Green Roofs Storage of Rainwater Alternative Systems

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ABSTRACT: The building roofs are elements that get the heat from the solar radiation. The green roof can be an alternative to minimise the heat effect, in addition to providing other benefits. The vegetation of the roof, as any others, needs care and water to grow. An alternative solution could be the roof storage and retention of rainwater, with aim to reduce the cost of irrigation became it sustainable. The objective of this study is evaluating the green roof storage of rainwater system using reusable materials. The experiment realised on the building roof at Pelotas University - Capão do Leão – Brazil- in the summer. The green roofs have in common the layers components: waterproofing, drainage, topsoil and grass, differing by with and without storage and retention water system. Two covers were implemented: the first, with four cells, one without storage water system, as a reference (1), and the others three with storage and retention water system consisting, respectively, PET bottle (2), eggs plastic packaging (3) and sowing plate, as a material alternative trade (4). Due to the straightening best presented by the cell (2), in the second coverage they were only used pet bottle, with different heights. The vegetation of the covers kept stable, while drying a little bit in dry periods. The green roof monitoring shows that the system areas with more storage water volume, has better results in qualitative and visual analysis, indicating that the green roof implementation with rainwater storage devices could be a sustainable and lasting solution.

Keywords *Green cover; garden terrace; ecologic roof; sustainability; rainwater storage*

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1. INTRODUCTION

The edification's roof is responsible for major heat absorption due to solar radiation. According to Araújo (2007), the rooftop is the main element exposed to thermal exchange between the building's interior and exterior, since it suffers constantly with solar radiation during the day, and loses heat at night and when it rains. Such thermal load is transmitted to the inner spaces, affecting directly the energy consumption due to the use of artificial air ventilation and the user's thermal comfort (Naranjo et al., 2011). A sustainable solution that can help reduce these effects on roofs is the use of green roofs.

It can be considered as a green roof every roof, plain or inclined, properly isolated and with a draining system for excess pluvial water, that has on its structure a layer of soil or substrate and another layer of vegetation. As reported by Morgado (1995), the green roof is a area of vegetation over a waterproof substrate, at any level, separated from the ground by an artificial structure.

They are classified, in relation to the adopted size, between extensive or intensive, differing, mainly, by the used substrate and vegetation thickness (Correa & Gonzalez, 2002). According to Araújo (2007), green roofs can still be classified as accessible or inaccessible, being the first an area open to people's use, such as suspended gardens or terraces, providing social benefits to its users as well as adding commercial value to the building, while the inaccessible ones do not allow people circulation, which can be plain, curve os with an inclination.

According to Disdale, Pearen and Wilson (2006), the hanging gardens of Babylon, built around 600 b.C. , were the oldest and most famous form of green roofs. As reported by Lopes (2007), although green roofs are an ancient technique, it is only now that they are becoming more present in Brazil. Studies on the subject are also very new. In the last decades green roofs started becoming a recurrent subject of studies in countries like Germany, Australia, Mexico, Singapore and Japan. However, with the new ecological conscience, concern about the environment well-being as well as the individuals' lifestyle, a new tendency to encourage and give support to the deployment of new green rooftops has emerged (Pouey, 1998).

In Brazil, there is no federal law imposing the implantation of green roofs, however, according to the News Council, the Urban Development Board from the House of Representatives approved the tax incentive to buildings that implement the new technology in at least 65% of its roof coverage. The initiative is defined in the Bill 1703/11 (BRAZIL, 2011) and will still be analysed by the Constitution, Justice and Citizenship Committee. Nonetheless, some Brazilian cities such as Recife has a municipal law 18.112/2015 (RECIFE, 2015), which states on Art. 1 that multi-family dwellings projects with more than four pavements and not residential ones with more than 400m^2 of roof area must contain green roofs. Just as Rio de Janeiro's Legislative Assembly regulated by law nº 6349/12, on Art. 1 that Executive Power is authorised to install the so called "green roofs" on Rio's public buildings, autarchies and foundations afterward the law enactment (RIO DE JANEIRO, 2012).

The benefits associated to the use of this kind of technology, as stated by the *Internacional Roof Association* - IGRA (IGRA, 2016), can be divided in "public benefits" and

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"private benefits". The public ones take into consideration the fact that green roofs are the natural habitat for fauna and flora, that it can retain rain water, decrease urban heat island effects as well as reduce the suspension of dust and pollution. The private benefits are associated to thermal and acoustic comfort provided, the contact with nature midst urbanization and the creation of leisure areas. As reported by Mendonça (2015), the implementation of green roofs is the solution for creating green spaces, taking into account that every day cities suffer from green spaces losses, resulting in hot and polluted urban microclimates.

D'elia (2009) also says that the green structures can help control the greenhouse effects, improve air quality through photosynthesis, reduce rainwater flow to public streets and mitigate heat pocket effects on metropolis.

The kind of vegetation on the roof is critical for its efficiency, since it is exposed to wind, the weather and harmful substances, besides the fact that most of the time it receives no care and relies only on rain water to develop itself. Therefore, it is worth to select robust plants and install irrigation. Due to the elevated cost of both implantation and maintenance of the irrigation system, the green roof becomes unviable. Now it has become an option to install green roofs with rainwater storage, maintaining soil's humidity, important aspect for the vegetation's development.

This research has the purpose of reporting two experiments using green roofs and alternative rainwater storage methods. Experiment 1: With three devices made from different materials. Experiment 2 was developed using the best results from the first experiment.

2. METHODOLOGY

The green roof experiments were stablished at Campus Capão do Leão at Federal University of Pelotas above the Engineering Centre's Soil Mechanics laboratory roof slab.

It was used a visual criteria on both experiments, paying attention to the grass' behaviour over time with the different devices: (a) Survives and maintain its aspects; (b) drys; (c) Recovers itself e becomes green again. This research has the purpose of evaluate the importance of rainwater storage on green roofs and the differences between each method used. This behaviour was registered photographically.

The water storage system is found below the geotextile mantle and layers of substrate and vegetation, with no contact once or ever with the exterior, making it impossible the proliferation of diseases through mosquitoes larvae.

2.1 Experiment 1

The experiment consisted on the construction of a green roof, with three different storage devices between its layers and some without. Among the materials used two were recycled, 2l PET bottles and plastic egg cartons. The third material is an alternative one - commercial seedcases to grow plants - that even though has a cost, can easily be made from polystyrene, helping with the thermal insulation.

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Superficially the green covering is the same, but underneath it was subdivided in four equal areas of 1.2m x 2.0m each, also being separated by bricks, having the total measurements of 5.8m x 2.4m, as shown on Figure 1.

These areas were called A1; A2; A3 and A4.

- A1 - Pattern- with the following layers: Slab, waterproof mantle, geotextile mantle, vegetable soil and "Catarina" grass (Fig. 2a);

In the following areas, the storage devices were placed between the waterproofed slab and the geotextile mantle:

- A2 – 2l PET bottle's bottom, clipped together (Fig. 2b);
- A3 – Plastic egg cartons, opened and wired together (Fig. 3a); and
- A4 – juxtaposed seedcases (Fig. 3b).

The exceeding rainwater is removed from the green roof system and discarded onto the drainage system.

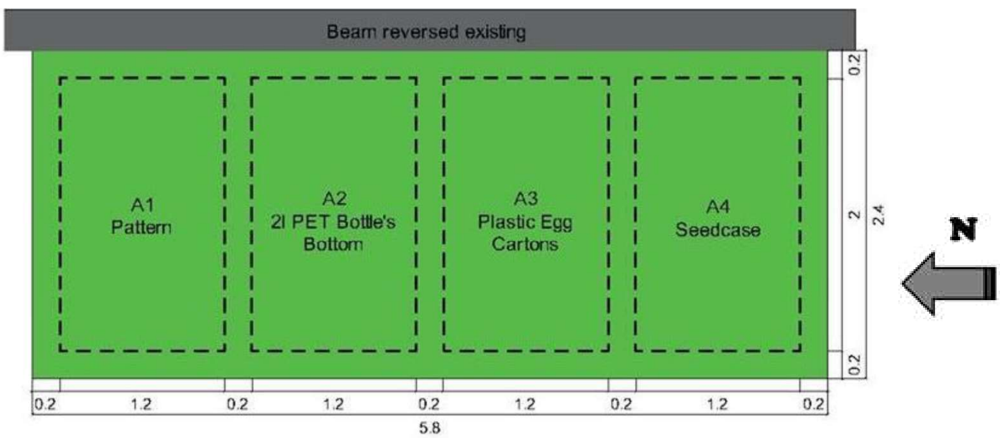

Figure 1. Experiment 1 - Scheme showing the experimental areas and each different water retaining mechanism.

(a) A1-Experiment implanted (b) A2 - 2l PET bottle's bottom

Figure 2a-b – Experiment 1- Devices made for rainwater storage (a) A1; (b) A2

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(a) A3 - plastic egg carton

(b) A4 - Seedcase

Figure 3a-b. Experiment 1 - Devices made for rainwater storage (a) A3; (b) A4

2.2 Experiment 2

This experiment was made taking into consideration the best results from experiment 1 and consisted of two observation areas, so called A5 and A6, identical cells, as shown at Figure 4. Each cell has $2m^2$, being 1m width, 2m length and 0.4m of depth.

Both had the same covering, consisting of the waterproofing of slab and wall; rainwater storage device; geotextile; substrate composed of vegetable soil (80%) and organic compounds (20%) dispersed on a 10cm layer; and “Bermuda Folha Larga” grass.

It was used 2l PET bottle’s bottom to make the water retaining device, with different heights: 5cm at A5 and 20cm at A6, being this the only difference between the two coverings. It was also created a drainage system to get rid of the residual rainwater. Figure 5a-c shows pictures of the assembly.

The experiment was made under critical circumstances, therefore, without irrigation, relying only on rainwater, during the summer (January, February and March), when the solar radiation is more intense.

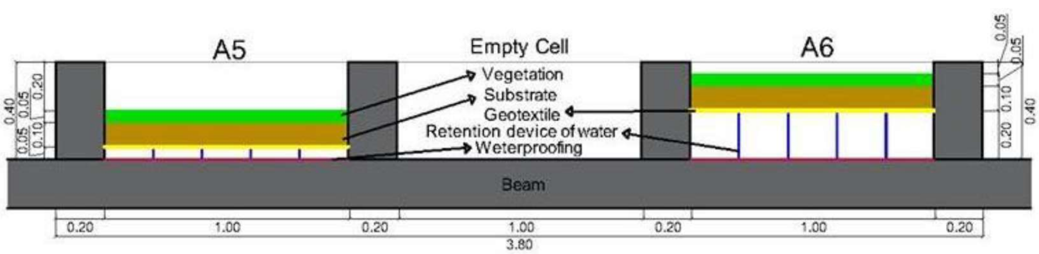

Figure 4. Experiment 2 - Sketches representing green coverings A5 and A6.

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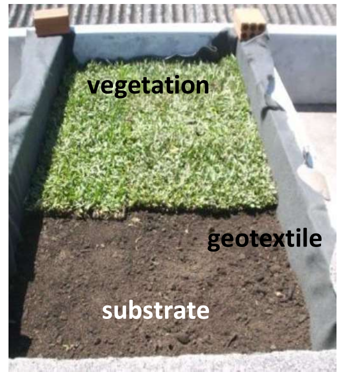

(a) Cell A5 (b) Cell A6 (c) Final layers: substrate and vegetation

Figure 5a-c. Experiment 2 - Assembly stages (a) A5; (b) A6; (c) final layers

3. RESULTS

Following the methodology, the criterion was visual, made by observing the behaviour of the grass, alongside with the measurement of the amount of water stored.

3.1 Experiment 1

The experiments allowed us to notice the tendency for the vegetation to grow stronger over the PET bottoms, probably because of the capacity to store more water than the rest of the devices. In every case the roots got through the geotextile blanket searching for water and nutrients, as shown at Figure 6a-b, that also shows a view of the green roof Figure 6c.


(a) A4 - Seedcase (b) A3 - plastic egg carton

(c)

Figure 6a-c. Experiment 1 – Results (a) Area A4; (b) A3; and over view (c).

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3.2 Experiment 2

The Green roof installation was made in November/2014. The experiment was analysed in summer. Table 1 shows the precipitation levels for the month of January, February and March of 2015. January and February stood out respectively, of excess (96.5%) and shortage (40.0%) of precipitation in relation to the normal value.

Figure 7a-b shows both cell A5 and A6 and the retained water on the day that followed an accumulative precipitation of 24.2mm, indicating the efficiency of the proposal. It is also clear that once again the roots went through the geotextile searching for water and nutrients.

Table 1. Rainfall data regarding the studied months.

	Precipitation		Precipitation accumulated		Maximum Precipitation (24hours)		Number of days of precipitation	
	mm		mm		mm		mm	
Month/ 2015	**Month**	**Normal**	**Month**	**Normal**	**Month**	**Normal**	**Month**	**Normal**
Jan	234.0	119.1	234.0	115.9	36.2	82.0	12.0	11.7
Feb	91.9	153.3	91.9	157.7	39.8	188.2	15.0	11.5
Mar	104.1	97.4	105.1	96.9	75.6	126.8	8.0	10.3

Source: Adapted from EMBRAPA (2015)

(a) **(b)**

Figure 7a-b. Water retained at A5 (a) and A6 (b)

Figures 8a-b e 10a –b present an visual and qualitative evaluation of the vegetation in areas A5 e A6, respectively on January and March 2015. Whilst Figures 9 and 11 show charts indicating precipitation distribution as well as solar radiation at the stated months.

January showed a great amount of rain and higher solar radiation, thus providing a good environment for the vegetation on both cases. February has a lower level of precipitation,

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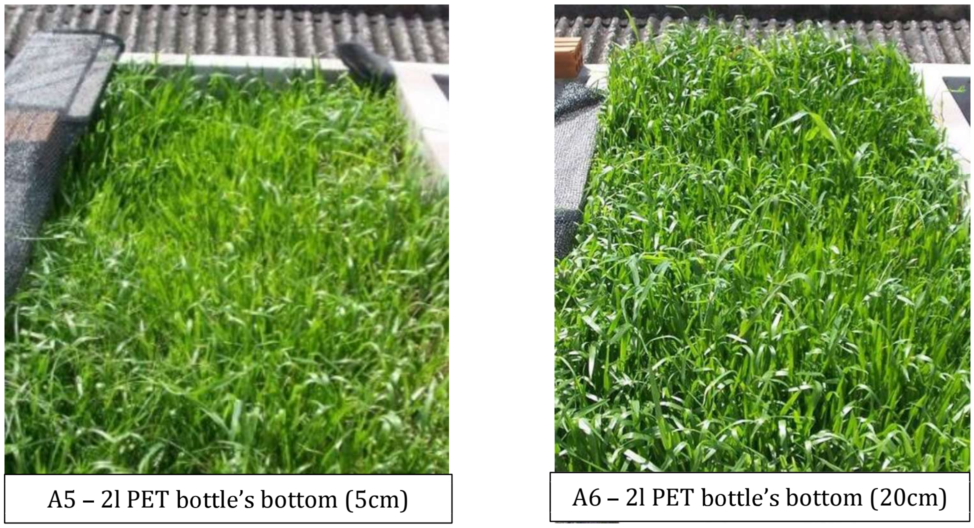
while March had good results only at the end of the month, therefore, the grass dried on both cells although A6 showed a slightly greener grass, as shown at Figure 8.



(a) (b)

Figure 8 a-b. Coverings A5 e A6 evaluation at January/2015 –(a) A5; (b) A6

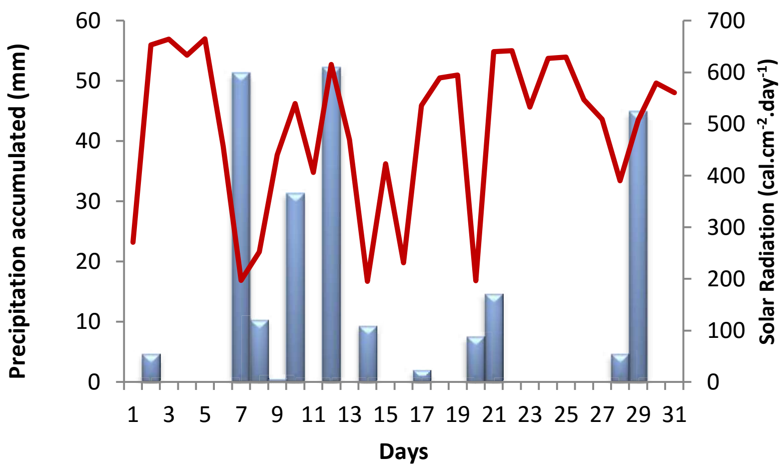


Figure 9. Distribution of rainfall and solar radiation at January/2015

Source: Adapted from EMBRAPA (2015)

The high levels of rainfall in March, helped the vegetation to recover from the wastage suffered in February, although its appearance is not equal to that submitted in January.

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Figure 10 a-b. Coverings A5 e A6 evaluation at March/2015 –(a) A5; (b) A6

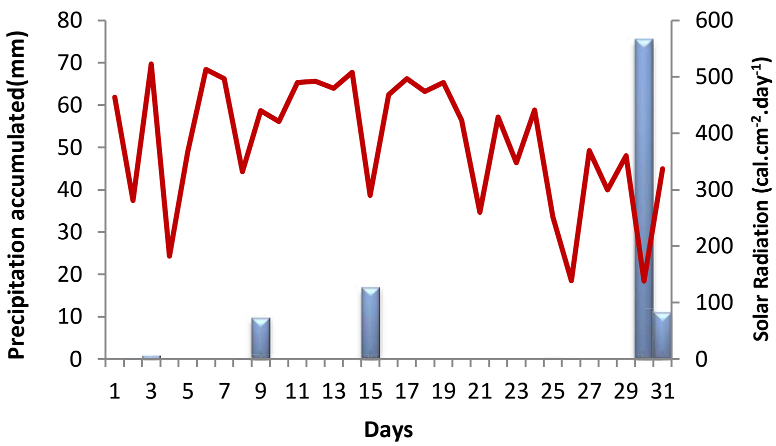

Figure 11. Distribution of rainfall and solar radiation at March/2015.

Source: Adapted from EMBRAPA (2015)

4. CONCLUSIONS

Experiment 2 showed better results for the proposed study, probably because the researched areas were installed at bigger e more isolated cells. On experiment 1, the common green area and its smaller dimensions did not show difference between them.

On experiment 2, considering the harshest period of summer, the vegetation continued present but suffered from the lack of rainfall and showed a change of colour. After monitoring the experiment it can be stated that the area A6, with storage device made with PET bottle's bottoms, presented the best results both on qualitative and visual analysis.

The studies presented indicate that the green roofs assembled with PET rainwater storage mechanisms are sustainable and durable. This study should continue on the following seasons.

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