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HYDROLOGICAL PERFORMANCE OF NATIVE PLANT SPECIES WITHIN EXTENSIVE GREEN ROOF SYSTEM IN MALAYSIA

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ABSTRACT

Little is known about the hydrological performances of different native plant species within extensive green roof system in Malaysia. Thus, this research focused on the runoff retention efficiency within extensive green roof system with respect to different native plant species in Malaysia. A total of six green roofs were constructed with five being vegetated and one left unvegetated. Four test beds were vegetated with Nephrolepis bisserata (fern), Axonopus compressus (cow grass), portulaca grandiflora cultivars (sedum) and Zoysia matrella (Manila grass). The fifth test bed was a combination of all species and the six test bed with bare soil acted as control. The runoff volume was measured volumetrically through connected to an surface runoff harvesting tank under the test beds. Water retention was calculated from the difference between the depth of rainfall and the depth of runoff from each test bed. Results showed that mixture of plant species was the most effective vegetation at reducing runoff water. The monoculture of portulaca grandiflora cultivars (sedum) performed the best runoff water retention efficiency for single plant species.

Keywords: green roofs, hydrological performance, Malaysia, native plant, runoff retention.

INTRODUCTION

Green roof is a green space created by adding layers of growing medium and plants on top of a traditional roofing system. Green roof technology is a technology of integrating plants with built environment. Green roof or planted roof also can be defined as roof that consist of vegetation and growing medium and also can be referring to roof garden in other places (Anon, 2007, Dunnett and Kingsbury, 2004). Green roof can be constructed as simple intensive, intensive and extensive (Berndtssona *et al.* 2009). The concept of eco-roof nowadays has increasingly popular as it brings many benefits toward the environment and promoting sustainable lifestyle. The green roof system can be defined as the one of the solutions to climate change at the cities by functioning to cool the urban areas. The effect of green roof application in town scales have been proven that it can reduce the temperature of the town (Alexandri and Jones, 2008). Green roofs can also reduce energy consumption by decreasing cooling and heating loads, provide amenity and aesthetic value, increase building values, improve stormwater runoff mitigation, lower air temperatures, enhance urban air quality, assist in urban stormwater pollutant removal, reduce noise in urban environments and mitigate urban heat island effects. Green roof technologies are the integrated knowledge of plants biology, hydrology and architecture. Designing the green roof required a good knowledge of engineering as all the critical aspects of design must be included such as weight of the systems, suitability of proposed plants and the environmental aspect at the regions. Commonly, the green roof consists of two layers, the vegetation and growing media or substrate for vegetation grows. (Nigel and Noel, 2004). The good substrate layer must be efficient in retaining and absorbing the water to achieve the purpose of building green roof, is to be water retention medium.

This study was aimed to determine the runoff water retention efficiency of different native plant species within extensive green roof system in Malaysia. Developing the extensive green roof under the tropical climate like Malaysia is a challenge because it needs to study the suitable native plants species that can endure the harsh environment of tropical climate. Therefore, there must be research conducted as the way to promoting sustainable lifestyle in Malaysia.

MATERIAL & METHOD

This study was conducted at the Civil Engineering laboratory building in Universiti Tenaga Nasional (UNITEN). A total of six green roof test beds which vary systematically in their vegetation options were established at the study site in July 2014 (Figure-1). Each test bed is 0.44 m x 0.32 m (length x width), installed to a 11.6% slope at height of 0.5 m from ground level. Four test beds were vegetated with monocultures planting of native plants (Nephrolepis bisserata (fern), Axonopus compressus (cow grass), portulaca grandiflora cultivars (sedum) and Zoysia matrella (Manila grass). These plants were selected by category of native plants namely fern, grass and sedum, which suitable to grow in Malaysia. The fifth test bed was vegetated with combination of all four species. The number of plants in each test bed was determined by plant species size and proximity to which 100% cover was to be expected by the end of the growing season.To maintain species composition, any plants not planted that germinated in the module were removed by hand once or twice a month during the study period. Soil with no vegetation (bare ground) was also be prepared for each types of substrate type as a control. Data collection

was started from December 2014 for accessing the effect of vegetation cover on stormwater runoff retention performance. Rainfall and temperature data were collected from a weather station which contributes data to the Department of Irrigation and Drainage Malaysia (DID) and was situated within 500 m of the experimental site. Runoff were measured volumetrically through connected to an infiltrated runoff harvesting tank under the test beds. Water retention was calculated from the difference between the depth of rainfall and the depth of runoff from each test bed.

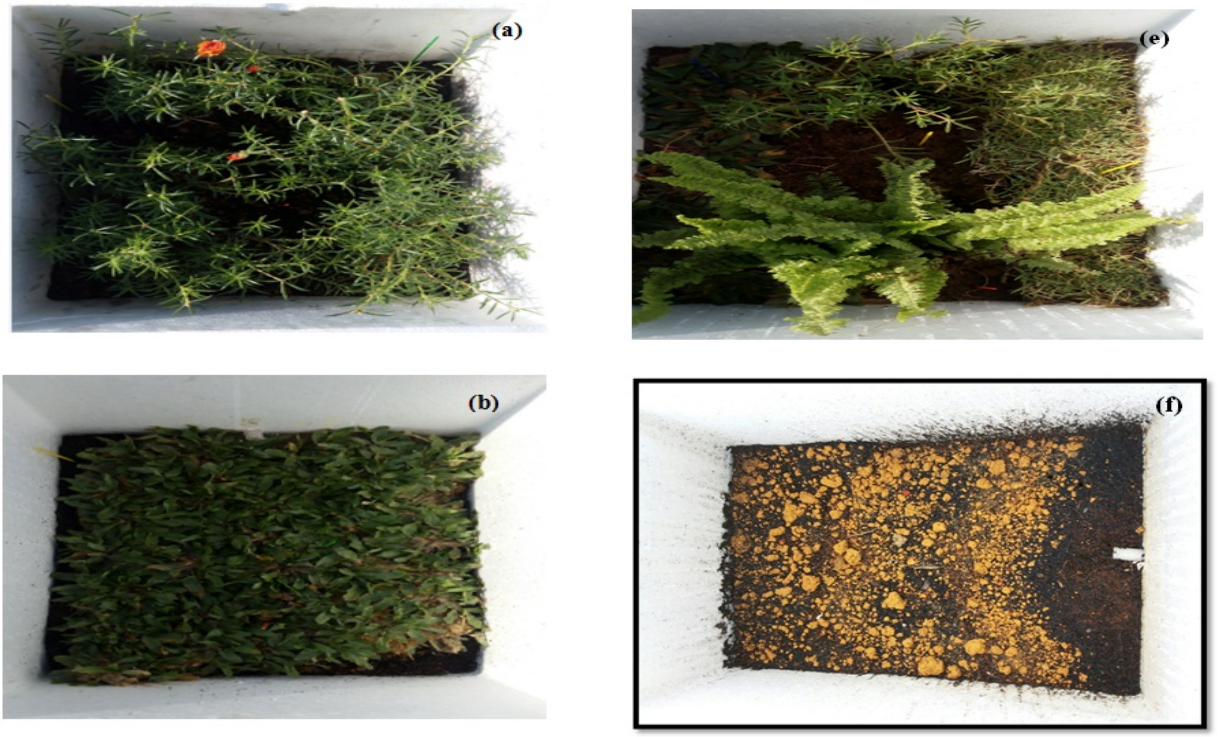

Figure-1. Types of vegetation used in extensive green roof system; (a) portulaca grandiflora cultivars (sedum); (b) Axonopus compressus (cow grass); (c)Zoysia matrella (Manila grass); (d) Nephrolepis bisserata (fern); (e) mixture of plant species; (f) bare soil.

RESULTS & DISCUSSIONS

Daily rainfall depth during the study period

Figure-2 shows the daily rainfall depth at the study site during the monitoring period. Between 21th November 2014 and 4th December 2014, a total rainfall depth of 128 mm was recorded at the study site. The highest rainfall depth is on 23th November which recorded a total of 57 mm. On the other hand, 3th and 4th December both have the lowest rainfall depth which are only 1 mm. The mean depth on a day when it rained was 14.2 mm.

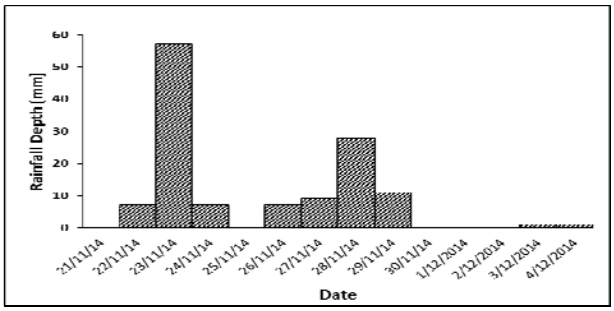

Figure-2. Daily rainfall depth during the monitoring period.

Cumulative water retention on different plant species

The amount of surface runoffs from different types of plant species within the green roof test beds in this study are summarized in Table-1. The results obtained from this study had revealed that significant different between the amount of surface runoff and vegetation type. The mixture of plant species showed the least amount of water runoff which collecting an average of 633.3 ml during the study period. The monoculture of sedum is more effective at reducing the water runoff by averagely collecting 833.3 ml of runoff water. The average amount of runoff water collected from fern species was 927.8 ml. Manila grass showed the largest amount of water runoff by collecting 1305.6 ml, whereas cow grass also collecting an average amount of 1177.8 ml. It was shown that different plant species influenced the amount of water runoff. Overall, the mixture of plant species was the most effective vegetation at reducing water runoff, followed by sedum and ferns. Interestingly, the bare soil showed that it captured the most water runoff with an average runoff amount of 111.1 ml.

Table-1. Amount of surface runoffs from different plant species.

Date	Type of Plants					
	Bare soil	Mix	Filipina Grass	Cow Grass	Sedum	Ferns
	Runoff (ml)					
21/11/14	0	0	0	0	0	0
22/11/14	150	300	1300	1000	650	800
23/11/14	250	1000	2300	2200	1750	1300
24/11/14	0	250	1250	1100	200	1000
25/11/14	0	0	0	0	0	0
26/11/14	150	450	1200	1100	900	800
27/11/14	100	1500	1700	1600	1500	1600
28/11/14	200	800	2000	1800	1000	1500
29/11/14	150	1200	1700	1500	1300	1200
30/11/14	0	0	0	0	0	0
01/12/14	0	0	0	0	0	0
02/12/14	0	0	0	0	0	0
03/12/14	0	100	150	150	100	50
04/12/14	0	100	150	150	100	100
Mean	111.1	633.3	1305.6	1177.8	833.3	927.8

Lundholm *et al.* (2010) stated that the highest water capture was observed in grasses, followed by tall forbs, creeping forbs and succulents. Nagase and Dunnett (2012) also found that grasses were the most effective for reducing water runoff, followed by forbs and sedum. Vanuytrecht *et al.* (2014) also found that grasses and herbs were more efficient in retaining water, but succulents and mosses suffered less from elevated temperatures and drought. The finding in this study is not consistent with previous studies that proved the effectiveness of grass in retaining runoff water within extensive green roof system. The obtained result indicated that mixture of plant species was the most effective at reducing water runoff. Plant diversity can be a good influence in capturing the water runoff because of the large area of vegetation and also the density of the plants. Maclvor and Lundholm (2011) showed how different species affect the stormwater capture ability; in their study, three graminoids (Carex argyrantha, C. Nigra, and Deschampsia flexuosa) captured more water than other species. Nagase and Dunnett (2010) also stated that a diverse plant mix was more advantageous than a monoculture in terms of greater survivability and higher visual rating under dry conditions. Lundholm *et al.* (2010) and Maclvor and Lundholm (2011) both studies found that bare soil (no vegetation) captured more water compared to most species.

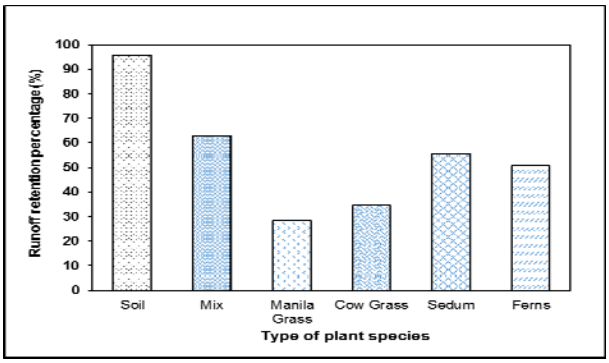

Figure-3. Mean runoff retention (%) for different plant species within green roof test beds.

Figure-3 shows the average percentage of runoff retention for different plant species within green roof system in this study. The mean runoff retention percentage for mixture of plant species is 63.1%. The monoculture of sedum was the most effective single species for retenting water runoff with an average percentage of 55.5%, followed by fern (50.9%), cow grass (34.8%) and Manila grass (28.3%). According to Maclvor & Lundholm (2011), plant species that can evapotranspire more water from the growing medium will create more space for water capture in subsequent rain events. Grass plants tend to show a high transpiration rate, and their growth rate is higher than that of sedum plants (Larcher, 2003). On the contrary, sedum plants generally have higher water use efficiency and retain more water in the substrate than grass and fern plants (Gravatt and Martin,1992).

A number of factors can affect the retention efficiency of green roofs. Speak *et al.* (2013) reported that season and density of rainfall had significant impact on water retention of green roof system. The previous study

has proved that shallow green roof models can actually retained more water (Volder & Drovak, 2014) and also the effect of vegetation types that can actually increased the ability of the green roof to retained more water. Some studies have shown that the depth and type of substrate has the major influence on green roof water retention capacity (Berndtsson, 2010; VanWoert *et al.*, 2005; Graceson *et al.*, 2013). The slope also given a significant effect for green roof water retention. The increasing number of slope will decreasing the quantities of runoff in green roof (Getter *et al.*, 2007).

Overall, the difference in amount of water runoff between vegetation types was very clear in this study. It is important to remember that the aim of this study was focused on the effect of vegetation and plant diversity on runoff reduction from extensive green roofs only. In addition, the extensive green roof used in this study was very simple; it consisted only of vegetation and green roof substrate whereas extensive green roofs usually include water retention layers, drainage layers and root protection layers. More detailed research is required to understand the processes that account for runoff depth from green roofs and to assess the water retention performance of different native plant species during storm events.

CONCLUSIONS

The result in this study has shown the hydrological performance of different native plant species within extensive green roof system in Malaysia. Based on the findings in this study, it is proved that different types of plants species have their own ability in retaining runoff water within extensive green roof system. The mixture of plant species was the most effective vegetation at reducing water runoff. The monoculture of portulaca grandiflora cultivars (sedum) has proved that it performed the best runoff water retention efficiency for single plant species. Further research on other types of native plant species in Malaysia is necessary in order to find the ultimate plant species that have the best hydrological performance for extensive green roofs that suitable for tropical climate.

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