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RAINFALL RUNOFF PERFORMANCE OF SMALL SCALE GREEN ROOFS SYSTEM

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Abstract: As green roof technology is still emerging, there is limited rainfall runoff data available at present under Malaysian climate. Located at equatorial region, Malaysia will sometimes experience high humidity and high temperatures throughout the year. Hence this study will present the initial outcomes of the joint initiative between Malaysia Agricultural Research and Development (MARDI) and Universiti Tun Hussein Onn Malaysia (UTHM) in promoting this green roof technology in Malaysia. The study aims to provide initial observation on rainfall runoff performance using the green roofs set up by MARDI. Initially this green roofs system were set up for the agriculture study of three different vegetation and two treatment systems which known as conventional and self-watering system, under two different substrate depths which are 50 mm and 100 mm. Six rainfall events were manually observed consists of one extreme rainfall and five moderate rainfall type. It is found that the highest retention from the event with total rainfall of 94.7 mm was 49.8% for 5SWLC (50 mm substrate depth + self-watering system + *Lantana camara*) but the retention varied between 38.1% and 47.0% for moderate rainfall range between 30.3 mm and 35.4 mm for the same roof treatment. At the same time, the other treatment systems with other type of vegetation and depths show lesser retention than the 5SWLC. It can be concluded that with the additional storage system, may increase the typical total retention for green roofs.

Keywords: *Green roof, rainfall runoff, roof water retention, storage system*

1.0 Introduction

Urbanisation is the replacement of permeable (green) surfaces with impermeable hard surfaces (i.e. roads, roofs), therefore less capacity are available to store rainfall. With less storage capacity for water in urban basins and more rapid runoff, urban streams will rise more quickly during storms and have higher peak discharge rates than rural streams (Konrad, 2016).

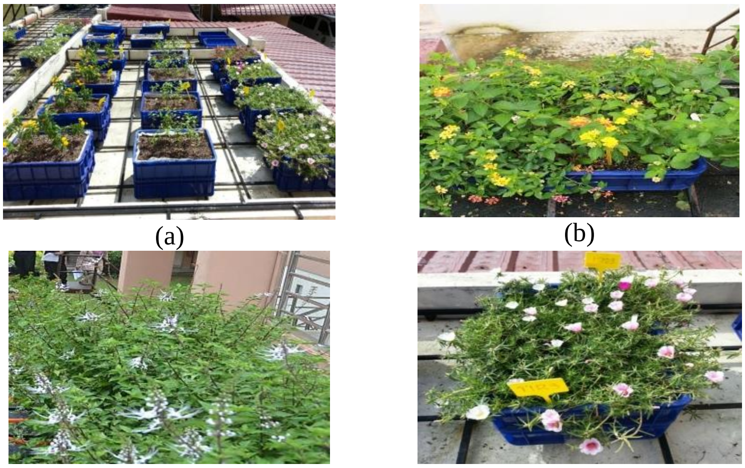
Sustainable urban drainage system (SuDS) is an approach of drainage management that mimicking the hydrological cycle of natural catchment system by providing more water storage capacity in urban area. Green roof is one of the SuDS storage structures that contain of vegetation for roof covering, as an alternative for traditional roof covering materials. Eco-roof or vegetated roof is an engineered roofing system that allows for rooftop vegetation production while protecting the underlying roof (Earth Pledge, 2005). Green roofs that consist of three basic layers are designed to absorb moist with vegetation/plant and soil on the rooftop and it will return water to the air through transpiration and evaporation process. Vegetative roofs are classified as extensive or intensive and semi-extensive based on planting medium depth (Dave, 2015). The vegetation selections may depend the roof type (extensive or intensive), local climatic condition, building design, available sunlight, irrigation requirements and anticipated roof use (EPA, 2014).

Most empirical green roof studies on rainfall runoff are based upon roofs located in seasonal climates, the majority of research being undertaken in the UK, Europe, USA, Australia and New Zealand (Voyde *et al*. 2010; Stovin *et al*. 2013; Wadzuk *et al*. 2013), while in tropical countries, the rainfall runoff green roof research (Vergroesen & Joshi, 2010; Kasmin & Musa, 2012; Qin *et al.* 2013) has been growing with recent developments from Singapore, Malaysia and Thailand (Kasmin *et al*., 2014). Therefore, this paper will highlight further on rainfall runoff study for small scale green roofs under Malaysian climatic condition.

2.0 Materials and Methods

2.1 Materials

Previously, a thermal experiment was conducted on two existing flat roofs belong to Malaysia Agricultural Research and Development (MARDI) Serdang, Selangor in Horticulture Research Centre, named as Roof 1 and Roof 2 (Kasmin *et al.*, 2015). This study was then conducted for rainfall and runoff experiment on the Roof 2. Roof 2 consists of green roofs that planted with three species of local vegetation named as *Lantana camara* (*bunga tahi ayam)* (LC),*Orthosiphon samineus* (*misai kucing*) (OS) and *Portulaca grandifola* (*ros jepun*) (PG). The treatments consist of two green roof system known as conventional system (CS) and self-watering system (SWS). The planter boxes have two different substrate depths which were 50 mm and 100 mm. For this study, there were 18 plots of planter boxes that consist of three different species of vegetation, two different depths of substrate, two different techniques of planting system and their replication (Figure 1); with 4 plots contain the substrate without vegetation and the other 2 plots were empty boxes for rainfall measurement. Substrate media for these roofs were a mixture of perlite, vermiculite and peat moss with the weight ratio of 1:1:1.



(a) (b) (c) (d)

Figure 1: (a) Roof 2 consists the green roofs planted with *Lantana camara*, *Orthosiphon samineus* and *Portulata grandiflora*; (b) *Lantana camara* species; (c) *Orthosiphon samineus* species and (d) *Portulata grandiflora* species

2.2 Methods

The rainfall runoff data were manually observed since no scientific instruments were available. Underneath of each 18 planter boxes, the same 18 empty measurement boxes were stacked overlapping (Fig. 2). The water storage volume for each of the measurement boxes were measured and calibrated, therefore each of 18 measurement boxes has their own rating curve. Rulers were used for each box to measure height of water level. Volume (ml) of each planter box was measured by pouring water until 1 cm water height reached. This procedure continues for every 1 cm water level height until it reaches maximum of 5 cm height. Values other than 1 cm, 2 cm, 3 cm, 4 cm and 5 cm (that are between 0 and 5 cm) were than interpolated using basic equation (1) based on 5 measured heights (as *y* values) and 5 measured volumes (as *x* values).

$$y = y_1 + \frac{(x - x_1)(y_2 - y_1)}{(x_2 - x_1)} \qquad (1)$$

Whenever there are rainfall events, two observants were needed to manually read the height of water level at 5 minutes interval for all 18 measurement boxes. Rainfall data is the average results from 2 empty boxes, runoff data is the results from the other 16 boxes.

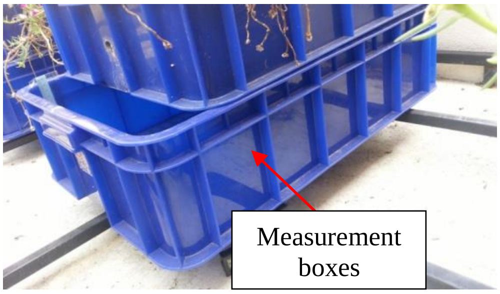
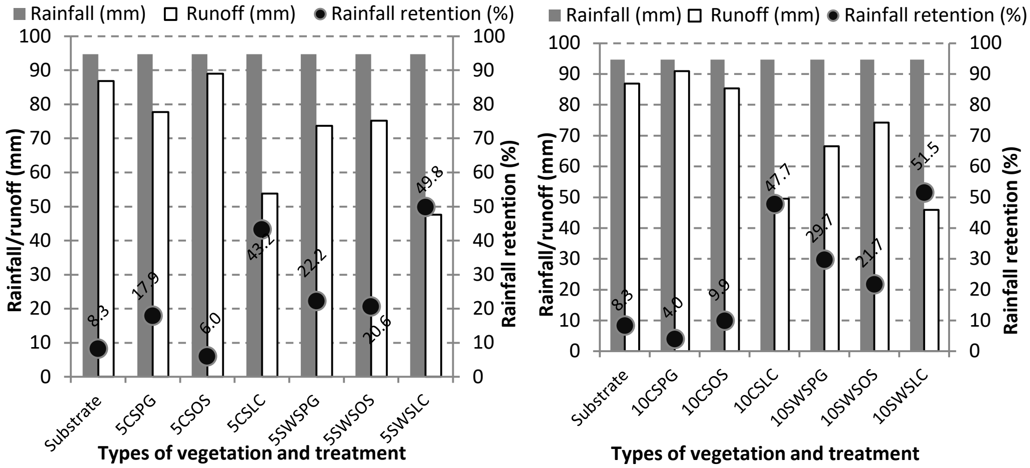


Figure 2: (a) Measurement box under one of the green roof plot (b) Example of measurement box with the ruler for height measurement

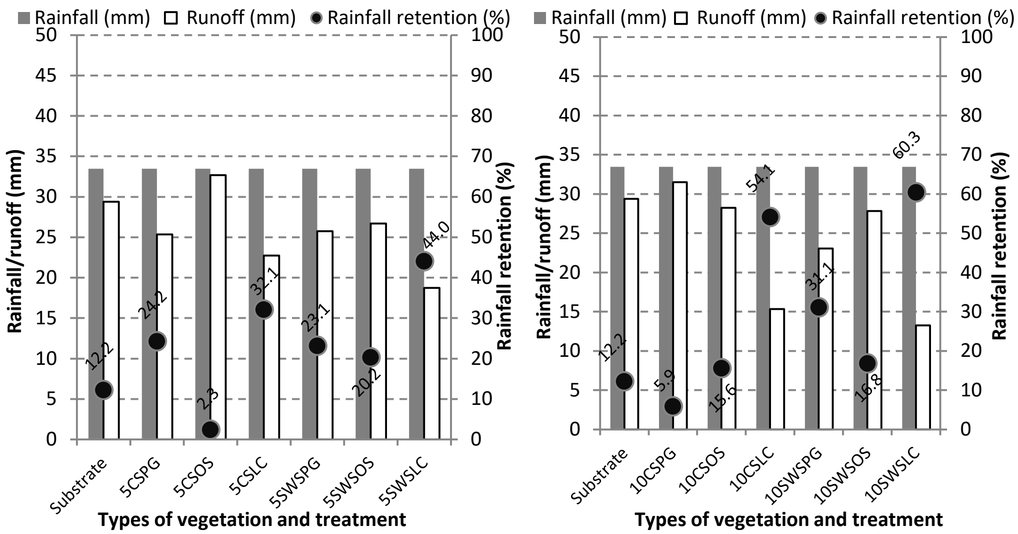
3.0 Results and Discussion

Figure 3, Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8 show the observed rainfall runoff for six rainfall events on 8, 15, 16, 19, 21 and 22 of May 2014, respectively. Five of the rainfall events were considered as moderate rainfall that ranges between 30.3 mm and 35.4 mm except rainfall event on 8 May 2014 which has total rainfall of 94.7 mm. Both of substrate treatment (without vegetation) boxes with substrate depths of 50 mm and 100 mm display the same rainfall and runoff values in all rainfall events. Further analysed on the data with the same treatment of vegetation shows that treatment using *Lantana camara* in conventional system (CS) exhibits reduction of total runoff from substrate depth of 50 mm to 100 mm and it occurred in all rainfall event measured. The same trend was also found in self-watering system (SWS) with *Lantana camara* treatment where reduction in total runoff also found in 100 mm substrate depth than the 50 mm. In addition, total runoff occurred from all rainfall events in *Portulaca grandifola* treatment were also shown similar trend in them where in CS shows increment in the deeper substrate but it was opposite reaction observed in deeper SWS. However for *Orthosiphon samineus* shows varied total runoff results whether in CS or SWS.



(a) (b)

Figure 3: Rainfall events on 8 May 2014 (a) on 50 mm substrate depth, (b) on 100 mm substrate depth



(a) (b)

Figure 4: Rainfall events on 15 May 2014 (a) on 50 mm substrate depth, (b) on 100 mm substrate depth

It is found that the highest retention from the event with highest total rainfall of 94.7 mm was 49.8% for 5SWLC (50 mm substrate depth + SWS + *Lantana camara*) but the retention varied between 38.1% and 47.0% for moderate rainfall range between 30.3 mm and 35.4 mm for the same roof treatment. At the same time, the other treatment systems with other type of vegetation and depths show retention but lesser than the 5SWLC. It may presents that with the additional storage system (i.e. better treatment systems, types of vegetation and substrate depths), the typical total retention for green roof may be increased. It was shown that after 7 days of dry days after rainfall occurrence on 8 May 2014, the green roof boxes may recovered its available storage when rainfall on 15 May 2014 exhibits similar trend of rainfall retention/runoff for each roof box treatment.

However, on 16 May 2014, measured runoff displays larger value than its rainfall in substrate treatment, may be due to saturated substrate (available storage was reduced for several roof treatments) from previous rainfall event on 15 May 2014. However, almost all treatments exhibit water retention except in 5CSOS and 10CSPG. This may demonstrated that some vegetation could potentially increase the available storage of the green roofs. However, vegetation treatment alone may not be really influential the available storage without the role of substrate depth and the treatment system itself.

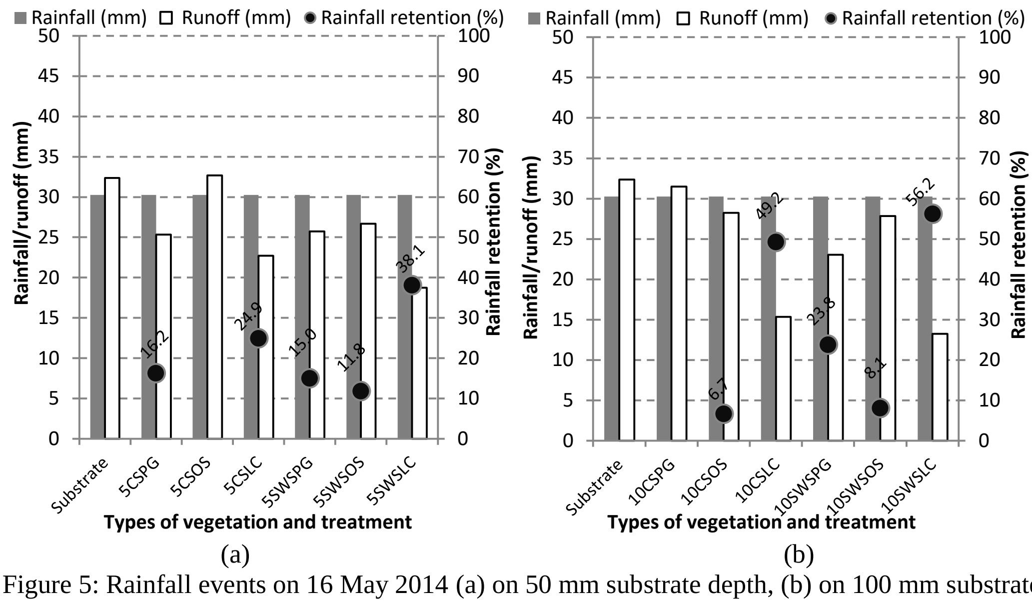
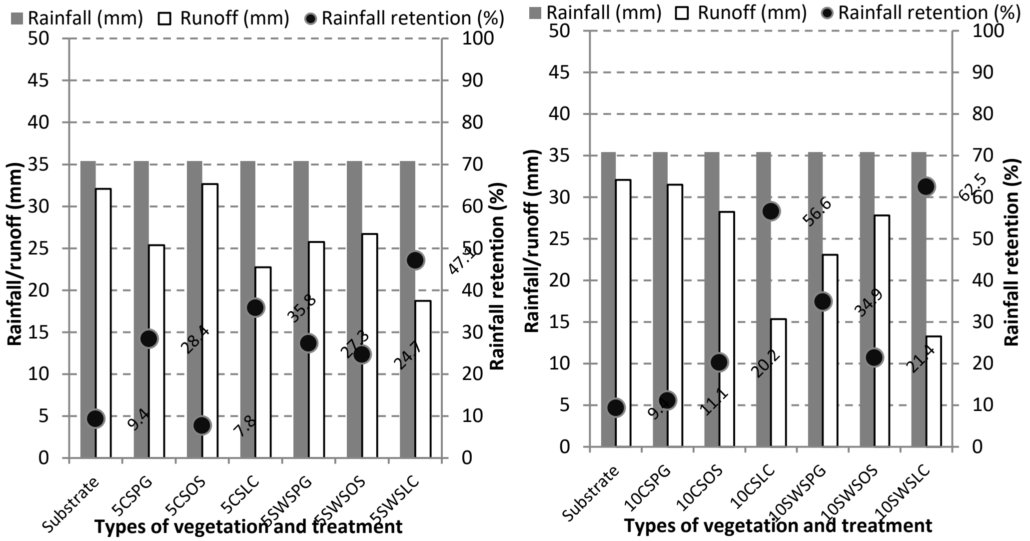
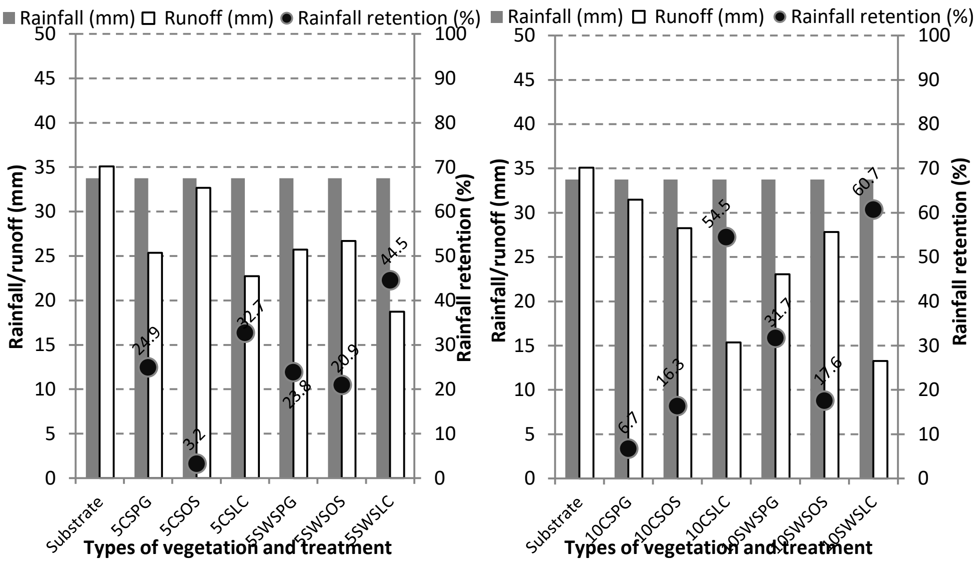


Figure 5: Rainfall events on 16 May 2014 (a) on 50 mm substrate depth, (b) on 100 mm substrate depth



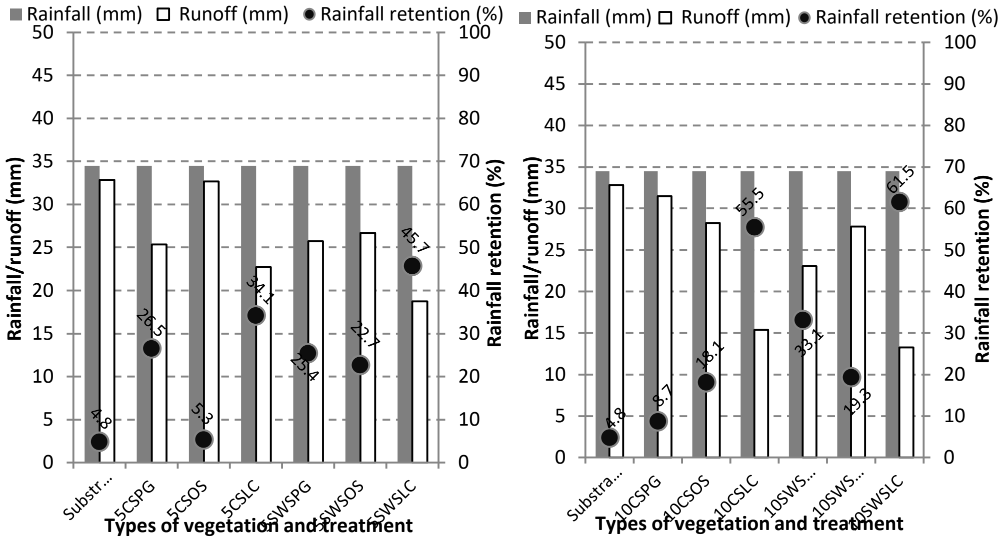
(a) (b)

Figure 6: Rainfall events on 19 May 2014 (a) on 50 mm substrate depth, (b) on 100 mm substrate depth



(a) (b)

Figure 7: Rainfall events on 21 May 2014 (a) on 50 mm substrate depth, (b) on 100 mm substrate depth



(a) (b)

Figure 8: Rainfall events on 22 May 2014 (a) on 50 mm substrate depth, (b) on 100 mm substrate depth

4.0 Conclusions

From this study, it can be concluded that rainfall runoff performance of any green roof system will be depending on the available storage within the green roof substrate. The available storage from this study is a function of substrate depth, climatic variables (including dry days), vegetation and type of the green roof itself. It seems that, *Lantana camara* has shown better potential to retain more water than the other two vegetation. This may due to its large foliage that can either intercept or transpire more, hence retain more water.

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