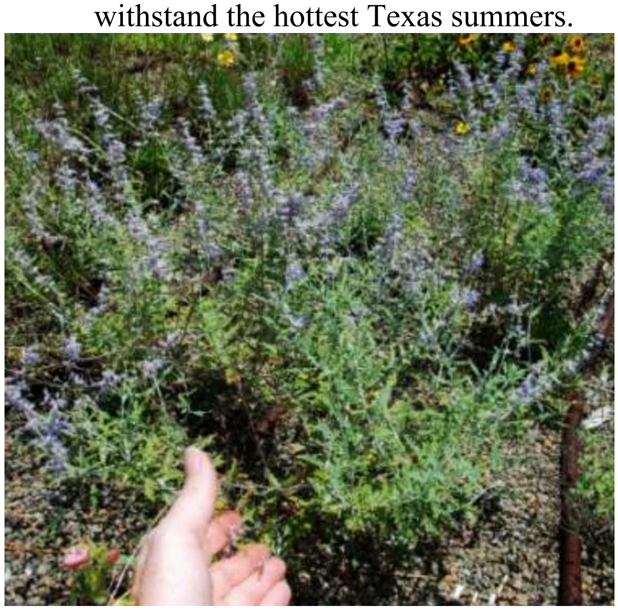

Figure 3.3: Chosen Garden Plants for CAPPA, Blackfoot Daisy: Blooms between March and November with small white flowers.

Figure 3.4: Chosen Garden Plants for CAPPA, Red Yucca: Been seen as most reliable in the studies and turns a slight purple come wintertime.

Figure 3.5: Chosen Garden Plants for CAPPA,
Dove Weed, Prairie Tea: Proved to be a true annual during the trials. Provides food for birds and butterflies and fills in bare areas.

Figure 3.6: Chosen Garden Plants for CAPPA,
Box Bud Primrose, Sundrops: Useful for an extensive roof garden and thrives in hot gravely conditions.

All photos above credited to Professor Hopman

The first step in the design process was determining a location for the garden. The northern section had the most open square footage without any major obstacles that would limit a garden. The proposed green space, as seen in figure 4, is an estimated 4,900 sqft. A large roof garden is optimal for increasing the sustainability of the building, as well as allowing for more students or faculty to enjoy the space. The concrete hardscape (approx. 1,400 sqft) is designated for stationary guests who wish to stay on the roof for longer periods of times or if classes would like a more casual space, hence the seating and tables as seen in figure 5.

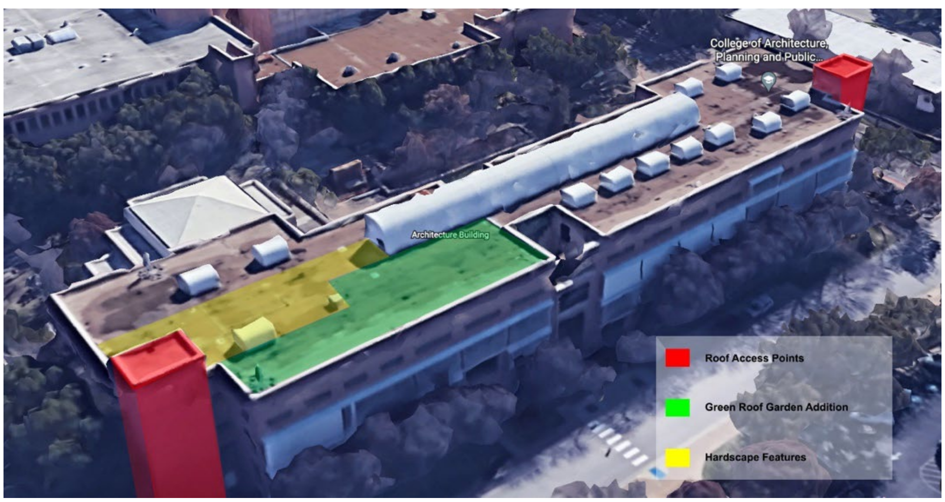

Figure 3.7: Zoning Plan for the CAPPA Building

Figure 3.8: Conceptual Plan for the CAPPA Building

The next step in the design process was the green space itself. A gravel path was placed through the garden as a small guide through the garden with a patch at the end for those who would like to spend time inside the garden. Gravel is utilized as it can be used as a protectant from rough weather, UV rays and the Box Bud Primrose flowers thrive in those conditions.

Figure 3.9: Depiction New Roof for CAPPA Building (A)

Figure 3.10: Depiction of New Roof for CAPPA Building (B)

Figure 3.11: Rendering for CAPPA Building Garden

CHAPTER 4

CONCLUSION

After reflecting on the research and the conceptual design, the conclusion is that although it will not be feasible for the CAPPA building, there are still other contenders at the university. With further review, the MAC, or Maverick Activity Center, would be a close contender that will be suitable for a green roof garden. Considering the higher amount of foot traffic and adjacency to the CAPPA Building, the garden's life span and usage will be much greater than that of the CAPPA Building. The ideology of the implementation of this project strive to bring more awareness to not only the benefits of the green roof garden, but also the problems we face as a growing city. CAPPA is home to the future architects, planning and landscape students, each one will be able to visit and learn for the green roof garden system and can use it as a precedent study for their future endeavors. The CAPPA building has the potential to become more sustainable and become a leading example for the benefits a green roof garden system can provide. In terms of UTA, the building can become more efficient energy wise, reducing the cost of operation. While UTA is already distinguished for its diverse community, the addition of environmental and sustainable measures will bring more fame to our name.

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BIOGRAPHICAL INFORMATION

Raul Morales is the son of immigrant parents, whose father made the journey from Mexico and mother, from Bolivia. Pursuing a higher education was always expected from him, and his sisters. His natural talent for drawing/design and mathematics made architecture seem like the perfect career plan, thus began his journey. With the influence of his sister, Carolina Morales, graduate of UT and Environmental Scientist, he decided to pursue a minor in Environmental and Sustainable Studies to ensure the future of architecture is designed with efficiency and sustainability in mind. Throughout Raul's college career, he had entered in numerous architectural design competitions, winning Editor's Choice Award and Commendations. With each competition and project worked on, Raul's interest in sustainable design only grew, and so, with his Honors Bachelor of Science in Architecture and minor in ESS, he wishes to pursue his sustainable designs into residential and/or landscape architecture.