J. Appl. Environ. Biol. Sci., 7(6)68-75, 2017

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Investigation of Sustainability through Green Roofs in Arid and Semi- Arid Areas

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Received: October 30, 2016
Accepted: March 26, 2017

ABSTRACT

Green roofs not only can change the balance of surface energy, but also help mitigate the heat islands of urban areas. But, because of evapotranspiration, the green roofs cooling mainly relies on the conditions of climate, the type of vegetation and density. The purpose of this paper is to review terms of sustainability in green roofs particularly in arid and semi-arid areas. This research provides information on environmental, economic and social benefits of green roofs and their technical aspects based on conditions in arid areas. In the hot and dry climate, green roofs need to resist during heat stresses. Selecting appropriate combinations of green roof layers and type of vegetable can increase the performance of these water-sensitive urban design structures. These green roofs mainly use natural precipitation in the form of rainfall and snow as a source of water supply. However, in arid and semi-arid regions supplementary irrigation water is often also required, depending on the type of plants and green roof materials. Though several experiments have been done which investigate the technical aspects of green roofs, more experiments are needed to achieve a comprehensive overview of green roofs implementation in arid and semi-arid areas.
KEY WORDS: Waste volumes; Heat islands; Storm water; Drought periods; Energy consumption

INTRODUCTION

Buildings construction and maintenance are associated with energy Approximately 40% of worldwide energy use are associated with the construction and maintenance of buildings [1]. Temperatures in rural areas are typically lower than in city areas, the urban heat island [2]. In the period of heat waves, the stress of heat in urban areas is oftentimes aggravated which will be more reiterated and drastic because of the greenhouse gas emissions augmentation. The surface energy alterations and radiation equipoise in constructing areas can be the reasons of elevated air temperatures. The thermal and aerodynamic features of cities are different from natural environments. Cities often have waterproof surfaces, retaining less amount of water, and they possess lower albedo, absorbing more radiation from the sun. In order to enhance the urban climate conditions and the quality of air, numerous cities have applied some programs to augment the vegetation of their urban areas[3, 4]. An organized investigation of tentative evidence of urban area's vegetation cooling effects was done by some researchers, deducing that urban vegetated areas, urban parks, are approximately 1 °C cooled that other areas, constructed areas, in cities. The two main reasons were trees shading effects and augmented evapotranspiration, ET. Further investigation is necessary to completely implement urban greening initiatives [3].

Green roofs are part of the green infrastructure which uses vegetation, soil and water to develop healthier urban environments [5]. Energy conservation, the urban island effect mitigation, attenuation of noise, provision of biodiversity, habitat and management of urban storm water are all results of green roofs implementation [6]. Green roofs consist of some layers, including waterproofing, drainage and substrate layers in which plants are grown. The depth of substrate, oftentimes <20 cm, is limited by weight loading limitations on constructions. Therefore, plant growth and durability are two main parameters that are mainly affected because in green roofs the available water undulates drastically between rainfalls[7, 8]. At last, it is paramount importance to choose the proper plant species to survive during drought periods, especially in semi-arid and arid areas. [9], especially in hot and dry climates. Therefore, the aim of this work is an investigation of sustainability through green roofs in arid and semi- arid areas.

1- LITERATURE REVIEW

For centuries, different countries have used several types of green roofs, having benefits in different climatic conditions and building characteristics [10]. The first applications of green roofs date back to the fifth century in

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Babylon's hanging gardens[10]. Another implementation of green roofs was in the ziggurats of ancient Mesopotamia. Roman architecture also used green roofs, as roof gardens like the Mysteries Villa [11]. Also, vernacular architecture in different countries has been affected by green roofs, Norway architecture used green roofs in order to enhance the thermal insulation [12]. Utilization of the green roofs during the modern age was rare. Passing this period, Swiss architect Le Corbusier, including the green roofs in the five points of modern architecture, started to use green roofs in the twentieth century [13]. At the same time, green roofs were introduced by American organic architects as a method of integrating buildings and nature. More intensive green roofs implementations were begun in German-speaking countries in the 1970s [14]. In the same years, green roofs gained popularity in France and Switzerland[14]. Some utilizations of green roofs in North America have then emerged, especially in Portland. Japan has indicated green roofs as a prime technology to decrease the urban heat island and promote sustainable buildings in last years. The recent attention towards green roofs is presented by dedicated conferences, associations, and competitions worldwide. Green roofs can be representative of a noteworthy solution, eliminating the lack of urbanized areas green space issue [15]. Green roofs can be as credible options to replace the lost green areas in modern cities, and support life behaviors within nature if they are efficiently designed and integrated [16]. However, the most regular advantage for which they are advanced and adopted is the energy-related performance of green roofs [17]. Green roofs substantially prevent the infiltration of solar heat to the covered building components [18]. Dunnet et al. claimed that ''they improve the thermal performance of a building through shading, insulation, and thermal mass'' [14]. Likewise, Saiz et al. noted that ''the key property of a green roof is its low solar absorption'' [19]. Green roofs energy-related interpretations coexist with their significance as a media for the ecological biodiversity development, with enhanced air quality and improved landscapes [19]. Several studies addressed the advantages of green roofs as for urban hydrology, storm water quality, and ecological habitats for wildlife [18]. In particular, several studies have concentrated on the green roofs ability to mitigate water runoff quantity, improving its quality simultaneously[8].

2- The advantages of Green roofs

In this section, economic, social and environmental advantages of green roofs are discussed in details.

2-1 Environmental benefits

Biodiversity of Habitat(Creation and Protection):

The ecologic systems health has been influenced by urban sprawl, interrupting the migration passages and controlling the natural environments supplies and vegetation. As a link, green roofs can be used for insects and bird's migration, using the urban environment as steppingstones for wildlife movement [14].The biodiversity potential relies on building altitude, food supply, height and species of plant and surface alterations.

Temperature Regulation (Heat Island Effect Reduction):

Standard roofs, buildings and parking lots, as inorganic surfaces, cover a city environment, corresponding to ambient temperature increase. This phenomenon is known as the urban heat island, UHI, effect. There are some reasons why natural cooling by wind is prevented and evapotranspiration is being done including impermeable surfaces, tall buildings and lack of vegetation. So, cities temperatures rise and they maintain their warmer atmosphere longer than the surrounding environment, cause some negative effects in urban environments because of extreme heat. Moreover, ground level ozone is formed by gaseous emissions chemical actions caused by increased temperature. This situation causes respiratory and cardiac irritation. The green roofs application can reduce UHI by using vegetation in some of the urban areas surfaces. Temperatures can be reduced by a less absorbing surface covering for the roofs and evapotranspiration application. Considerable economic gains, the reduction in energy costs, can be achieved by green roof coverage [20, 8]. Some design factors can lower UHI including square footage, type of plant, growing medium depth and composition and green roof moisture.

Improvement of Air Quality:

Increased particulates and air contaminants caused by cars, building emissions, industrial pollutants and elevated ambient temperatures result in poor air quality. In western states of USA, cities are suffering from temperature inversions, trapped polluted air causes remarkable reduction in air quality. One of the methods to alleviate this situation is application of green roofs. Green roofs make building more efficient, produce less emissions, reduce the air temperature on the roofs in summer and absorb particulates [21]. The contribution of green roofs to enhance the air quality depends on plant type, surface of leaf and tissue of leaf in order to capture air pollutants by vegetation.

Storm Water Management:

The quality and volume of storm water run-off depends on impermeable surfaces amount in an urban environment. A larger volume of storm water is sent through various management components, leading to stream, rivers and lakes, because cities have low permeable surfaces. The increased runoff volume and its frequency cause erosion and pollution in rivers, stream and lakes. Lowering and minimizing the storm water run-off [22], filtering pollutants and controlling temperature [23] can be achieved through green roofs application. Green roofs have been applied in

some sections of USA, most which are in areas with relatively high annual rainfall and humid climates. Green roofs in the semi-arid and arid areas have not yet been widely installed, although there are some green roofs in the semi-arid and arid west. More research needs to be implemented to find the best plant selection and design approach for semi-arid and arid climates.

2-2 Economic advantages

Energy Efficiency:

If roofs are Poorly insulated, warm air will escape in the winter and be absorbed in the summer. By attenuating heat flow through the roofing system, green roofs are lower the energy consumption for heating and cooling the construction [24, 25]. Investigations at the national research council of Canada have shown that heat flow through the roof can be reduced by 70% to 90% in summer time and 10% to 30% in winter time, reducing the necessary energy for space conditioning up to 75%, by implementing green roofs[26].

Durability of Prolonged Membrane:

Based on the climate, region and waterproofing membrane, a green roof can linger up to three times a traditional roof. In Germany, some green roofs have lasted up to 30-40 years more than twice the typical North American roof, 10-15 years. Green roofs lower the membrane stress, by hampering oscillations in temperature, through additionally covering the waterproofing membrane using a layer of organic and inorganic insulation. This is necessary in semi-arid and arid climates where conditions can be extreme.

Prevention of Fire:

Fire spread can be avoided using a green roof. Organic layers of matter with a low percent of moisture could be influential in avoiding the Fire spread. To lower the flammability of roofs, it is necessary to use suitable fire breaks, meeting the local fire codes. Furthermore, a seasonal burn is essential for some green roofs to develop the plants on them. The procedure should be implemented with local fire department observation.

Creation of Local Job:

Between the years of 2004-2005, employment, manufacturing, installation, design and maintenance of green roofs, rose by over 80%. This quickly emerging industry will need and create jobs not only within the profession, but also from the next job creation of space application in productive ways including recreational facilities and rooftop restaurants.

Meeting Regulatory Requirements for Urban Runoff Treatment:

The water that has been polluted by such contaminants including pet wastes, motor oil, pesticides etc. is called urban runoff. Areas where are covered by concrete, roof covers and asphalt are augmenting the urban runoff volume and velocity. Green roofs can be used in order to reduce the runoff speed and can help clean the water in the process. Along with the policies that are being implemented to clean and slow down water, at the starting point, green roofs can be used to meet future requirements. Ongoing investigations in order to examine the rate and efficiency at which the green roof is maintaining and cleaning the water is being done at the present time. Important factors that must be considered when designing a green roof system for water treatment are including type of plant species, growing medium depth and type and drainage system kind.

Reduce Community Resistance to New Developments:

As cites are becoming more plumb and compressed. In order to build new constructions in the urban area and avoid controversies, Green roofs can lower the objections to new development by providing fascinating views with seasonal and aesthetic worth for the area residents and business owners.

2-3 Social advantages

New Recreational and Aesthetics Space:

Green roofs help inspire a more considerate method to city arrangement by augmenting amenity and green space, motivating food production, community gardens and extending recreational and commercial spaces. The green roof application in the standard buildings creates a distinctive quality of visual significance. It has been suggested that introducing green are as in the city lowers stress and recovery time of patients, augments the values of property and has been related to a decrease in crime [27, 28].

Improved Health and Horticultural Therapy:

The availability of outdoor area and views of natural environment has confirmed to have a positive influence on human health. Researchers have found that even visual access to a natural environment causes a decrease in sick leave, stress, illness and has recovered overall health, satisfaction of job and productivity [29]. The interaction of people with a natural setting causes an augmentation in place pride and motivates physical and social activity. If individuals have a sense of place, this will act as a community building catalyst and pride. It also has been helped to reduce violence, discriminatory behavior and vandalism [27].

Blocking Electromagnetic Radiation and Noise Reduction:

Though the wireless devices and cell phone use effects on human health and the environment have not fully understood, some researchers claim such technologies may augment the rate of cancer in certain conditions [30].Green roofs have been investigated and shown to lower electromagnetic radiation up to approximately 94% [31].Green roofs can lower the noise level by 40-60 decibels, within the building. The type of plant, growing medium, thickness of the medium and plant coverage can affect the efficiency of the green roof to lower noise levels.

Urban Agriculture:

The distance between urban centers and agricultural production sites has been extended to the extent that the average distance is approximately 1350 miles [32]. Such distribution causes environmental burden, so, in order to address this problem, a new action of local production has emerged. The combination of green roofs and urban agriculture has yet to be fully understood, however the additional available area that a green roof provides for producing food should not be missed.

By joining food production in urban areas and farming facilities, the food that was produced locally can make cities be independent of the enormous food distribution model. Green roofs cannot be a replacement for farms, but can cooperate in starting a model for production of food in a small scale. Green roofs that are for producing food require little change from the costume system, but a few issues need to be noticed such as:

- The growing medium depth needs to be enough for anchoring and maintaining food plants
- Waterproofing membrane requires to be protected from periodic application of gardening instruments
- production quality and must be considered

Reduction of Waste Volumes:

If you build something which lasts for a long time, this action will be one of the main methods to lower the great amounts of waste that reach landfills every year. Green roofs last up to 2.5-3.0 times as long as traditional roofs by extending the life of the membrane, more than 50% of the necessary materials to fix the roof in its lifetime will be diverted. The efficiency of heating and cooling systems of the building will be improved because of additional insulation of the green roof [33], resulting in less repeated substitution of HVAC systems and diverting waste from landfills.

3- Green roofs technical aspects

The structure of a green roof includes the vegetation layer, the soil, the drainage layer and the membrane layer, serving as a filter and waterproofing layer [34]. Many other layers are often required, such as the root barrier (generally between the soil layer and the drainage one), the irrigation system (within or above the soil layer) and supplementary filters [35]. The development of a green roof can use versatile construction techniques such as a complete system, a modular system or precultivated blankets [36]. The complete system encompasses the entire roof while the other two are planted before being integrated above the rooftop. Regards the possible vegetation types, Cox states that different plant types could lead varying thermal insulation values [37]. Different plant choices in green roofs cause significant variations in the thermal insulation value. Sedum, one of the most popular types of plants for green roofs, provides high shading against solar radiation, has a short root structure and is compatible with limited water sources [38]. However, it is unable to avoid convective heat transfer under its leaves and consequently, it has a low thermal resistance value [38]. Ryegrass allows for much air circulation but its potential for shading is limited. Vince guarantees better shading compared to the others, however it also allows convective heat transfer [40]. The most important characteristics of the vegetation that influence heat transfer of a green roof are plant elevation, fractional coverage, leaf area index (LAI), stomatal resistance and albedo [17]. The fractional coverage is representative of the roof surface fraction that is directly covered by at least one leaf. The albedo is the surface reflectivity to the incident solar energy over the vegetation layer. At last, the stomatal resistance is a biophysical factor that relates to the rate at which the plant transpires moisture [17]. Simulations in different climates exploring variations in LAI have shown that a high LAI (LAI = 5) corresponds to an increase of energy consumption in winter and a reduction in summer [17, 41]. MacIvor et al. found that the dry land plants have higher thermal resistance than wetland ones by comparing many plant types [42]. Sutton et al. found that most of the vegetation kinds can successfully grow once sufficient irrigation and soil layer depth are provided [43]. The study by Schweitzer and Erellclaims that despite the confirmed benefits of green roofs in temperate and tropical regions, it is very challenging to use them in extremely hot and dry regions. The respective study has analyzed four different alternatives of plantations including Aptenia, Halimione, Sesuvium, and Pennisetum, and has found that Pennisetumclandestinum encompassed the most significant positive effect [44]. Durhman sugested to use several species of Sedum, among s. sediforme, s. acre, s. midden- dorffianum, s. album bella d inverno, s. spuriousLeningrad white, s. reflexes and s. spuriumsummer glory. Subordinate species, at specific substrate depths, include s. kamtschaticum s. dasyphyllum lilac mound, s. dasyphyllumburnatii, s. hispanicum, and s. diffusum [45].

Getter and Rowe proposed sempervivum and delospermaas for green roofs without irrigation [46]. Various studies proclaimed that the use of various kinds of plantations could be useful for maximizing the green roofs effectiveness [47]. But, the selection of plant type must be established according to the climatic conditions, the plant impact on the ecosystems [54, 55]. Overall, there is a need for research about comparisons among various types of plants to provide design guidelines for selecting the most appropriate plants for a given green roof[46]. These researches should consider different possible soil depths, local climates, water availability, and plant density, as there is often a misunderstanding of the impacts of these variables over the environmental of green roofs.

4- Application of green roofs in arid areas

In order to provide a various range of environmental benefits, green roofs are being built including conservation of energy by improved insulation of buildings and energy efficiency [17], urban heat island effect mitigation [48], attenuation of noise [49], provision of biodiversity habitat [50] and management of urban storm water [51, 52].

Green roofs include some layers, consisting of substrate, drainage and water-proofing. Restrictions of weight loading on constructions restrict the depth of substrate on green roofs. Water availability oscillatesdrastically between rain events, making green roofs difficult mediums for plant growth and survival [7, 8].As a result, throughout drought times, survival limits plant species in green roofs [9], especially in harsh climates.

Survival of plants on green roofs depends on some factors including depth of substrate and physical properties, especially capacity of water holding. Sedum species tolerance of droughtin response to substrate depth has been extensively studied, showing enhanced survival in greater depths [45, 53, 52]. But, species performance comparison, under drought situation and in various substrates with different physical characteristics has not been thoroughly investigated.

In order to assure the long term success of green roof, its substrates require to balance some of the properties. Low bulk density and good aeration are required to guarantee the substrate is lightweight, facilitating the respiration of plant and free draining, but it has to be balanced against enoughretention of water for survival and growing of plant [54, 55, 56]. These characteristics can be attained with light weight parts; but, most parts, especially organic materials, decompose and/or shrink during time, hence substrates of green roof are mostly composed of mineral ones. Composition of mineral based substrate varies based on cost and local availability, and many consist of waste or recycled products to maximize the green roofs environmental advantages[57].

Most substrates of green roof are emerged according to determined performance standards and guidelines, especially the American Standard Testing Methods or German FLL. Both of these standards determinelimits of values for different substrate characteristics and the necessary methodologies of testing. In green roofs of North American and European areas, in moderate climates, the genus Sedumsucculents are the most frequently used plant [8, 58]. Sedum species demonstrate some desired features including providing good lateral cover, low spreading habit and tolerance of drought [7, 52]. Their tolerance of drought is mainly because of physiological adaptations and high leaf succulence like Crassulacean Acid Metabolism, CAM, photosynthesis [60, 45].

Succulence of leaf makes plants to endure repeated drought through provision of consumable water once water/soil situations prohibit roots uptake [61]. A lot of Sedum species that were used on green roofs were from alpine zone due to their tolerance of frost and increased survival during winter [45], including S. reflexum, S. acre, Sedum album and S. spurium. As a result of enhanced tolerance of frost, these kinds demonstrate lowered succulence of leaf [62]. Because the succulence of leaf degree directly affects tolerance of drought [61], these Sedum kinds might not be appropriate in arid climates than the kinds with more succulence [10]. There area small number of large-scale green roofs in arid climates despite of extensive application in cooler climates [10]. Victorious green roofs application in arid climates is of paramount importance because of the environmental advantages are probably to be more than in temperate climates [63]. But, it is difficult to depend on practices of green roofs in temperate northern hemisphere without thorough investigation [10], because of suitable plants and substrate accessibility, differences in climate and not enough data on plant performance under drought conditions [9]. So far, to the best of our knowledge, inadequate study has been performed to determine green roof succulents' tolerance of drought and the different substrates suitability in harsh climates like areas with arid and semi-arid conditions.

Conclusions

Green roofs are important types of green infrastructures for cities in the future. They have potential benefits to make urban areas healthier and more livable for residents. The terms of green roofs, based on a compressive review in their environmental, economic and social benefits and their technical aspects were investigated. In order to implement green roofs in harsh environment of dry climates, environmental advantages are presumably more important. Without scientific testing and experiments, it is difficult to depend on practices of green roofs in temperate climates. Although several experiments have been done, investigating proposed technical aspects of green

roofs, more experiments are needed to achieve a comprehensive overview of green roofs implementation in arid and semi-arid areas.

REFERENCES

1.Berardi, U., Ghaffarianhoseini, A., & Ghaffarianhoseini, A. (2014). State-of-the-art analysis of the environmental benefits of green roofs. Applied Energy, 115, 411–428.

2.Grimmond, C. S. B., Roth, M., Oke, T. R., Au, Y. C., Best, M., Betts, R., … Emmanuel, R. (2010). Climate and more sustainable cities: climate information for improved planning and management of cities (producers/capabilities perspective). Procedia Environmental Sciences, 1, 247–274.

3. Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning, 97(3), 147–155.

4.Pincetl, S. (2010). From the sanitary city to the sustainable city: challenges to institutionalizing biogenic (nature's services) infrastructure. Local Environment, 15(1), 43–58.

5.Semaan, M., & Pearce, A. (2016). Assessment of the Gains and Benefits of Green Roofs in Different Climates. Procedia Engineering, 145, 333–339. http://doi.org/10.1016/j.proeng.2016.04.083

6. Farrell, C., Mitchell, R. E., Szota, C., Rayner, J. P., & Williams, N. S. G. (2012). Green roofs for hot and dry climates: interacting effects of plant water use, succulence and substrate. Ecological Engineering, 49, 270–276.

7. Nagase, A., &Dunnett, N. (2010). Drought tolerance in different vegetation types for extensive green roofs: effects of watering and diversity. *Landscape and Urban Planning*, *97*(4), 318–327

8.Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., … Rowe, B. (2007). Green roofs as urban ecosystems: ecological structures, functions, and services. *BioScience*, *57*(10), 823–833.

9.Bousselot, J. M., Klett, J. E., &Koski, R. D. (2011). Moisture content of extensive green roof substrate and growth response of 15 temperate plant species during dry down. *Hort Science*, *46*(3), 518–522.

10. Williams, N. S. G., Rayner, J. P., &Raynor, K. J. (2010). Green roofs for a wide brown land: Opportunities and barriers for rooftop greening in Australia. *Urban Forestry & Urban Greening*, *9*(3), 245–251.

11.Köhler, M., Schmidt, M., Wilhelm Grimme, F., Laar, M., Lúcia de Assunção Paiva, V., & Tavares, S. (2002). Green roofs in temperate climates and in the hot-humid tropics-far beyond the aesthetics. *Environmental Management and Health*, *13*(4), 382–391.

12. Coutts, A. M., Daly, E., Beringer, J., & Tapper, N. J. (2013). Assessing practical measures to reduce urban heat: Green and cool roofs. *Building and Environment*, *70*, 266–276.

13.Eisenman, T. (2006). Raising the bar on green roof design. *Landscape Architecture*, *96*(11), 22.

14.Dunnett N., Hallam A., Nagase A. 2008. The dynamics of planted and colonizing species on a green roof over six growing seasons 2001-2006: influence of substrate depth. Urban Ecosystems 11:373-384.

15. Lanham, J. K. (2007). Thermal Properties of Green Roofs in Cold Climates

16. Bates, A. J., Sadler, J. P., & Mackay, R. (2013). Vegetation development over four years on two green roofs in the UK. *Urban Forestry & Urban Greening*, *12*(1), 98–108.

17. Sailor, D. J. (2008). A green roof model for building energy simulation programs. *Energy and Buildings*, *40*(8), 1466–1478.

18. Chen, C.-F. (2013). Performance evaluation and development strategies for green roofs in Taiwan: A review. *Ecological Engineering*, *52*, 51–58.

19.Saiz, S., Kennedy, C., Bass, B., & Pressnail, K. (2006). Comparative life cycle assessment of standard and green roofs. *Environmental Science & Technology*, *40*(13), 4312–4316.

20. KÖHLER, M. (2004). Untersuchungenzuökologischen Vorteilenextensiver Dachbegrünungen. *Wissenschaftliche Zeitschrift Der Technischen Universität Dresden*, *53*(1-2), 109–114.

21. Clark, C., Adriaens, P., & Talbot, F. B. (2008). Green roof valuation: a probabilistic economic analysis of environmental benefits. *Environmental Science & Technology*, *42*(6), 2155–2161.

22. Carter, T., & Jackson, C. R. (2007). Vegetated roofs for storm water management at multiple spatial scales. *Landscape and Urban Planning*, *80*(1), 84–94.

23. [Frazer-Williams, R., Avery, L., Winward, G., Jeffrey, P., Shirley-Smith, C., Liu, S., … Jefferson, B. (2008). Constructed wetlands for urban grey water recycling. *International Journal of Environment and Pollution*, *33*(1), 93–109.

24.Krajcovicová, D., & Sprochová, K. (2007). Extensive roof garden as a thermal insulator. *Folia Oecologica*, *34*(1), 24.

25.Santamouris, M., Pavlou, C., Doukas, P., Mihalakakou, G., Synnefa, A., Hatzibiros, A., & Patargias, P. (2007). Investigating and analyzing the energy and environmental performance of an experimental green roof system installed in a nursery school building in Athens, Greece. *Energy*, *32*(9), 1781–1788.

26. Liu, K. K. Y., & Bass, B. (2005). Performance of green roof systems

27.Kuo, F. E., & Sullivan, W. C. (2001). Environment and crime in the inner city does vegetation reduce crime? *Environment and Behavior*, *33*(3), 343–367. *Sustainable Communities, Chigago*, 41–45.

28. Sullivan, W. C., Kuo, F. E., & Depooter, S. F. (2004). The fruit of urban nature vital neighborhood spaces. *Environment and Behavior*, *36*(5), 678–700.

29.Ulrich, R. (1984). View through a window may influence recovery. *Science*, *224*(4647), 224–225.

30. Hyland, G. J. (2003). How Exposure to GSM & TETRA Base-station Radiation can Adversely Affect Humans. *URL (consulted May 2004): Http://www. Buergerwelle. De/pdf/how_exposure_to_base_station_radiation_can_ Adversely_affect_humans. Pdf.*

31. Herman, R. (2003). Green roofs in Germany: yesterday, today and tomorrow. *Greening Rooftops for*

32.Pirog, R. S., & Benjamin, A. (2003). Checking the food odometer: Comparing food miles for local versus conventional produce sales to Iowa institutions.

33. Rowe, D. B. (2011). Green roofs as a means of pollution abatement. *Environmental Pollution*, *159*(8), 2100–2110.

34. Castleton, H. F., Stovin, V., Beck, S. B. M., & Davison, J. B. (2010). Green roofs; building energy savings and the potential for retrofit. *Energy and Buildings*, *42*(10), 1582–1591.

35.Palla, A., Gnecco, I., &Lanza, L. G. (2009). Unsaturated 2D modelling of subsurface water flow in the coarse-grained porous matrix of a green roof. *Journal of Hydrology*, *379*(1), 193–204.

36. Kim, J., Hong, T., & Koo, C.-W. (2012). Economic and environmental evaluation model for selecting the optimum design of green roof systems in elementary schools. *Environmental Science & Technology*, *46*(15), 8475–8483.

37. Cox, B. K. (2010). *The influence of ambient temperature on green Roof R-values*.

38.Emilsson, T. (2008). Vegetation development on extensive vegetated green roofs: influence of substrate composition, establishment method and species mix. *Ecological Engineering*, *33*(3), 265–277.

39. Rowe, D. B., Getter, K. L., &Durhman, A. K. (2012). Effect of green roof media depth on Crassulacean plant succession over seven years. *Landscape and Urban Planning*, *104*(3), 310–319.

40.Parizotto, S., & Lamberts, R. (2011). Investigation of green roof thermal performance in temperate climate: A case study of an experimental building in Florianópolis city, Southern Brazil. *Energy and Buildings*, *43*(7), 1712–1722.

41.Ascione, F., Bianco, N., de'Rossi, F., Turni, G., &Vanoli, G. P. (2013). Green roofs in European climates. Are effective solutions for the energy savings in air-conditioning? *Applied Energy*, *104*, 845–859.

42.MacIvor, J. S., Ranalli, M. A., &Lundholm, J. T. (2011). Performance of dryland and wetland plant species on extensive green roofs. *Annals of Botany*, *107*(4), 671–679.

43. Sutton, R. K., Harrington, J. A., Skabelund, L., MacDonagh, P., Coffman, R. R., & Koch, G. (2012). Prairie-based green roofs: literature, templates, and analogs. *Journal of Green Building*, *7*(1), 143–172.

44. Schweitzer, O., &Erell, E. (2014). Evaluation of the energy performance and irrigation requirements of extensive green roofs in a water-scarce Mediterranean climate. *Energy and Buildings*, *68*, 25–32.

45.Durhman, A. K., Rowe, D. B., &Rugh, C. L. (2007). Effect of substrate depth on initial growth, coverage, and survival of 25 succulent green roof plant taxa. *HortScience*, *42*(3), 588–595.

46. Getter, K. L., & Rowe, D. B. (2006). The role of extensive green roofs in sustainable development. *HortScience*, *41*(5), 1276–1285.

47. Wolf, D., &Lundholm, J. T. (2008). Water uptake in green roof microcosms: effects of plant species and water availability. *Ecological Engineering*, *33*(2), 179–186.

48. Bass, B., Liu, K. K. Y., &Baskaran, B. A. (2003). Evaluating rooftop and vertical gardens as an adaptation strategy for urban areas.

49. Van Renterghem, T., & Botteldooren, D. (2009). Reducing the acoustical façade load from road traffic with green roofs. *Building and Environment*, *44*(5), 1081–1087.

50.Brenneisen, S. (2006). Space for urban wildlife: designing green roofs as habitats in Switzerland. *Urban Habitats*, *4*(1), 27–36.

51.Berndtsson, J. C. (2010). Green roof performance towards management of runoff water quantity and quality: A review. *Ecological Engineering*, *36*(4), 351–360.

52.VanWoert, N. D., Rowe, D. B., Andresen, J. A., Rugh, C. L., & Xiao, L. (2005). Watering regime and green roof substrate design affect Sedum plant growth. *HortScience*, *40*(3), 659–664.

53. Getter, K. L., & Rowe, D. B. (2009). Substrate depth influences Sedum plant community on a green roof. *HortScience*, *44*(2), 401–407.

54.Nektarios, P., Tsiotsiopoulou, P., &Chronopoulos, I. (2002). Comparison of different roof garden substrates and their impact on plant growth. In *International Conference on Urban Horticulture 643* (pp. 311–313).

55. Rowe, D. B., Monterusso, M. A., &Rugh, C. L. (2006). Assessment of heat-expanded slate and fertility requirements in green roof substrates. *HortTechnology*, *16*(3), 471–477.

56.Thuring, C. E., Berghage, R. D., & Beattie, D. J. (2010). Green roof plant responses to different substrate types and depths under various drought conditions. *HortTechnology*, *20*(2), 395–401.

57.Molineux, C. J., Fentiman, C. H., &Gange, A. C. (2009). Characterizing alternative recycled waste materials for use as green roof growing media in the UK. *Ecological Engineering*, *35*(10), 1507–1513.

58. Snodgrass, E. C. E. C., & Snodgrass, L. L. (2006). *Green roof plants: a resource and planting guide*.

59. Butler, C. (2011). *Ecology and physiology of green roof plant communities*. TUFTS UNIVERSITY

60.Sayed, O. H. (2001). Crassulacean acid metabolism 1975–2000, a check list. *Photosynthetica*, *39*(3), 339–352.

61. Von Willert, D. J. (1992). *Life strategies of succulents in deserts: with special reference to the Namib Desert*. CUP Archive.

62.Teeri, J. A., Tonsor, S. J., & Turner, M. (1981). Leaf thickness and carbon isotope composition in the Crassulaceae. *Oecologia*, *50*(3), 367–369.

63.Alexandri, E., & Jones, P. (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. *Building and Environment*, *43*(4),480–493.