This publication is licensed under a CC BY-NC 4.0

Review Article
ISSN 2658-5553
Received: June 12, 2022 Accepted: June 27, 2022 Published: June 28, 2022

Selection of plants for extensive green roofs in climate zone A: A review

John, Gayanthi K.P. [1*]
Halwatura, Rangika U.[2]

[1] Institute of Technology, University of Moratuwa, Sri Lanka; gayanthijohn@gmail.com
[2] University of Moratuwa, Sri Lanka; rangikauh@gmail.com
Correspondence:* email gayanthijohn@gmail.com; contact phone +94771012416

Keywords:

Extensive Green roofs; Climate Zone A; Plant Selection; Vegetation Layer; Plant Selection Matrix

Abstract:

Countries in Climate Zone A have much to gain from implementing green roofs as a climate change adaptation measure. Due to the limited research on green roofs in Climate Zone A, the components of a green roof suitable to these geographical locations have not yet been identified. One of the major barriers to increasing the prevalence of green roofs in these regions is the lack of proven plant species suited to green roofs in the tropics. **The main objective of this study** was to develop a plant screening tool that can identify the plant species that can survive and be aesthetically pleasing in an extensive green roof in Climate Zone A. **The methodology of this study** consisted of a review of the existing knowledge on factors that influence the selection of plants for extensive green roofs. These factors were then critically analyzed for their relevance to Climate Zone A. **The result** of this analysis was a plant selection matrix that can identify the plant species putatively suited for extensive green roofs in the tropics. This developed plant selection matrix can provide the green infrastructure industry in Climate Zone A with a greater knowledge for plant selection.

1 Introduction

Rapid population growth and the resulting expansion of urban areas have transformed the natural landscape into a built environment [1]. As green areas become increasingly entombed by concrete and asphalt, a suite of urban environmental issues has emerged [2, 3]. Expansion of high albedo surfaces has led to increased absorption of short-wave solar radiation, leading to unnaturally warm city environments known as “Urban Heat Islands” (UHI) [4–6]. The salient features of the built environment, such as impervious paved surfaces, have led to an increase in the volume of surface run-off, leading to flash flooding [1, 7]. Furthermore, urban development has resulted in habitat replacement and loss of native biodiversity [2, 3, 7]. Collectively, these issues present enormous environmental, economic, and social challenges in metropolitan areas [1]. As the urban population exponentially increases and the effects of global warming are increasingly felt across the world, these conditions are expected to worsen in the future [8, 9]. Therefore, there is an immediate need to implement solutions to these challenges, to make cities more livable now and in the future [1, 10].

Incorporating diverse forms of vegetation into cities is an effective approach to addressing the energy and environmental crises resulting from urbanization [11–13]. Vegetation diminishes the UHI effect by masking the surfaces of buildings and deflecting radiation from the sun [14, 15]. They cool the environment by absorbing solar energy for evapotranspiration and photosynthesis [16]. An additional 10% of vegetation has shown to reduce temperature by 0.6 K [17]. Furthermore, increasing the green cover in urban areas increases the retention of water, thereby reducing the volume of storm water runoff [18].

This publication is licensed under a CC BY-NC 4.0

As building density increases to accommodate the growing population, the usable area for urban greening diminishes at a rapid rate [19]. Therefore, the logical solution to increasing the vegetation in urban areas is to integrate it onto the built structures [20]. The roof is an important part of the building envelope, accounting for 20%–30% of the total impenetrable area in a developed city [21, 22]. These harsh and barren surfaces are often underutilized and contribute to urban environmental issues, such as UHI and flash flooding [20, 23]. Therefore, greening the rooftops is a simple but effective method for restoring the ecological balance that has been disturbed by urbanization [20].

Rooftop greenery has a long history that stretches back to the legendary Hanging Gardens of Babylon constructed about 500 BC [24]. Green roofs have become a must in modern urban planning [19]. They help to compensate for the loss of urban greenery and restore ecosystem services [1]. Green roofs help to correct the environmental problems triggered by excessive urbanization [20].

Green roofs provide various services to the urban environment [25]. They provide localized cooling and are an impressive remedy for UHI effect [1, 26]. Herath et al. [27] reported that temperature reductions of 1.76 °C–1.79 °C, compared with existing UHI scenario, are possible by using green roofs. Further studies have concluded that, by converting flat roofs into green roofs, the surrounding temperatures in urban areas can be reduced by 1.5 °C [28]. Moreover, as buildings receive twice as much solar radiation from rooftops than from vertical surfaces, green roofs reduce indoor temperatures and provide increased thermal comfort compared with traditional roofs [29–31].

Green roofs are a technological solution for urban stormwater management [32]. They provide sanctuaries for animals, prevent noise pollution, and can be used as part of a plan for urban air pollution control [16, 32, 33]. The presence of greenery has a major psychological impact on urban dwellers. It enhances the visual aesthetics of the city and raises the value of real estate [1, 24]. Therefore, green roofs serve as a modern and highly efficient solution for urban environmental problems and provide multifaceted benefits to the environmental, ecological, social, and economic realms of cities [20, 34].

In the recent decades, the popularity of green roofs has increased and their implementation has expanded beyond Europe [16, 35]. However, green roofs are still not readily accepted into the urban landscape in many climate zones across the world [36]. One of the major barriers to increasing the prevalence of green roofs is the lack of scientific data available to evaluate their applicability to local conditions [37, 38]. Blank et al. [39] reported that over 66% publications on green roof research in the ISI Web of Science database are based in the USA and the EU. Therefore, green roof research and implementation are largely concentrated in the temperate regions [35]. Owing to the limited research on green roofs in the tropics, the components of a green roof suitable to these geographical locations have not been identified yet [24]. Adopting the green roof technology from temperate regions can be problematic because of considerable differences in climate and building characteristics [40, 41]. Apart from the added cost, there is a high possibility of failure due to non-compatibility [41]. This lack of knowledge on local research and experience on green roof performance in the tropics has hindered the application of green roofs in countries in Climate Zone A [35].

The vegetation layer on a green roof is one of the most critical determinants that impacts the ultimate performance of green roofs [34]. The type of plant used influences the thermal performance of the roof, the amount of maintenance required, and determines whether a green roof stays green [20], [42]. Plant species that successfully perform in green roofs in Climate Zone C may not perform well in the Climate Zone A. For example, *Sedum* species, which are the primary choice for green roofs in Climate Zone C, cannot cope with the warm humid conditions of Climate Zone A [16]. Therefore, climate-specific plant selection is crucial to the success of green infrastructure [16, 43].

As different countries have different climatic conditions, local research must be conducted to successfully implement green roofs in the local context [44]. As the majority of green roof research is concentrated in the United States and Europe, there is a lack of information on the type of plant species best adapted for green roofs in Climate Zone A [20, 35, 39, 45]. The research presented in this paper is an initial step forward to identifying plant species that can survive and be aesthetically pleasing in Climate Zone A.

Existing knowledge on factors that influence the selection of plants for extensive green roofs was critically analyzed for their relevance to Climate Zone A. This knowledge was then used to generate a plant selection matrix for identifying plant species putatively suited for extensive green roofs in Climate Zone A. A list of plant species identified through the matrix as suitable for the tropical climate in Asia was also presented. The main purpose of this study is to act as a roadmap that can assist in the development of future climate-specific guidelines for designing regionally appropriate green roofs in Climate Zone A.

This publication is licensed under a CC BY-NC 4.0

2 Materials and Methods

2.1 Factors Influencing the Selection of Plants for Extensive Green Roofs

Extensive green roofs are expansive areas with shallow growing media. They are designed for minimum maintenance. Therefore, plant species that establish quickly to provide a good coverage are preferred [16]. Plants with good coverage will prevent the substrate from being exposed to direct sunlight and heavy winds. Furthermore, such plant species will reduce potential erosion problems and will retard weed growth [24, 46]. Snodgrass & Snodgrass [47] have recommended an ideal rate of spread between 15 and 25 cm in the first year for plants transplanted as plugs. Plants with aggressive growth rates should be avoided [47].

The shallow substrate in an extensive green roof imposes a limitation on the maximum height of plants that can be allowed [20]. Short plants are less prone to wind damage and are easier to maintain than tall plants. Therefore, plant heights between 10 and 15 cm are considered ideal for extensive green roofs [47]. However, one drawback in limiting plant height is that the thermal performance of a green roof will decrease as plant height is reduced [29].

The canopy structure of the plant is another important criterion that must be considered in plant selection process. Studies have shown that plants with a lower leaf density absorb less carbon than their counterparts [48, 49]. Therefore, plants species with a mostly horizontal leaf distribution and have mat-forming or dense clumping growth habits are recommended [16, 22]. The high-density foliage reduces the transmission of solar radiation through the canopy and provides a higher cooling effect [50]. Furthermore, plants with a different colored vegetation have a higher cooling effect [50].

The root system of the plant is another important criterion. The root system should anchor the plant while binding the substrate together to prevent the substrate from scouring/eroding under strong winds or heavy rainfall. Plants species with shallow and dense root systems and with stems that root into the substrate as they grow are recommended [22].

Water-use efficiency is an important trait of plants used for extensive green roofs in the tropics [20], [29]. Despite high rainfall and humidity, xeric growth conditions exist on extensive green roofs in the tropics. The high levels of solar radiation combined with the limited water-storage capacity of the shallow growth medium and the nonuniformity of the rainfall distribution in the tropics cause the shallow substrate to regularly dry out. Over the course of a green roof project in Singapore, the substrate was depleted of moisture for four or more days in eight out of the twelve months over the period of one year from 2003 to 2004 [20]. Therefore, drought tolerance is a highly desirable trait in plants used for extensive green roofs [16].

Drought-tolerant species can maintain an adequate vegetation cover throughout the year [16]. Drought tolerance takes various botanical forms; succulent leaves, thick leaf cuticles, in-rolled leaf margins, small leaf area, grey or silver foliage; compact twiggy growth, reduced stomatal size and frequency, and Crassulacean acid metabolism (CAM) [20, 22, 29, 51].

Plants with CAM fix more CO_2 per unit of water lost from the leaves than plants with other modes of photosynthesis. During the daytime when evaporative loss of water from leaves is at its highest, CAM plants close their stomata. During the nighttime, the stomata are opened and CO_2 is absorbed and stored. This stored CO_2 is then used for photosynthesis during the daytime [20]. However, as CAM plants close their stomata during the daytime, dissipation of heat by transpiration is prevented. Therefore, the cooling effect provided by such plants is relatively low [16]. Winter & Holtum, [52] reported that in some plants, called inducible CAM plants, CAM is triggered by drought stress, and it can be reversed by adequate water and nutrient supply.

Paradoxically, although drought tolerance is a desired feature in extensive green roofs, plants that are used in Climate Zone A should also tolerate prolonged periods of moisture in the root zone, which can be expected during the wetter months [20]. For example, *Sedum* species are the most common choice of plant for extensive green roofs in temperate regions because of their unique characteristics, including drought tolerance [53]. However, most of these succulent plants are susceptible to moisture in the air or in the substrates [43]. Therefore, plant species used for extensive green roofs in Climate Zone A should be capable of withstanding intermittent flooding as well as drought [54].

The plants used in green roofs should provide long-term coverage as it reduces the need for future replanting and maintenance. Perennial species, hardy succulents, or herbaceous perennials are considered best for long-term coverage [16, 22]. Plant species that can self-propagate, such as self-seeding annuals, or plants that can spread vegetatively are preferred. These type of plant species are

This publication is licensed under a CC BY-NC 4.0

generally long-lived and will provide good coverage as long as the environmental conditions are favorable [46], [47].

Furthermore, plant species that are self-sustaining are recommended for extensive green roofs. Self-sustaining plants can exist perennially without human intervention, and given that they are irrigated according to natural rainfall patterns, they require minimal maintenance, which is ideal for extensive green roofs [43].

The selected plants should be adapted to the climatic and environmental conditions of the considered geographical location. The plant species must be able to withstand the average high and low temperatures, wind, and the amount and distribution of annual rainfall specific to the area [46]. Therefore, plant selection for green roofs, in most cases, should be restricted to native plant species [44]. Native plants have evolved to survive and grow in their regional meteorological conditions and are resistant against local diseases and pests [55]. Once established, native plants do not require water, fertilizers, or pesticides [55]. About 45% of the award-winning green roof designs mentioned in Peck's book [56] of "Award Winning Green Roof Designs" have used native plants.

Aside from decreasing the need for maintenance and irrigation, planting green roofs with native vegetation supports native wildlife by providing habitat and food resources for local fauna [53]. Native insects are more attracted to native vegetation because of the provision of appropriate pollen resources. Therefore, the use of native plant species will help to improve biodiversity. It will also help to replace the vegetation destroyed by development. Moreover, native plant species are less likely to become invasive [57–60].

However, green roofs are hostile and extreme growth habitats. Owing to the high exposure level at the top of the building, climatic parameters are often magnified on a roof top. Therefore, some researchers have raised concerns about the ability of native plants to perform well under these harsh conditions [7, 25]. Monterusso et al. [61] tested 18 native species and 9 nonnative *Sedum* species individually on a non-irrigated rooftop. Over three years, all the nonnative *Sedum* species maintained coverage compared with only four native species. However, Lundholm [7] stated that these results do not provide conclusive evidence indicating that either natives or nonnatives are superior as this study involved different species, i.e., *Sedum* species versus wildflowers and grasses. However, the fact that no single species occurs everywhere demonstrates the fit between species and their preferred habitats [7].

Green roofs are novel habitats that experience direct sunlight, elevated temperatures, strong winds, and high evaporation rates [23, 62]. The conditions offered on a rooftop may be either extremely dry or waterlogged. The microclimate on a rooftop can dramatically affect plant health and appearance and contribute to the failure of a green roof system [46]. Therefore, the selected plant species must be able to survive these challenging conditions [1, 23].

Dunnett & Kingsbury [25] suggested that species that evolved in extreme conditions, such as mountainous terrains, high-altitude environments, coasts, limestone substrates, or semideserts, are more suited for green roof habitation as they are preadapted to green roof conditions. This idea is supported by the fact that majority of plant species used for green roofs in temperate regions are drawn from European limestone pavements and dry meadows [25]. Furthermore, several research works have demonstrated that the plant species that spontaneously colonize urban habitats, such as pavements, walls, and roofs, have origins in areas where harsh conditions prevail [63, 64]. Therefore, plants species from habitats with environmental conditions similar to green roof conditions should be preferred over species that are native to an area [43, 65].

The criteria that should be considered in the selection of plants for extensive green roofs in the tropics, as identified through an extensive literature review, are summarized in Table 1.

Table 1. Factors Affecting the Selection of Plants for Extensive Green Roofs in Climate Zone A

Criteria		Source
Rate of Spread within the 1st year *Plants transplanted as Plugs	15–25 cm	[47]
Plant Height	2.5–20 cm	[16], [47]
Root Systems	• Shallow and Dense • Stems that root to the substrate	[22]

John, G.K.P.; Halwatura, R.U.;
Selection of plants for extensive green roofs in climate zone A: A review;
2022; *AlfaBuild;* **23** Article No 2301. doi: 10.57728/ALF.23.1

This publication is licensed under a CC BY-NC 4.0

Substrate	• Able to grow in shallow soil • Able to grow in well-draining soil • Can grow on nutrient-poor soil	[54], [66]
Canopy Structure	• Horizontal leaf distribution • High foliage density • Dense clumping/mat forming • Different colored vegetation	[50]
Drought-Tolerant Plants	• CAM Metabolism • Succulent leaves • Thick leaf cuticles • In-rolled leaf margins • Curved leaf surfaces • Grey or silver foliage • Compact twiggy growth	[16], [20], [22], [46]
Ability to withstand Intermittent Flooding		[20], [54], [66]
Long-term Coverage	• Perennial species • Hardy succulents • Herbaceous perennials • Self-seeding annuals • Spread vegetatively	[16], [22], [46], [47]
Adapted to Local Climatic and Environmental Conditions	• Native plants • Not prone to local pests/diseases • Able to survive local average high and low temperatures	[44], [46], [67], [68]
Resilience	• Ability to survive direct sunlight • Ability to survive strong winds • Not prone to nutrient deficiencies • Self-sustaining • Ability to regenerate after stress	[20], [43], [54], [66], [69]
Habitat	Similar to green roof conditions	[25], [63], [65]
User-friendliness	• Not poisonous to humans • Does not possess thorns	[16]

2.2 Development of the Plant Selection Matrix

Existing knowledge on factors that influence the selection of plants for extensive green roofs was critically analyzed for their relevance to Climate Zone A. This knowledge was then used to generate a plant selection matrix for extensive green roofs in tropics. The plant selection matrix was structured using a question-and-answer approach in which plant species were deemed as “highly suitable”, “suitable”, “suitable under certain conditions” or “unsuitable”.

This matrix was then applied to several plant species, and a group of plant species putatively suited for extensive green roofs in Climate Zone A was identified.

3 Results and Discussion

3.1 Plant Selection Matrix for Extensive Green Roofs in the Tropics

The plant selection matrix was developed to reflect the criteria listed in Table 1. Plant species suited for extensive green roofs for Climate Zone A can be identified through this 18-point matrix. The plant selection matrix is given in Figure 1.

This publication is licensed under a CC BY-NC 4.0

3.2 Plant Species for Extensive Green Roofs in Climate Zone A

Climate Zone A is blessed with a great plant diversity. This biodiversity provides the opportunity to create green roofs that are unique to this climate zone [20]. However, extensive green roofs have a smaller pool of potential plants because of the shallow depth of the substrate [45].

A list of plant species putatively suited for extensive green roofs in tropical Asia as identified through the plant selection matrix given in Figure 1 is provided in Table 2.

3.3 Discussion

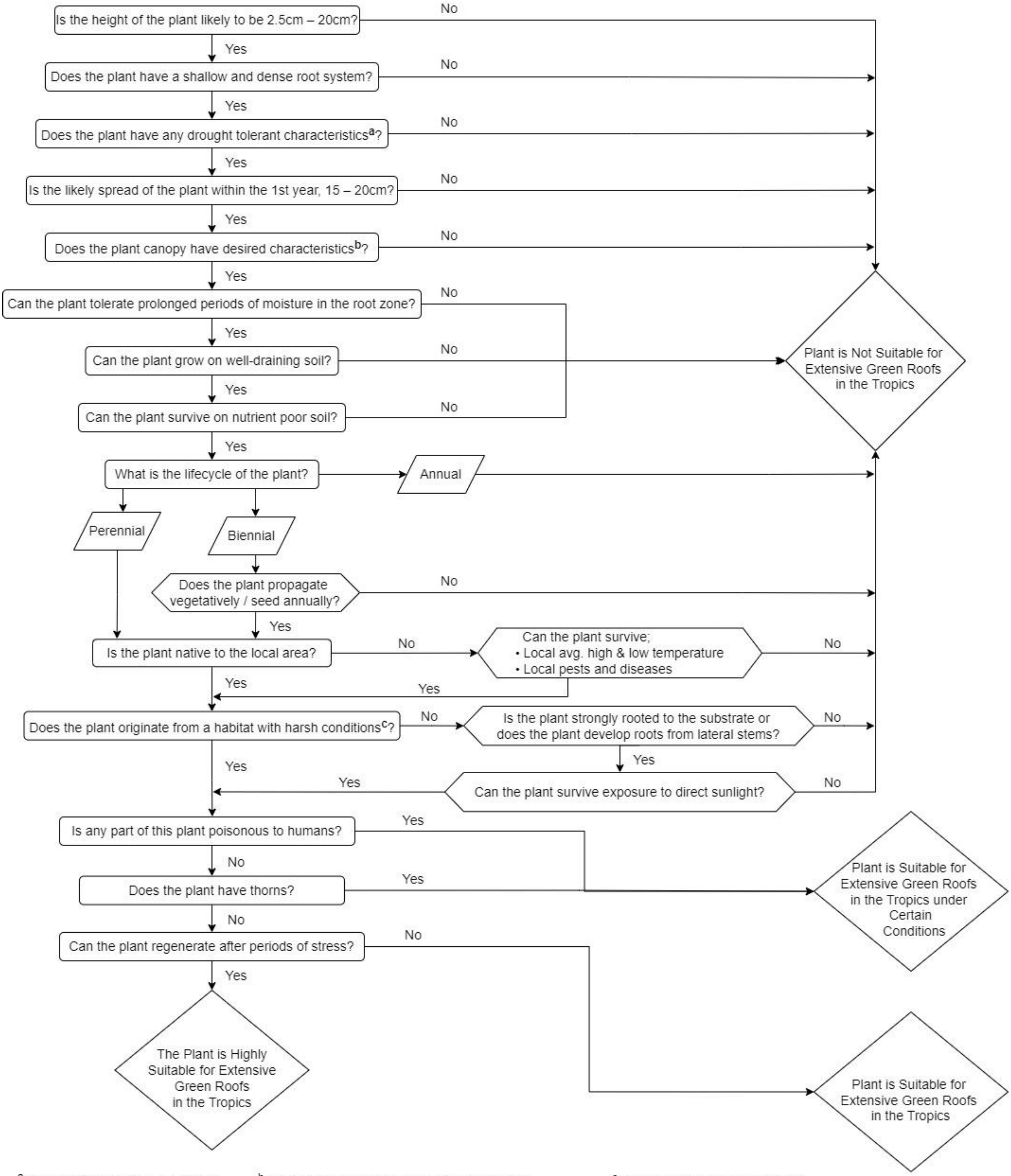
Majority of the earliest green roof research publications focused on evaluating the benefits of green roofs [70, 71]. However, each country must do local research to identify components for successful establishment of green roofs [41]. Plant species that have been proved to perform well in extensive green roofs under temperate climatic conditions can lead to failure of the green roof system over time owing to adaptability issues [41]. As different countries have different climatic conditions and building characteristics, plant screening must be conducted to identify plant species best suited to the local conditions [24]. Careful selection of plants is a crucial factor that determines the viability of green roofs over a long time period. The successful implementation of green roofs in Germany can be attributed to the extensive plant screening research trials that were conducted in the early development of the green roof industry in this country [22].

Countries in Climate Zone A have much to gain from implementing green roofs as a climate change adaptation measure. However, the lack of proven plant species suited to green roofs in Climate Zone A has deterred the growth of the green roof industry in Asia and other tropical countries. The overall aim of this research was to provide the green infrastructure industry in Climate Zone A with a greater knowledge for plant selection. Existing knowledge on plant selection and performance for extensive green roofs was reviewed and then used to generate a plant selection matrix. The plant selection matrix developed herein can be used to identify plant species putatively suited to extensive green roofs in Climate Zone A. Aside from the plant species listed in Table 2, many other suitable species can be discovered from among the diverse plant species available worldwide.

Aside from climate, plant performance in a green roof depends on various factors, such as building height and shade [72]. Therefore, the plant species identified through the matrix must be evaluated for their in situ performance prior to being applied for a green roof. Greenhouse experimentation and trials must be adopted to reduce potential errors and costs. Moreover, the contribution of the selected plant species to the overall performance of the green roof system must be evaluated. Various authors have reported that grasses and forbs are very effective in reducing stormwater runoff and provide improved thermal insulation when used in green roofs [73–75]. Furthermore, the inclusion of endemic herbaceous and shrub plants in green roof systems can provide an added value to green roof design.

The plant selection matrix presented in this paper is an initial step toward identifying plant species putatively suited to extensive green roofs in Climate Zone A. This matrix can pave the way for developing future climate-specific guidelines for designing climate-adaptive and regionally appropriate green roof systems.

This publication is licensed under a CC BY-NC 4.0



[a] Drought Tolerant Characteristics

- CAM Metabolism
- Succulent leaves
- Thick leaf cuticles
- In-rolled leaf margins
- Curved leaf surfaces
- Grey or silver foliage
- Compact twiggy growth
- Small evergreen leaves

[b] Desired Chararcteristics of the Plant Canopy

- High Foliage Density
- Horizontal Leaf Distribution
- Dense Clumping
- Mat Forming

[c] Habitats with Harsh Conditions

- High altitude environments
- Mountainous terrain
- Rocky habitats
- Dunes
- Riparian zones
- Lake shores
- Rocky beaches
- Coasts
- Limestone substrates
- Semi-deserts
- Open areas where harsh conditions prevail

Fig. 1 - Plant Selection Matrix for Extensive Green Roofs in the Tropics

This publication is licensed under a CC BY-NC 4.0

Table 2. A List of Plant Species Suited for Extensive Green Roofs in Climate Zone A

Plant Species	1	2	3	4	5	6	7	8	9	10	11	12	13
Sesuvium portulacastrum Sea Purslane	15 – 20	Root at Nodes	Full Sun	Succulent	Yes	Yes	Yes	Mat Forming	Perennial	Vegetatively & Seeds	Coastal Dunes	Yes	[20], [76]
Alternanthera sessilis Sessile joyweed	20	Root at Nodes	Full Sun	Grow in Xeric Conditions	Yes	Yes	Yes	Mat Forming	Perennial	Vegetatively & Seeds	Swamps, Dykes, Roadsides	Yes	[20], [77]
Desmodium triflorum Three-flowered Beggarweed	20	Root at Nodes	Full Sun to Partial Shade	Survive Dry Periods	Yes	Yes	Yes	Mat Forming	Perennial	Vegetatively & Seeds	Roadsides	Yes	[20], [78]
Zoysia matrella Siglap Grass	5– 20	Root at Nodes	Full Sun to Partial Shade	Yes	Yes	Yes	Yes	Dense Turf	Perennial	Vegetatively	Shoreline	Yes	[20], [79]
Murdannia nudiflora Dove Weed	20	Root at Nodes	Full Sun	Semi-succulent	Yes	Yes	Yes	Dense Mat	Perennial	Vegetatively & Seeds	Ditches, Dykes	Yes	[20], [80]
Cyanotis cristata	15– 30	Root at Nodes	Full Sun	Yes	Tolerate moist soil	Yes	Yes	Dense Mat	Perennial	Vegetatively	Coastal Dunes	Yes	[81]
Callisia repens Turtle Vine, Bolivian Jew	15	Root at Nodes	Full Sun – Partial Shade	Succulent	Tolerate moist soil	Yes	Yes	Dense mat	Perennial	Vegetatively	Riparian areas	No	[82]
Phyla nodiflora Frogfruit	5– 15	Root at Nodes	Full Sun	Once Established	Yes	Yes	Yes	Mat Forming	Perennial	Vegetatively	Stream banks	No	[83]
Vinca minor Common Periwinkle	15	Root at Nodes	Full Sun – Partial Shade	Once Established	Yes	Yes	Yes	Dense Mat	Perennial	Vegetatively	Slopes and banks	Yes	[84]
Arachis pintoi Pintoi Peanut	20	Root at Nodes	Full Sun to Partial Shade	Survive Dry Periods	Yes	Yes	Yes	Dense Mat	Perennial	Vegetatively & Seeds	Open Forests	No	[85], [86]

1 – Plant Height (cm); 2 – Shallow and Dense Root System; 3 –Sunlight Requirement; 4 – Drought Tolerant; 5 – Tolerate Intermittent Flooding; 6 – Grow on Well-draining Soil; 7 – Grow on Nutrient-Poor Soil; 8 – Plant Canopy/Foliage; 9 – Lifecycle; 10 – Self-Propagation; 11 – Common Habitat; 12 – Native to Asia; 13 - Source

This publication is licensed under a CC BY-NC 4.0

4 Conclusions

1. Climate specific plant selection is a crucial factor that determines the viability of green roofs over a long time period. The lack of proven plant species suited to green roofs in Climate Zone A has deterred the growth of the green roof industry in these countries.
2. The plant selection matrix developed herein can be used as a plant screening tool to identify plant species putatively suited to extensive green roofs in Climate Zone A.
3. The plant species identified through the matrix must be evaluated for their in-situ performance prior to being applied for a green roof.

5 Fundings

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. State of Victoria, Inner Melbourne Action Plan, University of Melbourne. Growing Green Guide: A guide to Gree roofs, Green walls and facades. National Library of Australia, 2014. ISBN:78-1-74326-714-1.
2. Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., Briggs, J.M. Global Change and the Ecology of Cities. Science. 2008. 319(5864). Pp. 756–760. DOI:10.1126/science.1150195. URL: https://www.science.org/doi/10.1126/science.1150195.
3. Pickett, S.T.A., Cadenasso, M.L., Grove, J.M., Boone, C.G., Groffman, P.M., Irwin, E., Kaushal, S.S., Marshall, V., McGrath, B.P., Nilon, C.H., Pouyat, R.V., Szlavecz, K., Troy, A., Warren, P. Urban ecological systems: Scientific foundations and a decade of progress. Journal of Environmental Management. 2011. 92(3). Pp. 331–362. DOI:10.1016/j.jenvman.2010.08.022. URL: https://linkinghub.elsevier.com/retrieve/pii/S0301479710002707.
4. Kleerekoper, L., van Esch, M., Salcedo, T.B. How to make a city climate-proof, addressing the urban heat island effect. Resources, Conservation and Recycling. 2012. 64. Pp. 30–38. DOI:10.1016/j.resconrec.2011.06.004. URL: https://linkinghub.elsevier.com/retrieve/pii/S0921344911001303.
5. Liddle, B., Lung, S. Age-structure, urbanization, and climate change in developed countries: revisiting STIRPAT for disaggregated population and consumption-related environmental impacts. Population and Environment. 2010. 31(5). Pp. 317–343. DOI:10.1007/s11111-010-0101-5. URL: http://link.springer.com/10.1007/s11111-010-0101-5.
6. Ranagalage, M., Estoque, R.C., Murayama, Y. An Urban Heat Island Study of the Colombo Metropolitan Area, Sri Lanka, Based on Landsat Data (1997–2017). ISPRS International Journal of Geo-Information. 2017. 6(7). Pp. 189. DOI:10.3390/ijgi6070189. URL: http://www.mdpi.com/2220-9964/6/7/189.
7. Lundholm, J.T. Green roofs and facades: a habitat template approach. Urban Habitats. 2006. 4(1). Pp. 87–101.
8. United Nations, Affairs, D. of E. and S., Population Division. World Urbanization Prospects, the 2009 Revision: Press Release. . 2010.
9. Wu, S., Bates, B., Zbigniew Kundzewicz, A.W., Palutikof, J. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE WMO UNEP Climate Change and Water. 2008.
10. Berardi, U., GhaffarianHoseini, A., GhaffarianHoseini, A. State-of-the-art analysis of the environmental benefits of green roofs. Applied Energy. 2014. 115. Pp. 411–428. DOI:10.1016/j.apenergy.2013.10.047. URL: https://linkinghub.elsevier.com/retrieve/pii/S0306261913008775.
11. Bowler, D.E., Buyung-Ali, L., Knight, T.M., Pullin, A.S. Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning. 2010. 97(3). Pp. 147–155. DOI:10.1016/j.landurbplan.2010.05.006. URL: https://linkinghub.elsevier.com/retrieve/pii/S0169204610001234.
12. Goddard, M.A., Dougill, A.J., Benton, T.G. Scaling up from gardens: biodiversity conservation in urban environments. Trends in Ecology & Evolution. 2010. 25(2). Pp. 90–98.

This publication is licensed under a CC BY-NC 4.0

DOI:10.1016/j.tree.2009.07.016. URL: https://linkinghub.elsevier.com/retrieve/pii/S0169534709002468.
13. Carter, T., Keeler, A. Life-cycle cost–benefit analysis of extensive vegetated roof systems. Journal of Environmental Management. 2008. 87(3). Pp. 350–363. DOI:10.1016/j.jenvman.2007.01.024. URL: https://linkinghub.elsevier.com/retrieve/pii/S0301479707000436.
14. Manso, M., Castro-Gomes, J. Green wall systems: A review of their characteristics. Renewable and Sustainable Energy Reviews. 2015. 41. Pp. 863–871. DOI:10.1016/j.rser.2014.07.203. URL: https://linkinghub.elsevier.com/retrieve/pii/S1364032114006637.
15. Pan, B.T.-C., Kao, J.-J. Comparison of indices for evaluating building green values based on greenhouse gas emission reductions. Ecological Indicators. 2021. 122. Pp. 107228. DOI:10.1016/j.ecolind.2020.107228. URL: https://linkinghub.elsevier.com/retrieve/pii/S1470160X20311675.
16. Perkins, M., Joyce, D. Living Wall and Green Roof Plants for Australia. (11)2012. 1–50 p. ISBN:9781742543529.
17. Theeuwes, N.E., Steeneveld, G.-J., Ronda, R.J., Holtslag, A.A.M. A diagnostic equation for the daily maximum urban heat island effect for cities in northwestern Europe. International Journal of Climatology. 2017. 37(1). Pp. 443–454. DOI:10.1002/joc.4717. URL: https://onlinelibrary.wiley.com/doi/10.1002/joc.4717.
18. Van Herzele, A., Wiedemann, T. A monitoring tool for the provision of accessible and attractive urban green spaces. Landscape and Urban Planning. 2003. 63(2). Pp. 109–126. DOI:10.1016/S0169-2046(02)00192-5. URL: https://linkinghub.elsevier.com/retrieve/pii/S0169204602001925.
19. Xiao, M., Lin, Y., Han, J., Zhang, G. A review of green roof research and development in China. Renewable and Sustainable Energy Reviews. 2014. 40(December 2020). Pp. 633–648. DOI:10.1016/j.rser.2014.07.147. URL: http://dx.doi.org/10.1016/j.rser.2014.07.147.
20. Yok, T.P., Sia, A. A Selection of Plants for Green Roofs in Singapore. 87(1)2009. 16–17 p. ISBN:9789810700522.
21. Carter, T., Jackson, C.R. Vegetated roofs for stormwater management at multiple spatial scales. Landscape and Urban Planning. 2007. 80(1–2). Pp. 84–94. DOI:10.1016/J.LANDURBPLAN.2006.06.005.
22. Dunnett, N., Kingsbury, N. Planting Green Roofs and Living Walls. Timber Press, 2008.
23. Emilsson, T. Extensive Vegetated Roofs in Sweden: Establishment, Development and Environmental Quality2006. ISBN:9157670862.
24. Vijayaraghavan, K. Green roofs: A critical review on the role of components, benefits, limitations and trends. Renewable and Sustainable Energy Reviews. 2016. 57. Pp. 740–752. DOI:10.1016/J.RSER.2015.12.119.
25. Dunnett, N., Kingsbury, N. Planting Options for Extensive and Semiextensive Green Roofs. Greening Rooftops for Sustainable Communities Conference. 2004.
26. Morau, D., Libelle, T., Garde, F. Performance Evaluation of Green Roof for Thermal Protection of Buildings In Reunion Island. Energy Procedia. 2012. 14. Pp. 1008–1016. DOI:10.1016/j.egypro.2011.12.1047. URL: https://linkinghub.elsevier.com/retrieve/pii/S1876610211044675.
27. Herath, H.M.P.I.K., Halwatura, R.U., Jayasinghe, G.Y. Evaluation of green infrastructure effects on tropical Sri Lankan urban context as an urban heat island adaptation strategy. Urban Forestry and Urban Greening. 2018. 29(November). Pp. 212–222. DOI:10.1016/j.ufug.2017.11.013. URL: https://doi.org/10.1016/j.ufug.2017.11.013.
28. Wijerathne, S., Halwatura, R. The impact of green roofs on urban heat island effect. Proceedings of the International Conference on Building Resilience (ICBR'11). 2011.
29. Liu, T.C., Shyu, G.S., Fang, W.T., Liu, S.Y., Cheng, B.Y. Drought tolerance and thermal effect measurements for plants suitable for extensive green roof planting in humid subtropical climates. Energy and Buildings. 2012. 47. Pp. 180–188. DOI:10.1016/j.enbuild.2011.11.043. URL: http://dx.doi.org/10.1016/j.enbuild.2011.11.043.
30. Halwatura, R.U. Effect of Turf Roof Slabs on Indoor Thermal Performance in Tropical Climates: A Life Cycle Cost Approach. Journal of Construction Engineering. 2013. 2013. Pp. 1–10. DOI:10.1155/2013/845158. URL: https://www.hindawi.com/journals/jcen/2013/845158/.
31. Dareeju, B., Meegahage, J.., Halwatura, R.U. Performance of green roof against the global warming. Transactions of the Institution of Engineers, Sri Lanka (IESL). 2011. Pp. 297–302. URL:

This publication is licensed under a CC BY-NC 4.0

http://dl.lib.mrt.ac.lk/handle/123/12078.
32. Mentens, J., Raes, D., Hermy, M. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landscape and Urban Planning. 2006. 77(3). Pp. 217–226. DOI:10.1016/j.landurbplan.2005.02.010. URL: https://linkinghub.elsevier.com/retrieve/pii/S0169204605000496.
33. Zaid, S.M., Perisamy, E., Hussein, H., Myeda, N.E., Zainon, N. Vertical Greenery System in urban tropical climate and its carbon sequestration potential: A review. Ecological Indicators. 2018. 91. Pp. 57–70. DOI:10.1016/j.ecolind.2018.03.086. URL: https://linkinghub.elsevier.com/retrieve/pii/S1470160X18302413.
34. Seyedabadi, M.R., Eicker, U., Karimi, S. Plant selection for green roofs and their impact on carbon sequestration and the building carbon footprint. Environmental Challenges. 2021. 4(November 2020). Pp. 100119. DOI:10.1016/j.envc.2021.100119. URL: https://doi.org/10.1016/j.envc.2021.100119.
35. Lugo, A., Rullan, J. The conservation message of the rehabilitated facilities of the International Institute of Tropical Forestry2015.
36. Kazemi, F., Mohorko, R. Review on the roles and effects of growing media on plant performance in green roofs in world climates. Urban Forestry and Urban Greening. 2017. 23. Pp. 13–26. DOI:10.1016/j.ufug.2017.02.006. URL: http://dx.doi.org/10.1016/j.ufug.2017.02.006.
37. Williams, N.S.G., Hughes, R.E., Jones, N.M., Bradbury, D.A., Rayner, J.P. THE PERFORMANCE OF NATIVE AND EXOTIC SPECIES FOR EXTENSIVE GREEN ROOFS IN MELBOURNE, AUSTRALIA. Acta Horticulturae. 2010. (881). Pp. 689–696. DOI:10.17660/ActaHortic.2010.881.113. URL: https://www.actahort.org/books/881/881_113.htm.
38. Williams, N.S.G., Rayner, J.P., Raynor, K.J. Green roofs for a wide brown land: Opportunities and barriers for rooftop greening in Australia. Urban Forestry & Urban Greening. 2010. 9(3). Pp. 245–251. DOI:10.1016/j.ufug.2010.01.005. URL: https://linkinghub.elsevier.com/retrieve/pii/S1618866710000099.
39. Blank, L., Vasl, A., Levy, S., Grant, G., Kadas, G., Dafni, A., Blaustein, L. Directions in green roof research: A bibliometric study. Building and Environment. 2013. 66. Pp. 23–28. DOI:10.1016/J.BUILDENV.2013.04.017.
40. Williams, N.S.G., Rayner, J.P., Raynor, K.J. Green roofs for a wide brown land: Opportunities and barriers for rooftop greening in Australia. Urban Forestry and Urban Greening. 2010. 9(3). Pp. 245–251. DOI:10.1016/j.ufug.2010.01.005. URL: http://dx.doi.org/10.1016/j.ufug.2010.01.005.
41. Wong, J.K.W., Lau, L.S.K. From the ‘urban heat island’ to the ‘green island’? A preliminary investigation into the potential of retrofitting green roofs in Mongkok district of Hong Kong. Habitat International. 2013. 39. Pp. 25–35. DOI:10.1016/J.HABITATINT.2012.10.005.
42. Jim, C.Y. Effect of vegetation biomass structure on thermal performance of tropical green roof. Landscape and Ecological Engineering. 2012. 8(2). Pp. 173–187. DOI:10.1007/s11355-011-0161-4.
43. Hwang, Y.H. Green roofs as local habitats in Singapore. Proceedings of the IFLA Asia Pacific Congress. 2014. Pp. 1–13. URL: https://scholar.googleusercontent.com/scholar.bib?q=info:gtwyGg4-cSMJ:scholar.google.com/&output=citation&scisig=AAGBfm0AAAAAV-BhUpp2enuRtZDDnWS4ft0vlnHFGcPl&scisf=4&ct=citation&cd=-1&hl=en.
44. Chow, M.F., Bakar, M.F.A., Wong, J.K. An overview of plant species and substrate materials or green roof system in tropical climate urban environment. AIP Conference Proceedings. 2018. 2030. DOI:10.1063/1.5066645.
45. Grullón – Penkova, I.F., Zimmerman, J.K., González, G. Green roofs in the tropics: design considerations and vegetation dynamics. Heliyon. 2020. 6(8). Pp. 0–7. DOI:10.1016/j.heliyon.2020.e04712.
46. ASTM International. Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems2015.
47. Snodgrass, E.C., Snodgrass, L.L. Green Roof Plants: A Resource and Planting Guide. Landscape Architecture. 2006. 97. Pp. 203. URL: http://www.loc.gov/catdir/toc/ecip0613/2006013821.html (date of application: 30.09.2021).
48. Charoenkit, S., Yiemwattana, S. Role of specific plant characteristics on thermal and carbon sequestration properties of living walls in tropical climate. Building and Environment. 2017. 115. Pp. 67–79. DOI:10.1016/J.BUILDENV.2017.01.017.

This publication is licensed under a CC BY-NC 4.0

49. Eksi, M., Rowe, D.B., Wichman, I.S., Andresen, J.A. Effect of substrate depth, vegetation type, and season on green roof thermal properties. Energy and Buildings. 2017. 145. Pp. 174–187. DOI:10.1016/j.enbuild.2017.04.017. URL: http://dx.doi.org/10.1016/j.enbuild.2017.04.017.
50. Wong, N.H., Kwang Tan, A.Y., Chen, Y., Sekar, K., Tan, P.Y., Chan, D., Chiang, K., Wong, N.C. Thermal evaluation of vertical greenery systems for building walls. Building and Environment. 2010. 45(3). Pp. 663–672. DOI:10.1016/J.BUILDENV.2009.08.005.
51. Catalano, C., Laudicina, V.A., Badalucco, L., Guarino, R. Some European green roof norms and guidelines through the lens of biodiversity: Do ecoregions and plant traits also matter? Ecological Engineering. 2018. 115(January). Pp. 15–26. DOI:10.1016/j.ecoleng.2018.01.006. URL: https://doi.org/10.1016/j.ecoleng.2018.01.006.
52. Winter, K., Holtum, J.A.M. Facultative crassulacean acid metabolism (CAM) plants: powerful tools for unravelling the functional elements of CAM photosynthesis. Journal of Experimental Botany. 2014. 65(13). Pp. 3425–3441. DOI:10.1093/JXB/ERU063. URL: https://academic.oup.com/jxb/article/65/13/3425/2877513 (date of application: 21.10.2021).
53. MacIvor, J.S., Lundholm, J. Performance evaluation of native plants suited to extensive green roof conditions in a maritime climate. Ecological Engineering. 2011. 37(3). Pp. 407–417. DOI:10.1016/j.ecoleng.2010.10.004. URL: https://linkinghub.elsevier.com/retrieve/pii/S0925857410002910.
54. Cameron, R.W.F., Taylor, J.E., Emmett, M.R. What's 'cool' in the world of green façades? How plant choice influences the cooling properties of green walls. Building and Environment. 2014. 73. Pp. 198–207. DOI:10.1016/j.buildenv.2013.12.005. URL: https://linkinghub.elsevier.com/retrieve/pii/S036013231300351X.
55. Environmental Protection Agency. Landscaping with Native Plants. . 2012URL: https://www.epa.gov/greenacres/.
56. Peck, S.. Award Winning Green Roof Designs. Pennsylvania, Schiffer Publishing Ltd, 2008.
57. Dunnett, N., Kingsbury, N. Planting Green Roofs and Living Walls. Timber Press, 2004.
58. Burghardt, K.T., Tallamy, D.W., Philips, C., Shropshire, K.J. Non-native plants reduce abundance, richness, and host specialization in lepidopteran communities. Ecosphere. 2010. 1(5). Pp. art11. DOI:10.1890/ES10-00032.1. URL: http://doi.wiley.com/10.1890/ES10-00032.1.
59. McKinney, M.L. Urbanization, Biodiversity, and Conservation. BioScience. 2002. 52(10). Pp. 883–890. DOI:https://doi.org/10.1641/0006-3568(2002)052[0883:UBAC]2.0.CO;2.
60. Tallamy, D.. Bringing Nature Home: How You Can Sustain Wildlife with Native Plants. Portland, OR, Timber Press, 2007.
61. Monterusso, M.A., Rowe, D.B., Rugh, C.L. Establishment and Persistence of Sedum spp. and Native Taxa for Green Roof Applications. HortScience. 2005. 40(2). Pp. 391–396. DOI:10.21273/HORTSCI.40.2.391. URL: https://journals.ashs.org/view/journals/hortsci/40/2/article-p391.xml.
62. Mowla, D.Q.A. Green Roof Concept for Eco-Sustainability in the Context of Urban Dhaka. 'GO GREEN; the Architecture of the New Order.' 2010. Pp. 13. URL: https://d1wqtxts1xzle7.cloudfront.net/33000863/MowlaLHR-ED_Roof_Garden_.pdf?1392456808=&response-content-disposition=attachment%3B+filename%3DGreen_Roof_Concept_for_Eco_Sustainabilit.pdf&Expires=1601732655&Signature=WS63V6N4FUGcKdt-Mt3czI81xGk6cglehBWcscZ.
63. Lundholm, J.T., Marlin, A. Habitat origins and microhabitat preferences of urban plant species. Urban Ecosystems 2006 9:3. 2006. 9(3). Pp. 139–159. DOI:10.1007/S11252-006-8587-4. URL: https://link.springer.com/article/10.1007/s11252-006-8587-4 (date of application: 21.10.2021).
64. Wittig, R. The origin and development of the urban flora of Central Europe. Urban Ecosystems 2004 7:4. 2004. 7(4). Pp. 323–329. DOI:10.1007/S11252-005-6833-9. URL: https://link.springer.com/article/10.1007/s11252-005-6833-9 (date of application: 21.10.2021).
65. Lundholm, J.T., Richardson, P.J. MINI-REVIEW: Habitat analogues for reconciliation ecology in urban and industrial environments. Journal of Applied Ecology. 2010. 47(5). Pp. 966–975. DOI:10.1111/j.1365-2664.2010.01857.x. URL: https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2010.01857.x.
66. Johnston, J., Newton, J. Building green : a guide to using plants on roofs, walls and pavements. 2004. (May). Pp. 120.
67. Dewey, D.W., Johnson, P.G., Kjelgren, R.K. Species Composition Changes in a Rooftop Grass and Wildflower Meadow: Implications for Designing Successful Mixtures. Native Plants Journal.

This publication is licensed under a CC BY-NC 4.0

2004. 5(1). Pp. 56–65. DOI:10.2979/NPJ.2004.5.1.56. URL: http://npj.uwpress.org/cgi/doi/10.2979/NPJ.2004.5.1.56.
68. White, J.., Snodgrass, E. Extensive green roof plant selection and characteristics. 1st Greening Rooftops for Sustainable Communities Conference. 2003.
69. Bird, R. Knowing and Growing Annuals and Perennials, an illustrated encyclopedia and complete practical gardening guide. Encyclopedia and complete practical gardening guide. Fulcrun Publication, 2004. Pp. 142.
70. Barrio, E.P. Del. Analysis of the green roofs cooling potential in buildings. Energy and Buildings. 1998. 27(2). Pp. 179–193. DOI:10.1016/S0378-7788(97)00029-7. URL: https://linkinghub.elsevier.com/retrieve/pii/S0378778897000297.
71. Dominguez-Hernandez, J., Lozano-Martinez-Luengas, A. Green Roof Systems. Adv. Ecol. Sc. 1998. 1. Pp. 615–624.
72. Ampim, P.A.Y., Sloan, J.J., Cabrera, R.I., Harp, D.A., Jaber, F.H. Green Roof Growing Substrates: Types, Ingredients, Composition and Properties. Journal of Environmental Horticulture. 2010. 28(4). Pp. 244–252. DOI:10.24266/0738-2898-28.4.244. URL: http://meridian.allenpress.com/jeh/article/28/4/244/79348/Green-Roof-Growing-Substrates-Types-Ingredients.
73. Nagase, A., Dunnett, N. The relationship between percentage of organic matter in substrate and plant growth in extensive green roofs. Landscape and Urban Planning. 2011. 103(2). Pp. 230–236. DOI:10.1016/j.landurbplan.2011.07.012. URL: http://dx.doi.org/10.1016/j.landurbplan.2011.07.012.
74. Lundholm, J., MacIvor, J.S., MacDougall, Z., Ranalli, M. Plant Species and Functional Group Combinations Affect Green Roof Ecosystem Functions. PLoS ONE. 2010. 5(3). Pp. e9677. DOI:10.1371/journal.pone.0009677. URL: https://dx.plos.org/10.1371/journal.pone.0009677.
75. Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R.R., Doshi, H., Dunnett, N., Gaffin, S., Köhler, M., Liu, K.K.Y., Rowe, B. Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. BioScience. 2007. 57(10). Pp. 823–833. DOI:10.1641/B571005. URL: http://academic.oup.com/bioscience/article/57/10/823/232363/Green-Roofs-as-Urban-Ecosystems-Ecological.
76. Tropical Plants Database. Sesuvium portulacastrum - Useful Tropical Plants. . 2019URL: http://tropical.theferns.info/viewtropical.php?id=Sesuvium+portulacastrum (date of application: 1.10.2021).
77. CABI. Alternanthera sessilis (sessile joyweed). . 2014URL: https://www.cabi.org/isc/datasheet/4404.
78. National Parks Board. Desmodium triflorum (L.) DC. . 2021URL: https://www.nparks.gov.sg/florafaunaweb/flora/5/6/5641.
79. Kaufman, S. Zoysia matrella (Manila grass). . 2016.
80. CABI. Murdannia nudiflora (doveweed). Invasive Species Compendium. 2017. URL: https://www.cabi.org/isc/datasheet/35180.
81. National Parks Board. Cyanotis cristata D.Don. . 2020URL: https://www.nparks.gov.sg/florafaunaweb/flora/1/9/1911.
82. National Parks Board. Callisia repens (Jacq.) L. . 2021URL: https://www.nparks.gov.sg/florafaunaweb/flora/1/7/1772.
83. National Parks Board. Phyla nodiflora (L.) Greene. . 2021URL: https://www.nparks.gov.sg/florafaunaweb/flora/3/7/3716.
84. National Parks Board. Vinca minor. . 2020URL: https://www.nparks.gov.sg/florafaunaweb/flora/2/5/2546.
85. Heuzé, V., Tran, G., Delagarde, R., Bastianelli, D., Lebas, F. Pinto peanut (Arachis pintoi). . 2017URL: https://www.feedipedia.org/node/702.
86. National Parks Board. Arachis pintoi. . 2020URL: https://www.nparks.gov.sg/florafaunaweb/flora/1/6/1684.