Kodituwakku, D., Ramachandra, T. and Madushika, U.G.D., 2023. A study of green roof application in Sri Lanka. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ramachandra, T. and Ranadewa, K.A.T.O. (eds). *Proceedings of the 11th World Construction Symposium*, 21-22 July 2023, Sri Lanka. [Online]. pp. 1-13. DOI: https://doi.org/10.31705/WCS.2023.1. Available from: https://ciobwcs.com/papers/

A STUDY OF GREEN ROOF APPLICATION IN SRI LANKA

Dasuni Kodituwakku[1], T. Ramachandra[2] and U.G.D. Madushika[3]

ABSTRACT

Green roofs are one of the green practices, having widespread use in the European and Asian regions due to their numerous benefits. However, country like Sri Lanka is yet to experience its optimum potential application. Thus, this study investigates the application of green roofs in Sri Lanka in terms of current status of its application, role in the green rating systems and implementation barriers to enhance its application in Sri Lanka. Initially, a preliminary survey, followed by semi-structured interviews with green roof construction professionals was conducted where the collected data were analysed using descriptive data analysis techniques. Amongst the identified set of applications, residential and commercial buildings are the most common building types with the extensive and semi-intensive green roof types. Although the most commonly used rating systems of GREEN$^{SL®}$ and LEED have various provisions, a very few out of number of buildings surveyed have incorporated green roofs. According to the green roof construction professionals, the application is limited in the Sri Lankan buildings due to fourteen (14) key barriers. Amongst those barriers, higher initial and maintenance costs, poor awareness of the public on the concept and lack of clients' willingness on the concept are the mostly identified barriers by the interviewees. Hence, the study recommends taking necessary actions to mitigate the barriers in order to enhance the green roof applications on the Sri Lankan buildings to optimise the multiple benefits if offers.

Keywords: *Application; Barriers; Green Roofs; Sri Lanka.*

1. INTRODUCTION

Modern world is running towards a foul direction with the competition among themselves while aligning with the rapid technological advancements (Dareeju et al., 2011b). The total population of the world is calculated as 7.8 billion in 2020 where it has predicted to increase by more than 25% in 2050 and become 9.9 billion approximately (Population Reference Bureau [PRB], 2021). Energy demand increases day by day and people tend to use low-cost energy sources available with higher greenhouse gas emission rates (Dareeju et al., 2011). However, since the growth and development of the world are considered as unavoidable constrains, immediate actions need to be sought to mitigate the negative impacts it causes on the planet earth (Clark et al., 2008).

Green roofing is considered as one of the worthful construction embedded concept in overcoming such negative impacts of global growths and developments (Mowla, 2010).

[1] Department of Building Economics, University of Moratuwa, Sri Lanka, ldasuni@uom.lk
[2] Department of Building Economics, University of Moratuwa, Sri Lanka, thanujar@uom.lk
[3] Department of Real Estate and Construction, The University of Hong Kong, Hong Kong, ugdmadu@connect.hku.hk

The unused roof spaces can be used to establish sustainable practices while aiding the natural green reduction of the built environments (Rowe & Getter, 2006). The modern enthusiasm on green roof concept was bloomed in Germany while encouraging its citizens to green their roofs (Barreiro, 2012). Researchers identified benefits offered by green roofs over conventional roofs in different aspects globally. Jaffal et al. (2012) identified a significant role of green roofs in reducing energy consumption and controlling indoor air temperature which results for less fuel usage in both summer and winter periods. Further, green roof was identified as a solution to mitigate the Urban Heat Island (UHI) effect in the study of Berardi et al.(2014).

Although green roofs offer more benefits, the applicability of green roofs is limited. One reason could be the financial capability of the people. This is because higher initial and maintenance costs of green roofs compared to the conventional roofs (Wilkinson et al., 2013). Adding to that, a lack of technical knowledge and data, maintenance manuals, accuracy and reliability of available data, and adequate documentation of proven successful green roofing of buildings can be considered as other barriers (Someh et al., 2014). Moreover, Zhang et al. (2012) indicated that lack of government incentives and promotion and social community among the public and private sectors were some other barriers to implementing green roofs. Similarly, Zhang et al., (2012) explained that lack of public awareness of the green roof concept, its benefits, and technology are collective reasons for less adaptation of this concept.

Sri Lanka is also not exceptional to global scenario, the concept is not much popular, and the public awareness is limited (Halwatura, 2013). Despite, few researchers have paid attention to investigate the green roof application in the local context. For example, Wijerathne and Halwatura (2011) experimented to measure the variation of CO_2 in greenery areas against city junctions and acknowledged that green roof implementation is beneficial to the cities of Sri Lanka. Subsequently, Subaskar (2017) has examined the applicability of green roofs to Sri Lankan high-rise buildings through an opinion survey. In addition, some of the studies have assessed the benefits of green roofing such as life cycle costing, mitigation of the urban heat island effect, and thermal performance of green roofing (Dareeju et al., 2011a; Halwatura, 2013).

Hence, prior to assessing the performance of green roofs in the local context, it is important to explore the awareness and application of the green roof concept in the local context as a foundation to enhance the green roof application. To this end, a study is undertaken to investigate the perception of professionals who have involved and gained experience and exposure in green roof application on the awareness based on their benefits and green features, implementation barriers, and strategies to enhance the application of green roofs towards promoting green roof application in Sri Lanka.

2. LITERATURE REVIEW

The green roof is one of the elements included in a green building as an effective strategy to enhance sustainability (Santamouris, 2014). Further, green, living, or eco-friendly roofs are used to provide durability, longevity, and aesthetics to buildings and those can be incorporated into new or existing buildings (Patnaik et al., 2018). Also, green roofs act as a solar protection cover that contributes to mitigating urban warming and cooling the ambient air (Subaskar, 2017). According to Almusaed and Almssad (2018), the origin of the green roof concept come over a long time. There are a variety of green roofs under

practice. Green roofs can be categorised based on the substrate thickness, bearing capacity of the rooftop, amount of maintenance required, installation cost, etc. (Capitanio, 2018). Mainly, there are three types of green roofs in practice; intensive, extensive, and semi-intensive (Patnaik et al., 2018). The main characteristics of different green roof types are presented in Table 1.

Table 1: Main characteristics of different green roof types

Details	Extensive	Intensive	Semi-intensive
Load bearing capacity	73-122 kg/m^2	171-391 kg/m^2	25-40 pounds
Substrate thickness	Less than 150 mm	Greater than 150 mm	125 mm - 200 mm
Vegetation usage	Grass	Trees, shrubs, bushes, grass	Shrubs, bushes
Irrigation requirement	Requires little or no irrigation	Requires regular irrigation	Requires considerable regular, little irrigation
Accessibility	Limited or no access	Accessible	Limited access
Structural design	Low or no additional structural design required	High additional structural design required	Moderate additional structural design required
Initial cost	Low	High	Moderate
Maintenance cost	Low	High	Moderate

Sources: (Shahidipour, 2014; Patnaik et al., 2018; Capitanio, 2018)

According to Vijayaraghavan (2016), the detailed layers of a green roof contain vegetation, growth substrate, filter fabric, drainage element, protection layer, root barrier, insulation layer, waterproofing layer and roof deck as shown in above Figure 1. However, the author further stated that the presence and absence of any of these layers will be depended upon the type of the roof, design and client requirements. Therefore, common basic green roof layers can be contrasted as vegetation, growth substrate, filter layer, drainage layer and waterproofing layer (Abass et al., 2020).

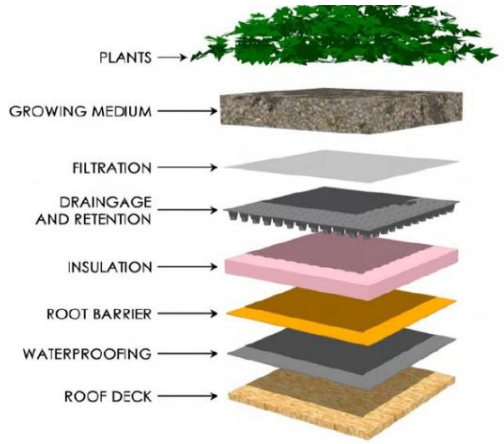

Figure 1: Cross-section of a typical green roof
Source: (Minnesota Pollution Control Agency, 2022)

Patnaik et al. (2018) stated that long-term client expectations and environmental benefits both can be achieved through proper selection of each layer. Hence, it is important to select each layer with due consideration as consisting of layers will affect the performance of a green roof (Shafique et al., 2018).

2.1 BENEFITS OF GREEN ROOFS

Green roofs can be identified as one of the green practices that offer more benefits in terms of environmental, economic, and social aspects. Figure 2 indicates a capture of multiple benefits that are offered by the green roofs.

Figure 2: Benefits of green roofs
Source: (Hussain et al., 2023)

Accordingly, improved air quality, ambient noise reduction, improved thermal insulation of the roof, building energy use reduction, new habitat for fauna and flora, reduction of stormwater runoff, ecological use of rainwater, food production, health and wellbeing and increase in roof life are the most significant benefits offered by the green roofs (Hussain et al., 2023). The benefits of improved air quality, ambient noise reduction, new habitat for fauna and flora, reduction of stormwater runoff, ecological use of rainwater can be categorised under the environmental benefits of green roofs (Ozyavuz et al., 2015) while improved thermal insulation of the roof, building energy use reduction and increase in roof life are categorised to the economic benefits of the roofing (Shafique et al., 2018). In addition, food production and health and wellbeing of the beings are the social benefits offered by the green roofs (Shafique et al., 2018).

2.2 BARRIERS TO THE APPLICATION OF GREEN ROOFS

Even though there are numerous benefits offered by the green roofs, still a deficiency can be observed in its application to the built environment (Hossain et al., 2019). Such a deficiency could be raised due to the various barriers that are forbidding the smooth application of the roof. Researchers have dedicated their studies to investigate such barriers that are limiting the application of green roofs in the built environment. Table 3

compiled a list of barriers to green roof application which were identified by various researchers in their studies.

Table 2: Barriers to green roof applications

Barrier	Source					
	(Zhang & He, 2021)	(Mahdiyar et al., 2020)	(Hossain et al., 2019)	(Ezema et al., 2015)	(X. Zhang et al., 2012)	(Williams et al., 2010)
Higher initial cost	√	√	√	√	√	
Higher maintenance cost	√	√	√	√	√	
Poor public awareness on the concept	√	√		√	√	
Lack of technical knowledge		√	√	√		√
Absence of government regulations	√	√		√		√
Challenges in installing on existing roofs	√	√		√	√	
Lack of skilled manpower	√	√	√			
Increase in structural loading	√		√	√		
Lack of established green roof industry						√
Issues in quality of the building	√		√	√		
Lack of suitable plants		√				
Lack of client's interest			√			

According to the table, there are twelve (12) key barriers that are limiting the green roof applications in the built environment. The additional structural requirements in terms of all planning, designing and construction perspectives have increased the initial costs of green roof application in compared to a conventional roof application (Hossain et al., 2019). In addition, there is a maintenance costs for green roofs as its components require regular maintenance activities (Mahdiyar et al., 2020). The concept is yet to have a wider spread in some contexts due to its poor awareness among general public, professionals in the construction industry and the governing authorities such as government (Hossain et al., 2019; Mahdiyar et al., 2020). Still worse, even if there is adequate awareness on the concept, in some contexts green roof application is hindered due to inadequate technical knowledge. The stakeholders do not willing to risks their investments in a concept with a poor technical knowledge and less competencies (Mahdiyar et al., 2020). Especially when the green roof installation is a retrofit for an existing roofing surface, the concerns raised with the structural loadings, design considerations and the quality level of the existing building elements (Hosaain et al., 2019; Mahdiyar et al., 2020). In addition, comparatively a smaller number of studies have identified lack of suitable plants (Mahdiyar et al., 2020) and lack of clients' interest on the concept (Hosaain et al., 2019). However, the limited availability of plants could be varied from context to context. The climatic conditions and the surroundings may determine the plants suitability. Therefore, there can be situations where the locally available plants also rejected in the suitability for the green roof installation. Finally, clients' preferences are also can be considered as a crucial factor in the green roof applications. Even though the roofing concept offer numerous benefits, the lesser willingness of the client on the concept may limit its

installations. Accordingly, the identified barriers can limit the green roof applications, which can be subjected to the variations from one context to another.

2.3 WHY FOCUS ON SRI LANKA?

Sri Lanka is a tropical country where rapid urbanisation can be observed in modern society (Halwatura, 2013). There is faster growth in changing urban non-built lands into built lands in the 2000s as 1268 ha per year while it was only 914 ha per year in the 1990s in Sri Lanka (Subasinghe, et al., 2016). Colombo, the commercial capital of the country is going to occupy the highest position in the green space reduction of the Indian sub-continent area (Li & Pussella, 2017). Sri Lankans also have been tensed more on green concepts with the negative impacts they experienced from urbanisation (Charles et al., 2019). Ranagalage, Estoque, and Murayama (2017) stated that the rapid increase in population and housing of the Colombo Metropolitan Area (CMA) has limited the green vegetation of the area, and needs to seek more alternative spaces for greenery. Halwatura (2013) identified green roofs as a positive solution for forthcoming impacts on both environment and society due to rapid urbanisation rates in Sri Lanka.

3. RESEARCH METHODOLOGY

Initially, a comprehensive literature review was conducted to review the existing knowledge on the green roof concept, technology, benefits, and barriers towards the green roof implementation. Thereafter, a preliminary survey was conducted through site visits, interviews with stakeholders and internet surveys to investigate the green roof application in the Sri Lankan buildings and its recognition in green rating systems. Subsequently, semi-structured interviews were conducted to explore the barriers toward less adaptation of the green roof concept in the Sri Lankan context. Accordingly, twelve (12) construction professionals who have directly involved with the identified green roof applications and having industry experience of more than five (5) years were interviewed including Architects, Landscape Architects, Quantity Surveyors, Green Roof Contractors, Maintenance Engineers and Design Engineers. The profile of the participants is presented in Table 3.

Table 3: Profiles of the interviewees

Respondent ID	Designation	Industry Experience
R1	Quantity surveyor	12 years
R2	Landscape Architect	7 years
R3	Chief Architect	25 years
R4	Quantity Surveyor	8 years
R5	Green Roof Contractor	10 years
R6	Green Roof Contractor	7 years
R7	Maintenance Engineer	12 years
R8	Design Engineer	17 years
R9	Landscape Architect	22 years
R10	Design Engineer	10 years
R11	Architect	10 years
R12	Quantity Surveyor	9 years

4. ANALYSIS AND FINDINGS

Green roof application in the Sri Lankan buildings was investigated through a preliminary survey as well as a questionnaire survey. The preliminary survey gathered data on the status of green roofs in the green rating systems, type of the buildings that incorporated green roofs, types of the green roofs available. Accordingly, following sections present the analysis and findings derived, related to green roof applications in the Sri Lankan buildings.

4.1 RECOGNITION OF GREEN ROOFS IN GREEN RATING SYSTEMS USED IN SRI LANKA

GREEN$^{SL®}$ and LEED are the two green rating systems commonly used in Sri Lanka. Green certification for the Sri Lankan buildings is mainly accomplished through two (2) main green rating systems as certification. To date, there are different versions of these rating systems available. For example, GREEN$^{SL®}$ has version 2.1 - the latest version with the total number of points that a building can earn under this rating system is 100 while the minimum point requirement for the certification is 40 points. Similarly, LEED-v4 is consisted of a total of 110 points and required minimum 40 points for its certification.

In both rating systems, there is not any direct points assigned for buildings embedding a green roof. However, there are various criteria whereby a building can indirectly earn credits for its green certification from a green roof. Table 4 illustrates a summary of various green features which support incorporation of green roof and the points assigned for those features.

Table 4: Possible sustainable criteria for embedding green roof

GREEN$^{SL®}$ - version 2.1		**LEED– v4**	
Criteria	**Points**	**Criteria**	**Points**
2.0 Sustainable sites		**Sustainable Sites**	
2.6.3 - Development of Footprint	2	*Open space*	1
2.7 – Storm water design, quality control	3	*Rainwater management*	3
2.8 – Heat Island effect, non – roof	1	*Heat island effect reduction*	2
2.9 – Heat Island effect - roof	1	**Energy and atmosphere**	
4.0 Energy and Atmosphere		*Optimise energy performance*	18*
4.1 – Optimise energy performance	10	**Indoor environmental quality**	
6.0 Indoor environmental quality		*Thermal comfort*	1
6.7 –R Thermal comfort, design and	1	*Acoustic performance*	1
8.0 Social and cultural awareness			
8.1.2 - Social wellbeing	1		

*Except schools and health care buildings. For schools 16 points, for health care buildings 20 points

As per Table, although the green roof is not identified as a separate technology, there is sufficient provisions made for embedding green roofs and absorb its benefits, via rating systems. On other hand, embedding green roofs help to achieve green certification as it contributes to earn required points through various criteria as evidence in Table 4.

4.2 GREEN ROOF APPLICATION IN DIFFERENT TYPES OF BUILDINGS

The survey identified altogether 30 different buildings with green roofs in Sri Lanka. Those buildings include both green certified and non-certified buildings. Figure 3 illustrates the distribution of those green roof applications.

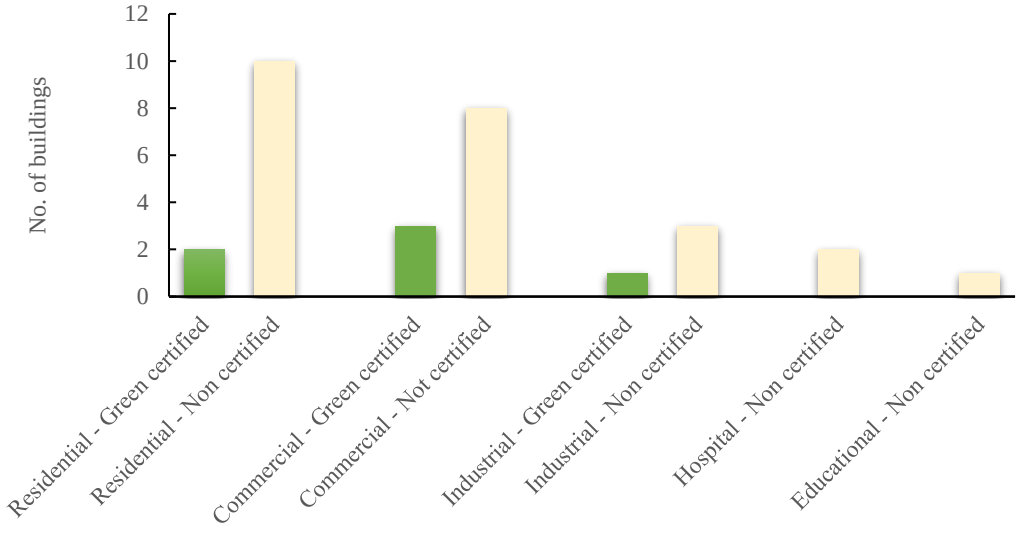

Figure 3: Green roof applications in different types of buildings

As seen from figure, amongst the surveyed buildings, residential (both apartments and single housing units), and commercial buildings (hotels and shopping complex), have mostly incorporated the green roofs, compared to other types. This could be due to owners' motive/willingness to attract the occupants through the green space. Amongst all types of buildings with green roofs, non-certified buildings are higher in numbers than certified. The most common concerns among the building owners were the lack of awareness on the green certification process and their non-willingness to obtain the certificate. Although most of them have installed green for the sake of recreational facility and the green space availability, the implied benefits such as cooling energy conservation, indoor air improvements or the stormwater run-off reductions were seemed to have achieved. It is worthy to note that even if the green ratings failed to provide recognition, building owners are willing to incorporate green roofs.

4.3 TYPES OF GREEN ROOF USED IN SRI LANKAN BUILDINGS

According to the collected green roof details, all three types of green roofs: intensive, semi-intensive and extensive are in use in the Sri Lankan buildings. Figure 4 represents the distribution of types of green roofs used in the thirty (30) buildings surveyed.

As seen from Figure 4, most of the considered buildings consist of extensive type (13) while the intensive type of roof is least used, only five (5). Semi-intensive type also could be observed in twelve (12) buildings. According to most of the green roof designers and owners of the 30 green roof applications, except a few large-scale green roof stakeholders, the green roofs are being embedded into their buildings for the purpose of aesthetic appearance than other benefits offered.

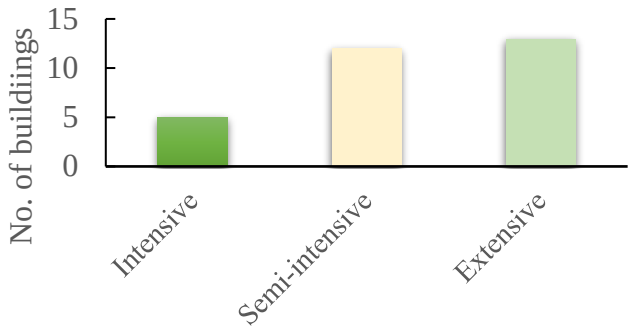

Figure 4: Different types of green roofs used in the buildings

The additional and complex structural design requirements have also influenced the type of green roof. In addition, the maintenance activities of vegetation, mainly the grass or the shrubs are quite simple than larger trees. These have motivated use of higher number of both extensive and semi-intensive.

4.4 BARRIERS TO GREEN ROOF IMPLEMENTATION IN SRI LANKA

The literature findings have mainly identified fourteen (14) barriers for green roof applications in the global context. Interviews with the construction professionals who have directly involved with the green roof applications in the Sri Lankan buildings were focused to investigate the barriers of green roof applications specifically in the Sri Lankan context. According to their responses, all the identified barriers from the literature are considerable in the Sri Lankan context. In addition, the respondents identified that the complexities in the green roof designing and lack of knowledge sharing institutions are also key barriers that limits the green roof application in the Sri Lankan buildings. Table 5 summarises the opinions of the interviewees on all identified barriers to the green roof applications on the Sri Lankan buildings.

Table 5: Summary of responses of the interviewees

Barrier	Respondent												Total
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	
Higher initial cost	√	√	√	√	√	√	√	√	√	√	√	√	12
Higher maintenance cost	√	√	√	√	√	√	√	√	√	√	√	√	12
Poor public awareness on the concept	√	√	√	√	√	√	√	√	√	√	√	√	12
Lack of client's interest	√	√	√	√	√	√	√	√	√	√	√	√	12
Absence of government regulations	√	√	√	√	√		√	√	√		√		9
Lack of knowledge sharing authorities		√	√	√	√		√	√		√	√		8
Increase in structural loading	√		√	√		√	√		√	√		√	8

Barrier	Respondent												Total
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	
Challenges in installing on existing roofs	√	√		√		√		√		√	√		7
Lack of technical knowledge			√	√		√				√	√	√	6
Issues in quality of the building	√	√			√		√	√			√		6
Lack of established green roof industry		√	√			√	√	√	√				6
Design difficulties	√				√		√			√		√	5
Lack of skilled manpower				√			√			√		√	4
Lack of suitable plants		√								√			2

According to the Table, all interviewees have identified high initial cost, high maintenance costs and poor public awareness on the concept as the key barriers to the green roof applications in the Sri Lanka. The barriers were similarly identified as significant in the literature (Hossain et al., 2019; Mahdiyar et al., 2020). However, lack of clients' interest on the roofing was only identified in the study of Hossain et al. (2019) while other referred studies have not identified it. Conversely, all the interviewees have identified the lack of interest of the client as a key barrier to green roof applications in the Sri Lankan buildings. *"Clients are not willing to install green roofs due to their narrow understanding on the concept"* stated by the R2 respondent. *"Therefore, it is required to have knowledge sharing institutions to enhance the awareness on green roof applications in Sri Lanka"* was further added by the respondent. However, there are very few knowledge sharing institutions for green roofs. *"Even there are institutions, those are not specific to the green roofs"* was added by R5 respondent. In addition, R1 respondent emphasised that the design difficulties in green roof installation is still a concern in the Sri Lankan context. *"In the unique designs of green roofs, sometimes our designers are not rich enough to determine some key design considerations"* stated by the R1 respondent. Once again, the issue can be overcome with the availability of a knowledge sharing institution where all the stakeholders can obtain all kinds of advices when required. Similarly, the interviewees have extended their opinions on the other identified barriers also. However, the lack of suitable plants was only identified by 2 interviewees while others stated that the local plants would facilitate any lacking situation. However, the fact emphasised by the R2 respondent was *"we need properly examined a vegetation type before it installs, so how we simply can rely on any locally available plant for the sake of necessity?".* The argument was same in the study of Mahdiyar et al. (2020), which the only study that the barrier was mentioned. Accordingly, it shows that there are many obstacles that limits the green roof application in the Sri Lankan buildings. Therefore, the stakeholders should take necessary actions to mitigate and overcome these barriers for the smooth application of green roofs in the Sri Lankan buildings.

5. CONCLUSIONS

Amongst the selected sample buildings, residential and commercial buildings have incorporated green roofs mostly. The green spaces attract occupants of those buildings and contribute to increase income and property values. However, the study included a randomly selected limited sample buildings due to accessibility constrains. Another noteworthy conclusion is that most of the buildings (24 out of 30) are not green certified. This gives an indication that even the awareness of green certification lacks, building owners are willing to adopt green roofs. In terms of the type of the green roofs, buildings have mostly embedded extensive and semi-intensive green roofs, different to the experience in global context where intensive type is considered more beneficials while expensive is nature. In terms of the barriers, interviewees have identified all the barriers that stated in the literature while introducing two (2) additional barriers. Among those barriers, high initial and maintenance costs, poor awareness and lack of clients' willingness are the mostly identified barriers by the interviewees. Accordingly, the study recommends the stakeholders to take necessary actions to overcome these barriers while prioritising the most significant barriers.

6. REFERENCES

Abass, F., Ismail, L. H., Wahab, I. A., & Elgadi, A. A. (2020). A review of green roof: definition, history, evolution and functions. *IOP Conference Series: Materials Science and Engineering*, *713*(1), pp.1-8. https://doi.org/10.1088/1757-899X/713/1/012048

Almusaed, A., & Almssad, A. (2018). Introductory chapter: Overview of sustainable cities, theory and practices. In A. Almusaed & A. Almssad (Ed.), *Sustainable Cities-Authenticity, Ambition and Dream.* (pp.3-22), London: IntechOpen Limited. doi:10.5772/intechopen.82632

Barreiro, L. (2012). *Rooftop gardening in an urban setting: Impacts and implications*. [Master's thesis]. Duquesne University, USA. https://dsc.duq.edu/etd/278

Berardi, U., GhaffarianHoseini, A. H., & GhaffarianHoseini, A. (2014). State of the art analysis of the environmental benefits of green roofs. *Applied Energy*, *115*, pp.411–428. https://doi.org/10.1016/j.apenergy.2013.10.047

Capitanio, M. (2018). Assessing the manifold potential of green roofs in Shimokitazawa, Tokyo. *Smart and Sustainable Built Environment, 7*(2), pp.212-222. DOI: 10.1108/SASBE-03-2018-0012

Charles, S., Vidyaratne, H., & Melagoda, D. G. (2019). Prospects and restraints of green roofs for high-rise buildings in Sri Lanka. *Built Environment Project and Asset Management*, *10*(2), pp.246–260. https://doi.org/10.1108/BEPAM-11-2018-0150

Clark, C., Adriaens, P., & Talbot, F. B. (2008). Green roof valuation: A probabilistic economic analysis of environmental benefits. *Environmental Science & Technology*, *42*(6), pp.2155–2161. https://doi.org/10.1021/es0706652

Dareeju, B., Meegahage, J., & Halwatura, R. (2011a). Indoor thermal performance of green roof in a tropical climate. In D. Amaratunga, R. Haigh, K. Keraminiyage, U. Kulatunga, & C. Pathirage (Eds.), *International Conference on Building Resilience (IBR 2011), Kandalam, Sri Lanka*, 19-21 July 2011. International Institute for Infrastructure Renewal and Reconstruction. https://www.researchgate.net/profile/Rangika-Halwatura/publication/278032434_Indoor_Thermal_Performance_of_Green_Roof_in_a_Tropical_Climate/links/557abdb008aee4bf82d5729f/Indoor-Thermal-Performance-of-Green-Roof-in-a-Tropical-Climate.pdf

Dareeju, B., Meegahage, J., & Halwatura, R. (2011b). Performance of green roof against the global warming. *In Annual Transactions of IESL 2011, Sri Lanka.* (pp. 297-302). The Institution of Engineers, Sri Lanka. https://www.researchgate.net/profile/Rangika-Halwatura/publication/278035848_Performance_of_Green_Roof_against_the_Global_Warming/links/557af8b708aea62633570340/Performance-of-Green-Roof-against-the-Global-Warming.pdf

Ezema, I. C., Ediae, J., & Ekhaese, E. N. (2015, May). Opportunities for and barriers to the adoption of green roofs in Lagos, Nigeria. *In Proceedings of the International Conference on African Development Issues (CU-ICADI 2015*), 11-13 May 2015. (pp. 220-226), Covenant University Ota, Ogun, Nigeria. https://core.ac.uk/download/pdf/32226341.pdf

Halwatura, R. (2013). Effect of turf roof slabs on indoor thermal performance in tropical climates: A life cycle cost approach. *Journal of Construction Engineering, 2013*, 845158. https://doi.org/10.1155/2013/845158

Hossain, M. A., Shams, S., Amin, M., Reza, M. S., & Chowdhury, T. U. (2019). Perception and barriers to implementation of intensive and extensive green roofs in Dhaka, Bangladesh. *Buildings, 9*(4). https://doi.org/10.3390/buildings9040079

Hussien, A., Jannat, N., Mushtaha, E., & Al-Shammaa, A. (2023). A holistic plan of flat roof to green-roof conversation: Towards a sustainable built environment. *Ecological Engineering, 190*, 106925. https://doi.org/10.1016/j.ecoleng.2023.106925

Jaffal, I., Ouldboukhitine, S. E., & Belarbi, R. (2012). A comprehensive study of the impact of green roofs on building energy performance. *Renewable Energy, 43*, pp.157–164. https://doi.org/10.1016/j.renene.2011.12.004

Li, L., & Pussella, P. G. R. N. I. (2017). Is Colombo city, Sri Lanka secured for urban green space standards? *Applied Ecology and Environmental Research, 15*(3), pp.1789–1799. https://doi.org/10.15666/aeer/1503_17891799

Mahdiyar, A., Mohandes, S. R., Durdyev, S., Tabatabaee, S., & Ismail, S. (2020). Barriers to green roof installation: An integrated fuzzy-based MCDM approach. *Journal of Cleaner Production, 269*. https://doi.org/10.1016/j.jclepro.2020.122365

Minnesota Pollution Control Agency (2022, August 15). *Cross-section of a typical green roof*. Minnesota Stormwater Manual. https://stormwater.pca.state.mn.us/index.php?title=File:Cross-section_of_a_typical_green_roof.PNG

Mowla, Q. A. (2010). Green Roof Concept for Eco-Sustainability in the Context of Urban Dhaka. In *International seminar on GO GREEN; The Architecture of the new Order, Lahore, Pakistan*, 25-30 October 2010. (pp. 25-30). ARCASIA. https://www.academia.edu/6084128/Green_Roof_Concept_for_Eco_Sustainability_in_the_Context_of_Urban_Dhaka

Ozyavuz, M., Karakaya, B., & Ertin, D. G. (2015, April 15-17). The effects of green roofs on urban ecosystems. *GreenAge Symposium, Mimar sinan fine arts*, 15-17 April 2015. (pp. 1-8). University Faculty of Architecture, Istanbul, Turkey. https://www.researchgate.net/profile/Murat-Oezyavuz/publication/315792406_The_Effects_of_Green_Roofs_on_Urban_Ecosystems/links/58e54b49a6fdcc6800b144f1/The-Effects-of-Green-Roofs-on-Urban-Ecosystems.pdf

Patnaik, B., Sekhar, S., Mathewos, E., & Gebreyesus, T. (2018). Impact of green roofs on urban living. *International Journal of Current Engineering and Technology, 8*(6), pp.1656-1659, doi:10.14741/ijcet/v.8.6.21

Peck, S., & Callahan, C. (1999). *Greenbacks from green roofs: forging new industry in Canada*. Ottawa: Canada Mortgage and Housing Corporation. https://commons.bcit.ca/greenroof/files/2012/01/Greenbacks.pdf

Population Reference Bureau. (2021, June 24). 2020 World population data sheets. Retrieved June 24, 2021, from https://interactives.prb.org/2020-wpds/

Ranagalage, M., Estoque, R. C., & Murayama, Y. (2017). An urban heat island study of the Colombo metropolitan area, Sri Lanka, based on landsat data (1997-2017). *International Journal of Geo-Information*, *6*(7), 189. https://doi.org/10.3390/ijgi6070189

Rowe, D. B., & Getter, K. L. (2006). The role of extensive green roofs in sustainable development. *HortScience, 41*(5), pp.1276–1285. https://doi.org/10.21273/HORTSCI.41.5.1276

Santamouris, M. (2014). Cooling the cities-A review of reflective and green roof mitigation technologies to fight heat islands and improve comfort in urban environments. *International Journal for Solar Energy, 103*, pp.682-703. doi:10.1016/j.solener.2012.07.003

Shafique, M., Kim, R., & Rafiqe, M. (2018). Green roof benefits, opportunities, and challenges. *Renewable and Sustainable Energy Reviews, 90*, pp.757-773. doi:10.1016/j.rser.2018.04.006

Someh, M., Basiri, M., & Azim, A. (2014). The role of green roofs in urban sustainability. *European Scientific Journal, 10*(10), pp.69 – 75. https://eujournal.org/index.php/esj/article/view/4790

Subasinghe, S., Estoque, R. C., & Murayama, Y. (2016). Spatiotemporal analysis of urban growth using GIS and remote sensing: A case study of the Colombo metropolitan area, Sri Lanka. *ISPRS International Journal of Geo-Information, 5*(11), 197. https://doi.org/10.3390/ijgi5110197

Subaskar, L. C. (2017). *Applicability of green roofs in Sri Lankan highrise buildings: Drives and barriers.* [Unpublished undergraduate dissertation]. University of Moratuwa.

Tassicker, N., Rahnamayiezekavat, P., & Sutrisna, M. (2016). An insight into the commercial viability of green roofs in Australia. *Sustainability*, *8* (7), 603. doi.org/10.3390/su8070603.

Vijayaraghavan, K. (2016). Green roofs: A critical review on the role of components, benefits, limitations and trends. *Renewable and Sustainable Energy Reviews*, *57*, pp.740–752. https://doi.org/10.1016/j.rser.2015.12.119

Wijerathne, S. N., & Halwatura, R. (2011). Amplification of comfort and the air quality with green roofs in cities. *In Proceedings of the International Conference on Structural Engineering Construction and Management, Kandy, Sri Lanka, 16–18 December 2011*. (pp. 1-10). http://dl.lib.mrt.ac.lk/handle/123/8376

Wilkinson, S., Gosh, S., & Page, L. (2013). Option for green roof retrofit and urban food production in the Sydney CBD, *Proceedings of RICS COBRA Conference*, New Delhi, India. (pp. 1-8). https://www.researchgate.net/profile/Sara-Wilkinson-2/publication/291832869_Options_for_green_roof_retrofit_and_urban_food_production_in_the_Sydney_CBD/links/56a739da08ae0fd8b3fdee51/Options-for-green-roof-retrofit-and-urban-food-production-in-the-Sydney-CBD.pdf

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 and Urban Greening, 9*(3), pp.245–251. https://doi.org/10.1016/j.ufug.2010.01.005

Zhang, G., & He, B.-J. (2021). Towards green roof implementation: Drivers, motivations, barriers and recommendations. *Urban Forestry & Urban Greening, 58,* 126992. https://doi.org/https://doi.org/10.1016/j.ufug.2021.126992

Zhang, X., Shen, L., Tam, V. W., & & Lee, W. W. (2012). Barriers to implementing extensive green roof systems: A Hong Kong study. *Renewable and Sustainable Energy Reviews*, *16* (1), pp.314-319. doi.org/10.1016/j.rser.2011.07.157.