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# REVIEW OF SIGNIFICANT MAINTENANCE CRITERIA FOR TROPICAL GREEN ROOFS IN MALAYSIA

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## ABSTRACT

The implementation of green roofs on the top of buildings is becoming a trend in urban cities as they provide numerous benefits for green development growth. In Malaysia, numerous approaches towards sustainable development have been adopted in order to overcome crucial environmental issues such as urban heat islands, air pollution and lack of green spaces. One of the sustainable approaches that helps to minimize such problems is the use of vegetation or plant material on rooftops, also known as green roofs. Among the benefits of implementing green roofs or buildings are reducing heat flux, optimizing energy efficiency, and improving storm water management. Despite the benefits of green roof installation, the maintenance consideration is still largely unexplored and is a significant factor in the viability of green roof installation. Therefore, this paper aims to identify the significant criteria for green roof maintenance practice in Malaysia, as an added value to the existing practice that has previously been more concerned with design and benefit considerations. The literature findings reveal that there are generally 20 criteria related to such maintenance. Out of these, six are identified as the most significant factors in the best practice of green roof maintenance, being appropriate and important for the Malaysian tropical climate. The findings can serve as added value to existing practice, which has previously been more concerned with design and benefit. Therefore, they will also help to improve current green roof maintenance undertaken by building operators and maintenance managers.

*Keywords:* Green roof; Green roof maintenance; Maintenance; Maintenance criteria; Tropical

## 1. INTRODUCTION

Malaysia is a tropical country located on the South China Sea, lying at latitude 3.12 °N and longitude 101.55 °E (Mirrahimi et al., 2016). The tropical region is an uncomfortable climate zone that experiences a large amount of solar radiation, high temperatures, high levels of relative humidity, and long periods of sunny days all year round (Al-obaidi et al., 2014). This is also supported by Khalil & Husin (2009), who describe the location of Malaysia as a tropical climate region, which is naturally hot and humid. Moreover, due to the rapid growth of the urban population, this region has experienced a rise in urbanization, especially in developed countries such as Singapore, Malaysia and Indonesia (Al-obaidi et al., 2014). The boom in the urban population has led to mass development and has reduced the number of green areas.

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In 2012, a study by Yusof and Johari (cited in Chow & Abu Bakar, 2016) stated that the green areas of Kuala Lumpur had been reduced from their original 24,222 hectares in the city area to 14,386 hectares (59.4% of the total). This rapid development has also boosted the intensity of urban heat islands (UHIs) (Wong & Yuen, 2011). All of these risks are emerging as sustainability challenges that must be addressed by urban governments, so climate mitigation and adaptation efforts are intrinsic aspects of long-term city planning (Hidayatno et al., 2015). Nevertheless, the construction industry in Malaysia has been developing concurrently with sustainable development and is working to end the problems which have occurred in recent decades. One of the sustainable approaches to help minimize environmental problems is the use of of vegetation or plant material on rooftops, also known as green roofs.

Many buildings in developed countries such as Germany, Canada, Japan, America and Singapore have used green roofs as a solution to reduce environmental problems and provide benefits. As stated by Herman (2003), about 14% of all flat roofs in Germany have adapted the green approach and the supportive government policies have made it typical to have green roofs in cities. At the same time, over the past few decades, green roofs have become well accepted and more popular across Europe (Kamarulzaman et al., 2014). Furthermore, Getter & Rowe (2006) also mention that the roof area in most urban regions would usually constitute around 21%–26% of the total area. Therefore, such roofing would provide the possibility to add to the urban green area. The technology is also becoming common in the USA, for instance in Chicago, Portland, Atlanta and other cities (Ismail et al., 2016). Meanwhile in Canada, the Canadian government began incorporating green roofs in a series of sustainable initiatives, making them eligible for partial reimbursement and funding (Snodgrass & McIntyre, 2010). Moreover, the Ministry of Federal Territories and Urban Wellbeing Malaysia through "The Greening of Greater KL" program, have targeted a total area of conventional roofing of 150,000 $m^2$ to be converted into green roofs by 2020 (Getter & Rowe, 2006). That was a very great initiative by the Government to help promote the implementation of green roofs in the country, even though the program is still at the preliminary stage.

Although the application of green roofs in the country is still low, there have been some successful green roofs applications applied to a few buildings in Malaysia, and it is slowly becoming a trend in the building industry. Regardless of the green roof implementation on certain buildings that has taken place, challenges in terms of maintenance should also be taken into account and given attention. There have been cases where the main problems in green roofs have been technical issues, such as damage to water proofing; leakage onto the floor structure at green roof level; and blockage in the drainage system, increasing the occurrence of water ponding, as well as mosquito breeding (Ismail et al., 2010). Thus, the lack of maintenance is seen to be observable fact that can result in roof gardens not functioning as intended *(*Ismail et al., 2010). The establishment of plant material on rooftops provides numerous benefits to people and nature. When considering the viability of the installation of green roofs, the maintenance process is a highly important factor, and is believed to be one of the major obstacles to their installation.

Therefore, the aim of this paper is to identify the significant criteria for green roof maintenance practice in Malaysia. The objective of the research is to establish current practices and the vital criteria needed for green roof maintenance. Hence, the findings of the paper are presented to achieve the research objective. Moreover, the findings can serve as added value to existing practice, which has previously been more concerned with design and benefit consideration. In order to achieve this aim, previous studies on types of green roof, and their relation to the significance of maintenance and maintenance criteria, have been explored in both local and international contexts.

## 2. TYPES OF GREEN ROOF: EXTENSIVE AND INTENSIVE

A green roof is defined as a flat or sloping rooftop designed to help support vegetation, in addition to being designed to provide a fully functioning roof for a building (Ismail et al., 2010; Kamarulzaman et al., 2014). Snodgrass and McIntyre (2010) state that a green roof is characterized by plants on the top layer of the roof, or by a roof covered by vegetation in a layer of soil or growing medium in order to enhance roof performance as well as its appearance. Additionally, it is also classified as a vegetated roof system, with plants growing on the rooftops in order to replace the vegetated footprint that was destroyed when the building was built (Getter & Rowe, 2006; Fauzi et al., 2013; Chow & Abu Bakar, 2016). In short, a green roof is basically a flat or sloping roof covered and layered with vegetation in order to maximize the use of green space, especially in urban areas.

Essentially, green roofs can be divided into two distinct types: extensive or intensive (Hui, 2010; Abdul Rahman et al., 2013; Abdul Rahman et al., 2015; Silva et al., 2015; Jim, 2017). As shown in Figure 1, an extensive green roof is thinner, simpler and a lighter kind of roof, which it is normally suitable for lightweight buildings. Usually, it only needs a shallow substrate of a depth of about 15 cm or less, and the selection of vegetation is more limited than with a intensive green roof, with the plants adopted usually small plant species, such as sedum, shrubs and bushes that only need low maintenance and can be self-generative. This means an extensive green roof is cheaper and easier to build and maintain than an intensive one. This type of green roof is rarely accessible to the public, most of the time only being accessible for maintenance purposes (Abdul Rahman et al., 2013).

(a) (b)

Figure 1 (a) Extensive; and (b) intensive green roofs (Getter & Rowe, 2006)

Intensive green roofs, also known as roof gardens, are heavier and strong enough to support an additional load, and are suitable for underground garages and heavy buildings, as shown in Figure 1. Therefore, as they are generally heavy, the system requires specific support from the building (Abdul Rahman et al., 2013). Moreover, they require a deeper substrate of a minimum depth of 15 cm, and can support a variety of vegetation including trees, big shrubs, bushes and many species of ornamental plants. As described by Hui (2006), they sometimes have additional features such as walkways, benches and playgrounds, or even ponds can be set up on the roof. Hence, they require regular garden maintenance and need proper irrigation systems, which make them costly to build and maintain, as intensive maintenance is needed periodically by skilled labor (Fauzi et al., 2013). The intensive green roof is usually accessible to the public, as it has the same facilitates as a park or normal garden; it is simply that the garden is located on the building structure which makes it different from a normal one. Table 1 shows the

differences between intensive and extensive green roofs, as compiled from Bass et al. (2013) and Getter & Rowe (2006).

Table 1 Key differences between extensive and intensive green roof (Getter & Rowe, 2006; Bass et al., 2013)

| Key Difference | Extensive Green Roof | Intensive Green Roof |
|---|---|---|
| Growing Medium/ Structural Preparation (source: Bass et al., 2013) | • Depth of growing media generally between 50–100 mm (2–4 inches)<br>• Minimal to no irrigation<br>• Lightweight<br>• Structural engineering usually not required<br>• Suitable for covering large surface areas | • Depth of growing media greater than 100 mm (4 inches)<br>• More likely to require irrigation<br>• Heavier in weight<br>• Requires structural engineering<br>• Used over smaller areas or in landscaped containers |
| Vegetation (source: Bass et al., 2013) | • Stressful conditions for plants require low-growing drought-resistant species<br>• Can support few plant species, generally monoculture | • Deeper substrate can support a wider range of native plant species<br>• Can be designed to simulate a greater range of plant species and habitats |

Even though the scenario of green roofs in Malaysia is still at a preliminary stage, the country has already initiated a green roof project, which includes a rooftop paddy field, known as the "Rice Garden", in Langkawi built in the late 90s (Zahir et al., 2014). Since then, several buildings have been built with green roofing features, but the numbers are not encouraging. Table 2 shows a list of successful buildings with green roofs in Malaysia.

Table 2 Implementation of green roofs in Malaysia (Zahir et al., 2014)

| Building | Types of Green Roof | Year |
|---|---|---|
| Rice Garden Museum (Laman Padi), Langkawi. | Intensive | 1998 |
| Ministry of Finance, Putrajaya | Extensive and Intensive | 2002 |
| Putrajaya International Convention Centre (PICC), Putrajaya | Intensive and Extensive | 2003 |
| Putrajaya City Hall, Putrajaya | Extensive | 2004 |
| Malaysian Design Technology Centre (MDTC), LKW, Cyberjaya | Extensive | 2004 |
| Serdang Hospital | Intensive | 2005 |
| Faculty of Social Sciences and Humanities, UKM | Retrofit Extensive | 2007 |
| Sime Darby Oasis, Damansara | Extensive | 2009 |
| KL Sentral Park @ Platinum | Intensive | 2009 |
| Newcastle University Medicine Malaysia, Nusajaya | Extensive | 2011 |
| Laman PKNS, Shah Alam | Intensive | 2013 |
| Heriot-Watt University, Putrajaya. | Extensive | 2014 |
| Tun Razak Exchange (TRX), Kuala Lumpur. | Intensive | Expected in 2018 |

By considering the type of green roof, the maintenance criteria are therefore critical factors in the operational phase of a building. As mentioned by Saiz et al. (2006), building maintenance and operation is one of the critical factors in the stages of the building life cycle. To sustain the building life span with a green roof installation, the criteria of green roof maintenance should ideally be highlighted when reviewing the viability of its installation. Determining suitable criteria for maintenance helps to prolong the lifespan of building, thus achieving sustainability. As argued by Khalil et al. (2015), appropriate building and maintenance assessment through suitable criteria and indicators can help organizations to reduce building operation costs, including green roof maintenance.

## 3. GREEN ROOF MAINTENANCE CRITERIA

As buildings age, they require maintenance. Nowadays, it is a truism that no building is maintenance-free. In accordance with the Government's instruction on the maintenance management of government buildings and assets through General Circular (No.1) dated 11th February 2003, building maintenance must be efficiently and properly executed (Mohd-Noor et al., 2011). Maintenance is defined as the required services to preserve, repair and protect a building after its completion to fulfill its intended functions without drastically upsetting its basic features and use (Olanrewaju, 2010). Idrus et al., (2010) describe maintenance as continuous care and protection, entailing minor repair works to certain elements to ensure good conditions and to prolong the building lifespan. It can also be explained as a process in which the structure and components of a building undergo preservation and restoration activity (Akasah et al., 2009). In short, maintenance is the work executed to maintain an asset and preserve its continuity of use at a reasonable level of performance without any unforeseen renewal or major repair activities.

Hence, this section employs the maintenance criteria derived from previous researchers to examine green roof systems. It was found that many studies have been conducted on green roof implementation issues in both local and international contexts, concerning the design approach, benefits, characteristics and installation requirements. However, only a few studies have focussed on the maintenance of green roofs, particularly in Malaysia. Clearly, maintenance should be considered in the early design of green roofs, since the duration of building operation lasts longer than other building stages. By exploring and understanding the viewpoints of past studies, the maintenance criteria for green roofs can be ascertained, leading to better results. Therefore, this paper is addressed as an exploratory step and initial establishment in assessing the suitable maintenance criteria that can be used in this study.

Limiting the exploration to the maintenance of green roofs, several elements or maintenance items were ascertained. For example, a study carried out by Kamarulzaman et al. (2014) pointed out that vegetation, the growing medium, filter mats, drainage layer, insulation, root barrier and waterproof membrane were the main criteria needed in the maintenance of green roofs. Meanwhile, Ismail et al. (2016) highlighted several other elements or criteria, such as roof slabs, waterproofing membrane, drainage system, fertilization, pruning, weed control and irrigation system.

In addition, Tolderlund (2010) emphasizes the green roof maintenance criteria of waterproofing membrane, drainage inspection, rooftop structures, plants and growing medium, together with weeding, watering, pruning, fertilization, replacing plants and also irrigation. Luckett (2009) stresses more the vegetation aspect, involving watering, fertilizers, weeds and pests. Harris (2014) analyses the criteria of irrigation, fertilization, plant management and clearance or debris removal. Silva et al. (2015) divide the criteria into two groups, layers and other elements, while Townshend (2006) underlines the importance of waterproofing inspection, drainage inspection, plant health inspections, replacing plants, irrigation, pruning, fertilizing, pest control and weeding as the important criteria in maintaining green roof systems. Moreover, Gedge et al. (2013) discuss the criteria of functional layers, roof deck, climate, thermal performance, stability, insulation, waterproofing, storm water management and also the vegetation of the green roof.

Based on the above, the findings are further compiled and summarised, as shown in Tables 3 and 4. Table 3 lists 20 criteria and descriptions, indicated by abbreviations. These criteria are deemed to be the significant factors that should be considered in the maintenance management of green roof applications.

Table 3 Abbreviation and description of the maintenance criteria

| Abbreviation | Maintenance Criterion |
|---|---|
| CL | Climate |
| DR | Debris removal |
| DS | Drainage system |
| FT | Fertilization |
| FM | Filter mats |
| GM | Growing medium/ Soil substrate |
| INS | Insulation |
| ISW | Irrigation system/ Watering |
| OS | Occupancy & safety / Accident prevention |
| PC | Pest and disease control/ Plant health inspections |
| PR | Pruning |
| RA | Roof access |
| RS | Roof slab/ Structural deck |
| RB | Root Barrier |
| SS | Slope stability |
| TP | Thermal performance |
| VG | Vegetation |
| WR | Water retention/ Storm water management |
| WM | Waterproofing membrane |
| WC | Weed control |

From the description of the criteria and their abbreviations, Table 4 gives a summary of previous research that considered the maintenance criteria of green roofs.

Table 4 Maintenance criteria for green roofs

| Source | Maintenance Criteria | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CL | DR | DS | FT | FM | GM | INS | ISW | OS | PC | PR | RA | RS | RB | SS | TP | VG | WR | WM | WC |
| Silva et al., 2015 | | | √ | | | √ | √ | √ | √ | | | √ | | √ | | | √ | | | |
| Harris, 2014 | | √ | | √ | | | | √ | | | | | | | | | √ | | | |
| Gedge et al., 2013 | √ | | | | | | √ | | √ | | | | √ | | √ | √ | √ | √ | √ | |
| Tolderlund, 2010 | | √ | √ | √ | | √ | | √ | | | √ | | √ | | | | | | √ | √ |
| Luckett, 2009 | | | | √ | | | | √ | | √ | | | | | | | | | | √ |
| Townshend, 2006 | | √ | √ | √ | | | | √ | | √ | √ | | | | | | | | √ | √ |
| ASTM International, 2006 | | | | √ | | | | √ | | | | | | | | | | | | |
| Ismail et al., 2016 | | | √ | √ | | | | √ | | | √ | | √ | | | | | | √ | √ |
| Kamarulzaman et al., 2014 | | | √ | | √ | √ | √ | | | | | | | √ | | | √ | | √ | |
| Mode / Frequency | 1 | 3 | **5** | **6** | 1 | 3 | 3 | **7** | 2 | 2 | 3 | 1 | 3 | 2 | 1 | 1 | **4** | 1 | **5** | **4** |

Both compilations address the maintenance criteria in both international and local contexts. The compilation is highlighted as an initial establishment of the significant criteria for green roof maintenance in Malaysia.

## 4. METHODS

The study was conducted through an extensive analysis of the literature on tropical green roofs and their maintenance criteria. The resources for the study were mostly journal articles, conference proceedings, and also existing green roof guidelines from leading databases such as Scopus, Web of Science, Taylor & Francis, Google Scholar and Academic Search Premier. These were mainly drawn from the period 2007 to 2018 in order to assure the most up-to-date data on green roof system were used. They were compiled from both international and local contexts, since little research has been undertaken in Malaysia regarding this field. The article search was then limited to maintenance criteria for green roofs in the global and Malaysian contexts. Based on the review of the current scenario and existing literature, the maintenance criteria for green roofs were then analysed. The six most frequently described maintenance criteria by previous studies, based on the reviewed articles, were chosen as the most significant maintenance criteria for this study, taking into account both international and local conditions in order to suit the Malaysian tropical climate.

## 5. DISCUSSION OF THE FINDINGS

According to Ismail et al. (2016), maintenance is essential in order to preserve the function of green roof gardens; thorough protection and maintenance is needed from the moment they are installed. They are also needed to prevent high capital costs, as well as the maintenance costs of green roofs (Ismail et al., 2016). As supported by Isa et al. (2017), maintenance works must be prioritised and consider the building's current conditions and ease of access, as both influence related costs. Therefore, based on the analytical review of the literature, it was found that the results had a number of similarities with the maintenance criteria for green roofs found in previous studies. It was also found that one criterion was closely related to the other criteria. For instance, the criterion of weed control is closely related to debris removal and fertilisation, while the drainage criterion is related to water retention and irrigation systems. However, the criteria were not grouped into specific categories, as the maintenance approach will differ in accordance with the characteristics of the criteria. Since most of the research conducted in the international context might not be suitable for application to the Malaysian building scenario, as Malaysia has a tropical climate rather than the four seasons experienced in other countries, the reviewed articles were compiled together in the international and local contexts. In addition, according to Khor (2010), green building technologies have received little attention from local researchers and scientists for producing the green technology that could be adapted by engineers and contractors to be applied to typical buildings in Malaysia. Therefore, based on the preliminary findings, it was decided to use the common criteria based on the mode or frequency values identified in the previous studies in establishing the suitable criteria for green roof maintenance in Malaysia. Out of the 20 listed criteria, it was found that six were most commonly referred to in the reviewed articles, thus comprising the important criteria for maintenance of green roofs. These were:

1) drainage
2) fertilization
3) irrigation
4) vegetation
5) waterproofing
6) weed control

These criteria were considered to be the most significant factors to be included in the maintenance process and will be listed in the initial establishment of the green roof maintenance framework, while the other criteria were not considered to be suitable for the Malaysian tropical climate due to the lack of attention received by previous studies. The justification for the appropriateness of the maintenance criteria is discussed below.

### 5.1. Drainage Systems

All drains must remain free of vegetation and foreign objects. Inspection of drainage flow paths is crucial because of the severe consequences of drainage back-ups. According to Fioretti et al. (2010), green roofs are suitable for reducing heat gain thanks to the large thermal mass determined by their drainage and mostly by the soil layer. The drainage network controls the volume detention, which determines the reduction and delay in storm water runoff peaks. Hence, every drain on a green roof must remain permanently accessible in order to allow for regular inspections and maintenance. Roof outlets, drains, interior gutters and emergency overflows should be kept free from obstruction by either providing a drainage barrier or equipping them with an inspection shaft (Tolderlund, 2010).

### 5.2. Fertilization

Fertilization is the process by which additional nutrients can be supplied to plants, enhancing germination, flowering and resistance to weather extremes. It may be used during the establishment phase to promote plant health, with organic products recommended (Tolderlund, 2010). Fertilization is not recommended for extensive green roofs because they typically have low nutrient requirements and are therefore often fertilized on an annual basis, using a slow-release fertilizer. Meanwhile, intensive green roofs, with a wider range of planting using a more fertile growing medium, require more regular fertilization (Harris, 2014). Fertilizer application should be only be at minimum level (Ismail et al., 2016). Annual fertilization is necessary for the first 3 to 5 years (Luckett, 2009), while periodic fertilization may be necessary to maintain lush growth (ASTM International, 2006).

### 5.3. Irrigation Systems

Irrigation is a process by which water is supplied using artificial means; for example, by pipes. According to Harris (2014), irrigation and maintenance requirements are dependent upon the plant species installed. However, they also depend on the design of roof; the more intensive the roof, the more likely it will be that an artificial irrigation system is required. This implies that vegetation particles from the air pass over the plants, settling on leaves and stems, which are washed down via irrigation. Other than pipes, sprinklers or drip irrigation systems also can be used by installing their tanks, pipes and emitters during the design phase of the green roof. As an intensive green roof can be accessed, the more likely it will be that an irrigation system is required (Ismail et al., 2016). Meanwhile, extensive roofs should not require irrigation in general. However, it may be advisable to have an irrigation system in place in case the site experiences an extended drought or other unusual weather patterns (ASTM International, 2006).

### 5.4. Vegetation

The type of plants and vegetation used for a green roof depend on the type of roof design, the depth of growing medium installed, and the climate zone. An intensive green roof may use any type of plant, including shrubs, perennials and trees. Meanwhile, extensive green roofs generally use drought resistant plants with shallow roots, such as sedums and lawns (Kamarulzaman et al., 2014). Therefore, it important to acknowledge the types of vegetation and their suitability before they are installed on the green roof, as this will determine the different approaches of vegetation maintenance. By considering the tropical climate of Malaysia, which receives sunlight and rainfall throughout the year, the vegetated beds may have higher levels of rainfall retention compared to unvegetated beds. The ability of plants to survive

on a green roof is directly proportional to the amount of maintenance time and budget allocated to the project, particularly in the first two years when they are becoming established (Ismail et al., 2016).

### 5.5. Waterproofing Membrane

This membrane, either as a liquid or in sheets, is applied to the building surface and keeps water from leaking into the building construction. In some cases, the membrane will also contain a root barrier, either as a laminated surface or through chemical additives in the coating (Kamarulzaman et al., 2014). Leakage is one of the main defects found in intensive green roofs, and can be detected by using various methods, such as Flood Testing, Flowing Testing, Electric Field Vector Mapping (EFVM), Capacitance, Infrared (IR) Thermal Imaging and Moisture Sensors (Hui, 2010). The roof membrane will need to be replaced after 30–50 years, according to roof size, building height, type of planting and depth of the growing medium (Ismail et al., 2016). Meanhwhile, regular inspections are advised at least three times per year (Tolderlund, 2010).

### 5.6. Weed Control

Weeds are wild plants growing where they are not wanted, especially among garden plants, and need to be taken out of the ground. Basically, manually weeding should be included on a routine basis, not merely depending on necessity. Weeds can compete for water and food and choke out the intended green roof plants. They can also have much more aggressive roots, which, if left unchecked, are capable of exploiting weaknesses in root barriers and damaging roofing membranes. Weed eradication is necessary throughout the life of the roof, usually involving hand weeding using garden gloves and energetic weed pullers. The use of herbicides is strongly discouraged because of environmental concerns (Luckett, 2009).

For tropical climate countries such as Malaysia, Singapore and Indonesia, plant coverage is critical in reducing heat absorption through the roof, and the elements of open and covered areas are essential in the design of these green spaces (Hamzah et al., 2016). Therefore, prioritizing these maintenance criteria is important for the maintenance of the green roof and to enable it to achieve greater sustainability and lifespan intensity.

## 6. CONCLUSION

The green movement has become a global trend in the construction industry, as numerous studies on the concept of green roofs have exemplified. However, in Malaysia concern for green roof maintenance has not been prioritized in terms of the viability of its application. The maintenance of the green roof system itself is often neglected, but maintenance plays an important role in sustaining the green roofs for their intended function. The outcome of this study has focused on the green roof concept in assessing the appropriate maintenance criteria to be applied in Malaysia. These are considered to be appropriate and significant in the context of green roof maintenance in Malaysia. Inevitably, the maintenance criteria should be well acknowledged by the building owner and operators before the green roof is implemented. A future study path will outline the strategic ways and best practices as an improvementt for the current maintenance practice of green roof.

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