Experimental evaluation of the thermal performance of semi-intensive green roofs in the cooling season

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Abstract

Efficiency and sustainability are nowadays two important values in construction and green roofs are a way to achieve it by improving air and life quality in city centers. The study herein is based on the experimental evaluation of the thermal performance of semi-intensive green roofs, during the summer season. The case study chosen includes four trays installed on the Instituto Superior de Agronomia (ISA) with different substrates and vegetation. Temperatures, relative humidities, heat fluxes and solar radiation have been monitored. There was the concern to choose different combinations of vegetation in order to be able to assess different effects of shading and evapotranspiration. The influence of soil conductivity was also measured by choosing the trays with the same vegetation and different substrates. Results are presented for all monitored campaign as well as specific studies of the hottest day for a more detailed analysis of the phenomena. The main conclusions were that the *brachypodium* is a good soil protector against solar radiation as it has light colors and high density of vegetation; the rosemary and the lavender, did not attain such good results because they have darker colors, when compared to *brachypodium* and lower vegetation density. Regarding the moss, it has not proven as an effective soil protector because it was dry. It has been found that the substrate in the hottest part of the day, has a major contribution on the reduction of the heat fluxes through the green roof.

Keywords: semi-intensive green roof, monitoring summer campaign, thermal evaluation, heat transmission.

1 Introduction

One of the subjects (matters) whose importance has been changing for the last few years is environmental sustainability, mainly due to man's impact on the planet, despite having some awareness of the problem, his actions are not enough to solve the issue (NWEI, 2015)

One of the possible constructive solutions to mitigate these impacts is the use of green roofs. These, besides improving the aesthetic appearance of the building, allow the use of some of the areas taken from nature for construction, creating green spaces in urban environments and enhancing the transformation of carbon dioxide into oxygen and reducing the formation of "heat islands" (EcoD, 2010). More than environmental advantages, the green roofs can provide a good thermal insulation for the buildings: during the summer season it keeps heat out together with the shade effect caused by the vegetation and, during the winter season protects against cold temperatures. This quality may result in decreasing the energetic costs to heat and cool the internal environment of the buildings (Liu, 2003).

With climate change to become increasingly prominent, one of the consequences that has been observed are more severe summers and winters with greater frequency and intensity of storms and torrential rain that leads to flooding and landslides.

When compared to a waterproof surface the soil has the advantage to retain part of the rainwater, making it flow more slowly. By increasing the green areas one can be contributing to the reduction of flooding, clogging and overloads of the sewage systems in urban areas, by retaining some of this water in the soil (Simmons et al., 2008).

The maintenance and implementation costs as well as the overload on the roofs of the buildings and infiltration risks are the setbacks of this solution, being necessary to evaluate if the advantages compensate its use. Therefore, the studies done on this topic have been increasing but nowadays are still low in number, also the implementation and use of green roofs in the Mediterranean area is still at a very early stage; it is then appropriate to continue to evaluate the advantages of a green roof and deepen the study of this subject with different parameters.

This master's dissertation fits into this theme and aims specifically to the study of the experimental evaluation

of the thermal performance of semi-intensive green roofs.
Therefore, for the implementation of the experimental part, the same trays were used as case study as the ones used in NativeScapeGR project which are located at the Instituto Superior de Agronomia (ISA), in the Tapada da Ajuda.
For this experimental situation it was intended to evaluate the thermal performance of experimental tray tables during the summer season, the goal is to compare the thermal performance of various types of soils as well as the use of insulation, and lastly it is planned to analyze the influence of different species of vegetation and identify other parameters that can be of influence to the thermal performance of green roofs. The hottest day of the campaign will also be used in order to understand the thermal behavior of the green roof in a severe summer situation.

Nomenclature

S1	Substrate nº1
S2	Substrate nº2
T3	Tray nº 3
T5	Tray nº5
T6	Tray nº6
T7	Tray nº7
Wi	With insulation
X	Random variable representative of each table tray, *x* = [3, 5, 6, 7]
HD+	Hottest day
$T_{sol\text{-}air}$	Sol-air temperature (°C)
h_{se}	Heat transfer coefficient of the exterior surface (W/m^2°C)
α	Absorption coefficient
ρ	Reflection coefficient
τ	Transmission coefficient
Fl^{ic},7	Heat flux calculated through insulation layer (W/m^2)

2 Green roofs

The green roof is a solution to the plantation on top of buildings (slabs and roofs) and can be partially or completely covered by a layer of soil and vegetation which can be undergrowth plants, shrubs and trees, depending on the green roof category.
In a simplistic way, a green roof is characterized by having installed on the structural slab and intermediate layers of insulating and protective membranes a layer of substrate with vegetation.
Green roofs can be divided into three categories depending on the thickness of the soil layer and the utilization given to the green roof (accessible or not) as well as the maintenance costs (Wark & Wark, 2003; Henry & Frascaria-Lacoste, 2012): extensive, semi-intensive and intensive. Extensive roofs have a thin layer of soil (i.e. between 6 and 20cm), are easily implemented on site, require little maintenance and are not accessible therefore less expensive (Fioretti et al., 2010). Intensive roofs have a greater thickness (more than 15cm) and may contain various types of vegetation (e.g. trees). This kind of roof is used in accessible rooftops of heavier buildings and garages and requires a more regular maintenance. The last category is semi-intensive roofs and these have mixed characteristics of both extensive and intensive green roofs.
Although all environmental, aesthetical, protective and housing comfort advantages, green roofs have some disadvantages such as the initial cost of installation, maintenance and irrigation costs, and the overload applied to the structure of the buildings.

2.1 Previous studies

There have been many studies conducted about green roofs in several countries and different climates: in cold climates (Liu, 2003; Liu & Minor, 2005; Lanham, 2007; Sailor et al., 2008; Sailor et al, 2011), tropical climates (Wong et al., 2003; Simmons et al., 2008; Feng et al., 2010; Qin et al., 2012; Dvorak & Volder, 2013; Yang et al, 2015) and Mediterranean climates (Niachou et al., 2001; Lazzarin et al., 2005; Sfakianaki et al., 2009; Schweitzer & Erel, 2014; Bevilacqua et al., 2015).
Regarding the cold climates it has been studied that, a vegetation with a high LAI (Leaf Area Index), a high relation in aggregate/sand and a low quantity in organic matter in the soil, and also low tenor of moisture, are all factors that favor cooling of a building in the summer season, while in cold seasons, the insulation layer is the main factor to maintain the inner temperature, hence green roofs are more efficient in warmer climates. Concerning the reduction of the volume of drained waters from haste, this value overcomes the 50% and all reductions in energetics costs show values above 10%.
In tropical climates, the soil and vegetation characteristics have a big influence on the preformance of the green roofs. Adding to this influence, and by being located in places with a high tenor of moisture, it was concluded that green roofs are efficient even without a constant irrigation and also on days without rainfall. It was verified that green roofs can diminiuish the heat island effect in urban centers and can also reduce thermic fluctuations on themselves. In rainning events, it was found that the

bigger the event, the lower the water retention capacity, although for small events, water retention capacity can reach levels above 50%, as shown for cold climates.
The authors that studied the Mediterranean climates reached conclusions regarding the importance of the shadow effect caused by the vegetation on the soil and its moisture content since these two factors help green roofs to cool the buildings, in a passive way during summer. A reduction in heat fluxes through green roofs presented values over 50%, and in some cases being nonexistent, when the soil was wet. Resembling tropical climates, the need of refrigeration has been decreasing up to values above 10 %. It was proven that 8cm of substrate is sufficient to stabilize the temperature in the layer base of the roof.

3 Case Study

The campaign was conducted in four metallic trays, located in ISA, each with 2,5m long, 1m wide, 20cm high and a constant thickness of 1,5mm. Trays are supported by a metal frame that elevates them about 0,8m height from the rooftop.
Each tray contains 13cm height growing medium. This is placed on a drainage system consisting of a mechanical protection layer (i.e. geotextile), followed by a drainage layer (i.e. Floradrain FD 25-E) and a filter (i.e. geotextile) which with the resistant support (i.e. tray plate) represents a total thickness of 2 cm (Figure 1).
All the trays were insulated on its sides (i.e. from the height of the tray to the floor) and bottom part. In order to do this there have been placed plates of extruded polystyrene with 10cm thick which were pressed with straps and locking methods.
A plate of extruded polystyrene with 3cm was placed on a tray zone in order to have distinction between an <u>insulated area</u> and another <u>non-insulated area</u>.

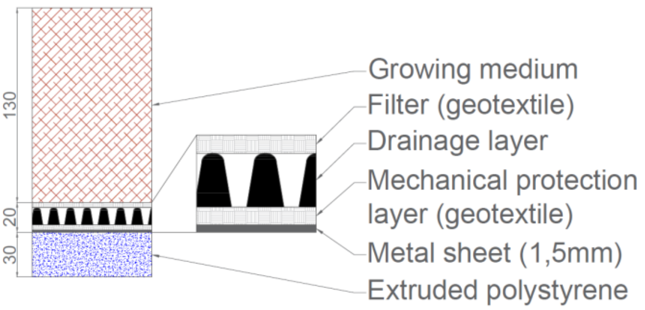

Figure 1 - Profile of the layers of the trays [mm].

There are two types of substrates (i.e. soils S1 and S2) that differ in concentrations of sand, silt and clay. Regarding the plant composition there are three bushes (i.e. *Brachypodium Phoenicoides*, *Rosmanirus Officinalis*, *Lavandula Luisieri*) and a moss (*Pleurochaete*). Its distribution per tray is present on Table 1.

Table 1 - Substrates and vegetation of each tray.

Tray	Soil	Vegetation		
		Common name	Scientific name	Height (cm)
T3	S2	N/A	*Brachypodium Phoenicoides*	20-25
T5	S1	Lavender	*Lavandula Luisieri*	50-60
		Rosemary	*Rosmanirus Officinalis*	30-50
		N/A	*Brachypodium Phoenicoides*	20-25
		Moss	*Pleurochaete*	1-2
T6	S1	Rosemary	*Rosmanirus Officinalis*	30-60
T7	S1	N/A	*Brachypodium Phoenicoides*	20-25

About the irrigation, all trays were subjected to the same daily amount of water which was equal to 60% ET_0 (Allen, Pereira, Raes, & Smith, 1998). The only difference regarding irrigation is the number of irrigations per day: on the board with moss, T5, watering was carried out at 8am, 10am and at 7pm, through two systems (i.e. drop by drop and water pulverization); in the remaining trays (i.e. T3, T6 and T7) there was only a daily watering at 8am performed by the drop by drop system.

3.1 Experimental procedure

The equipment installed in each tray is present in Table 2 and Table 3 and its location is displayed on a tray-type illustrated in Figure 2.

Table 2 - Equipment on tray T3 and T5.

Tray	Cell	Description	Unit
T3	Tse,3	Exterior surface temperature in NIA*	°C
	Th1,3	Soil temperature (h=6.5cm) in NIA	°C
	Th2,3	Soil temperature (h=0cm) in NIA	°C
	Tsi,3	Interior surface temperature in NIA	°C
	Tse^{wi},3	Exterior surface temperature in IA**	°C
	$Th1^{wi}$,3	Soil temperature (h=6.5cm) in IA	°C
	$Th2^{wi}$,3	Soil temperature (h=0cm) in IA	°C
	Tsi^{wi},3	Interior surface temperature in IA	°C
	Ti,3	Interior temperature	°C
	Ti,3,R	Interior temperature by Rotronic	°C
	Hi,3,R	Interior relative humidity by Rotronic	%
T5	Te,5	Exterior temperature	°C
	Tse,5	Exterior surface temperature in NIA	°C
	Th1,5	Soil temperature (h=6.5cm) in NIA	°C
	Th2,5	Soil temperature (h=0cm) in NIA	°C
	Tsi,5	Interior surface temperature in NIA	°C
	Tse^{wi},5	Exterior surface temperature in IA	°C
	$Th1^{wi}$,5	Soil temperature (h=6.5cm) in IA	°C
	$Th2^{wi}$,5	Soil temperature (h=0cm) in IA	°C
	Tsi^{wi},5	Interior surface temperature in IA	°C
	Ti,5	Interior temperature	°C
	Fl,5	Heat flux in NIA	W/m^2
	Fl^{wi},5	Heat flux in IA	W/m^2

*non-insulated area
**insulated area

Table 3 - Equipment on tray T6, T7 and exterior.

Tray	Cell	Description	Unit	Tray	Cell	Description	Unit
T6	Tse,6	Exterior surface temperature in NIA	°C	T7	Te,7	Exterior temperature	°C
	Th1,6	Soil temperature (h=6.5cm) in NIA	°C		Tse,7	Exterior surface temperature in NIA	°C
	Th2,6	Soil temperature (h=0cm) in NIA	°C		Th1,7	Soil temperature (h=6.5cm) in NIA	°C
	Tsi,6	Interior surface temperature in NIA	°C		Th2,7	Soil temperature (h=0cm) in NIA	°C
	Tse^{wi},6	Exterior surface temperature in IA	°C		Tsi,7	Interior surface temperature in NIA	°C
	$Th1^{wi}$,6	Soil temperature (h=6.5cm) in IA	°C		Tse^{wi},7	Exterior surface temperature in IA	°C
	$Th2^{wi}$,6	Soil temperature (h=0cm) in IA	°C		$Th1^{wi}$,7	Soil temperature (h=6.5cm) in IA	°C
	Tsi^{wi},6	Interior surface temperature in IA	°C		$Th2^{wi}$,7	Soil temperature (h=0cm) in IA	°C
	Ti,6	Interior temperature	°C		Tsi^{wi},7	Interior surface temperature in IA	°C
	Ti,6,T	Interior temperature by Tinytag	°C		Ti,7	Interior temperature	°C
	Hi,6,T	Interior relative humidity by Tinytag	%		Ti,7,R	Interior temperature by Rotronic	°C
Ext.	Te,T	Exterior temperature by Tinytag	°C		Hi,7,R	Interior relative humidity by Rotronic	%
	He,T	Exterior relative humidity by Tinytag	%		Fl,7	Heat flux in NIA	W/m^2
	SR	Solar radiation in horizontal plan	W/m^2		Fl^{wi},7	Heat flux in IA	W/m^2

*non-insulated area
**insulated area

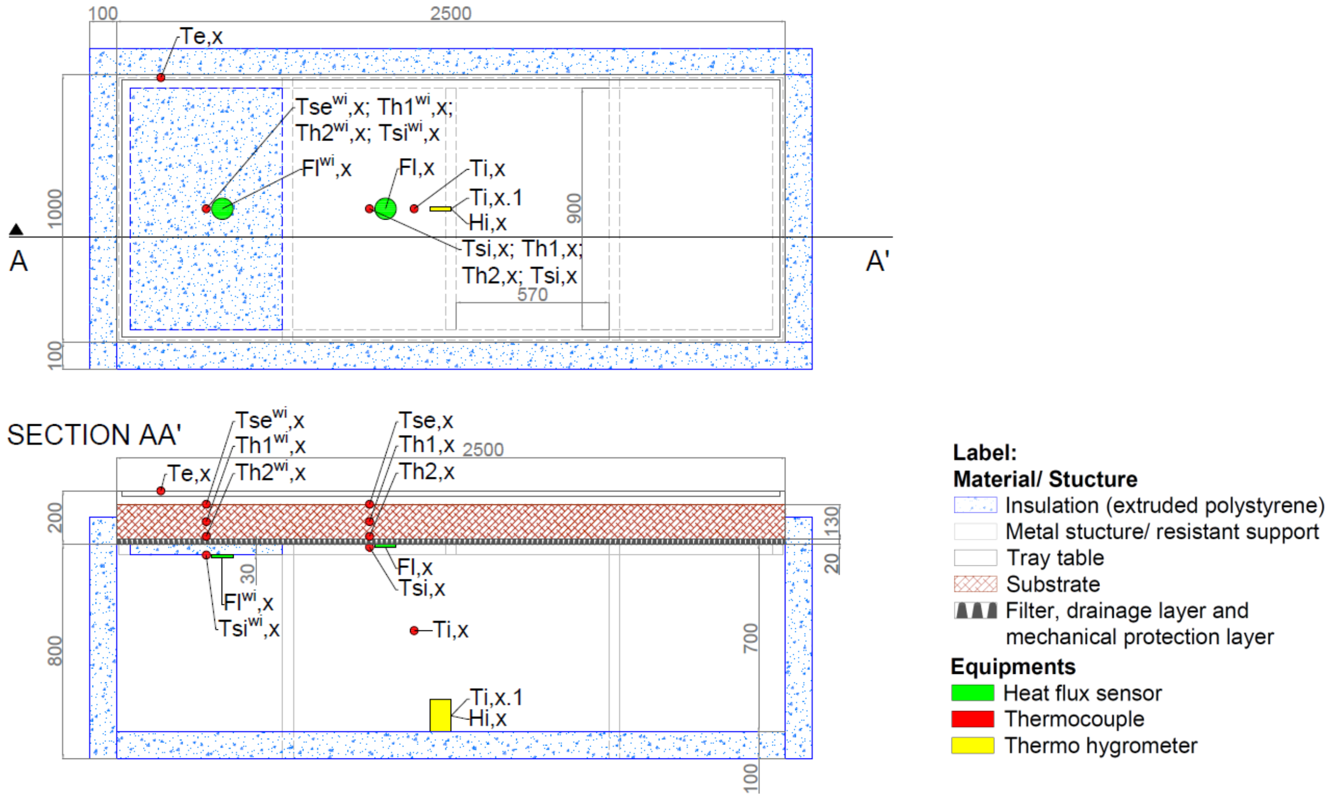

Figure 2 - Tray-type with probes in plant (top) and in profile (bottom).

A total of 48 thermocouples, 4 heat flux sensors, 4 thermo hygrometers, 1 pyranometer and two data acquisition systems (Delta-T - DL2e Data Logger and Campbell – CR10) have been used.

4 Discussion and Analysis of Results

A database was created containing the values collected from the various instruments for a total of 51 cells, each containing a total of 2.017 entries over 14 days and 10 minutes making it 102.867 data. Although the readings were done once per minute, each log matches the average of every 10 minutes.

The campaign started on the 16th of June around 10:30am and ended on the 30th of June at the same time.

The results are divided into two parts: the campaign itself where a period of 13 days will be accounted for, from 00h00m of 17th to 23h50m of 29th; and a day-type that is representative of the hottest day (HD+), on which it was recorded the higher sol-air temperature (i.e. the value of fictitious outdoor air temperature which, in the absence of any radiation exchanges,

provides the same heat flow rate to the outer surface equivalent to the combination of outside temperature with the incident solar radiation) (Jones, 2011).
In order to calculate the maximum sol-air temperature it was needed to use the equation 4.1, also the principle of conservation of energy (equation 4.2) (Silva, 2013) and Table 4:

$$T_{sol-air} = Te + \frac{\alpha \times RS}{h_{se}} \; [°C] \qquad \textbf{(4.1)}$$

$$1 = \alpha + \rho + \tau <=> \alpha = 1 - \rho \qquad \textbf{(4.2)}$$

Table 4 - Values to calculate the absorptivity.

Tray	T3	T5	T6	T7
SR reflected (W/m²)	90	70	70	110
SR incident (W/m²)	380			
Reflection coefficient (ρ)	0,24	0,18	0,18	0,29
Reflection coefficient (average)	0,76	0,82	0,82	0,71
Absorptivity (α)	0,78			

The HD+ its 27th of June of 2015, with a sol-air temperature of 56,30°C.
There is a need for a reference tray which in this case the chosen one was tray T7.

4.1 General campaign

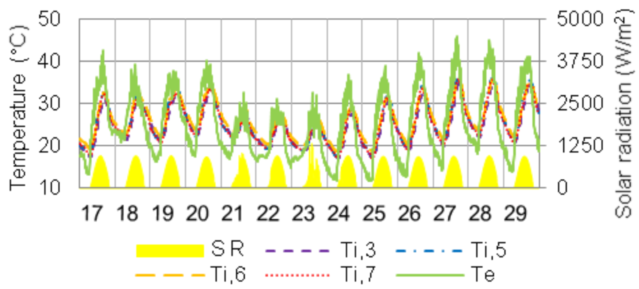

Figure 3 - Inside temperature of all trays, exterior temperature and solar radiation.

Even though solar radiation presents identical values throughout the campaign, the readings regarding exterior and interior temperatures have a more irregular behavior throughout the days; because of this we can assure that a maximum solar radiation doesn't represent a maximum temperature. Knowing this we can conclude that the temperature varies together with other factors other than solar radiation.
Interior temperatures of the tray tables when compared to the exterior temperature presented a lower temperature range (Figure 3). Despite the differences over the days all the tray tables show the same pattern of temperatures, from the 21st to 23rd of June 2015 both the maximum for the exterior temperature and the daily accumulated solar radiation are decreasing, reaching respectively to a reduction of about 30% and 40%, when compared to hottest day, creating the same impact in the interior temperatures of the trays. However this is not a break that can change the default behavior of the temperatures observed throughout the campaign.

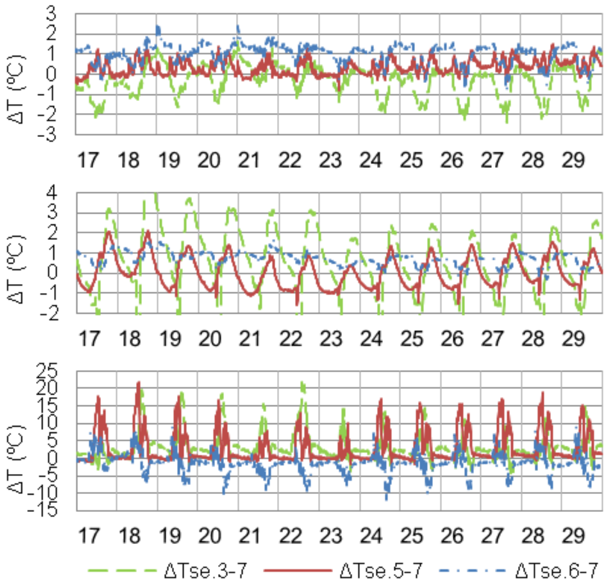

Figure 4 - Variations of interior temperature (top) interior superficial (middle) and exterior superficial (bottom) of all of the trays comparing to the reference board.

Observing Figure 4, on which the three trays are compared to the reference one, it can be concluded that:

- The T3 board presents lower inner and ambient temperatures then the reference board during the day, during the night the ambient temperature it is the same or higher relatively to the reference board, while the inner superficial temperature is always superior in relation to the night period on the reference board. Having different substrates and equal vegetation it allows us to conclude that the S1 soil (clayey) has a higher thermal conductivity than the S2 soil (sandier). With regard to the exterior superficial temperature, this tray (T3) have higher values in almost the entire campaign, but more pronounced numbers during the day, which is explained by the absorption coefficient being higher in this tray, with a value of 0,76 against 0,71 of the reference tray.
- Tray T5 has demonstrated that the interior temperature variations when compared to the reference tray are lower but positives. Interior superficial temperatures are superior in the second half of the day and lower in the first half; also the exterior superficial temperature is higher than the one registered on the reference tray during the day. This implies that tray T5 is saving more

energy in the form of heat, coming from the solar radiation. The absorption coefficient value for tray T5 is 0,82 and tray T7 is 0,71, this can be justified by the fact that tray T5 has a browner vegetation and less density. On the other hand the reference tray can keep its green color and plant density allowing the maintenance of a low absorption coefficient and a high shadow effect.

- Tray T6 has a higher interior temperature than tray T7, during the night and similar to it during the day. Interior superficial temperature is always higher than the one registered on the reference tray. Regarding the exterior superficial temperature on tray T6 is lower than the reference tray during the day – this information is opposite to the information obtained by the absorptivity coefficient of this tray, which is 0,82 to 0,71 on the reference tray (i.e. higher absorption coefficient suggests higher exterior superficial temperature). This phenomenon is due to the shadowing of the cell at a particular time of day.

Analyzing the temperature differences on every day of the campaign, this data presents the same daily behavior, proving that despite the difference in the outside temperature (-30 %) and variation of the solar radiation (40%) from the 21st to the 23rd of June, as seen in Figure 3, these variations do not have enough impact to change the default behavior of roof temperatures.

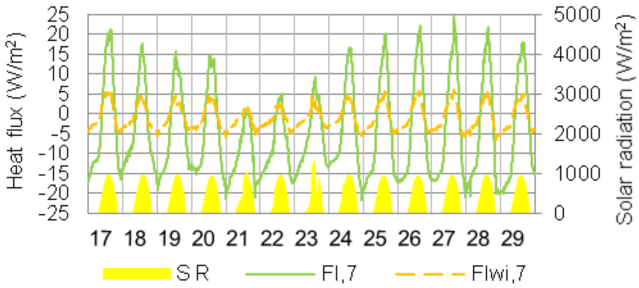

Figure 5 - Heat flux of the area with and without insulation and solar radiation in the reference tray.

As regards the heat fluxes of the reference tray is clear the distinction between the areas with and without insulation and the daily variation of the flows, in the insulated zone, this variation is lower than the area without insulation (Figure 5).

From the 21st to the 23rd of June, as seen in Figure 5, the heat flow for the daytime, in the insulated area, is similar to the one on the non-insulated area. This shows the impact of the reduction of the exterior ambient temperature together with the accumulated solar radiation, that when compared to the hottest day, with a 30% reduction in temperature and 40% of solar radiation, there was a total reduction of 60-80% in the heat flow during the day. The losses suffered during the night for the same period of time were the same compared to the other days.

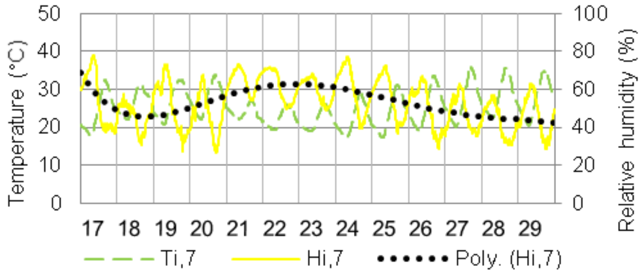

Figure 6 - Relative humidity and interior temperature of the reference tray.

Concerning humidity (Figure 6), this is higher in the first half of the day and lower in the second half, while in the temperature the reverse was observed. In the chart a polynomial trend line (grade 5) of the relative humidity is present. This line has its maximum on 23rd of June and the interior temperature had its lowest values at that time. By associating this data to the irregularities of solar radiation throughout that day, it can be concluded that the sky was cloudy. The relative humidity on the inside from the 21st to the 23rd of June, showed an average increase of about 20% compared to rest of the days, which is a possible consequence of the decreasing of the exterior temperature and the daily accumulated solar radiation.

4.2 Day-type – HD+

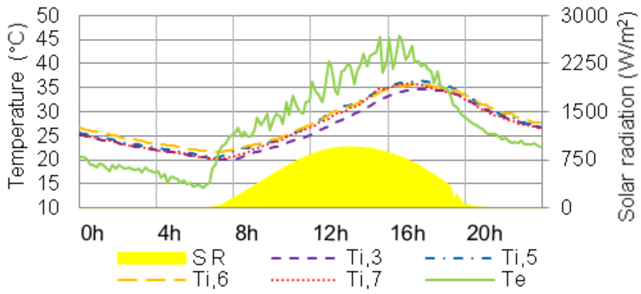

Figure 7 - Interior temperature of all trays and solar radiation.

The values of the interior temperatures are more stable and have a smaller range when compared to the exterior temperature. The interior and exterior ambient temperatures start to rise as soon as the solar radiation value increases too (Figure 7);

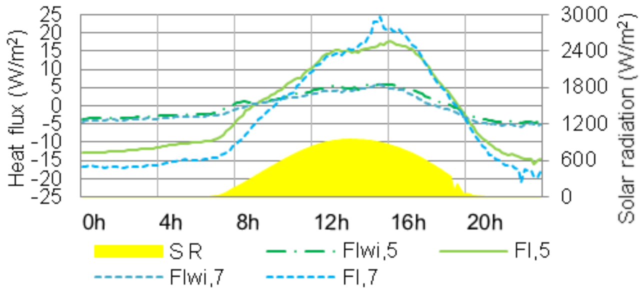

Figure 8 - Heat flux of the area with and without insulation on trays T5 and T7 and solar radiation.

Through Figure 9, it can be observed the heat fluxes on the insulated area are much more stable than the ones for the non-insulated area. This difference between areas has a 67% impact on tray T5 and 75% on tray T7 by reducing the descending heat flux throughout the day. During the night the values for the ascending heat fluxes were of 70% and 68% on the insulated areas in trays T5 and T7;

In Figure 9 is exposed the heat flux for the reference tray in the insulated area (Fl^{wi},7) and the calculated heat flux of the insulation layer on the same tray (Fl^{ic},7). Through this chart it will be possible to evaluate the contribution of the substrate and vegetation on the green roof. This will allow comparing a solution with insulation only to the experimental solution on an insulated area.

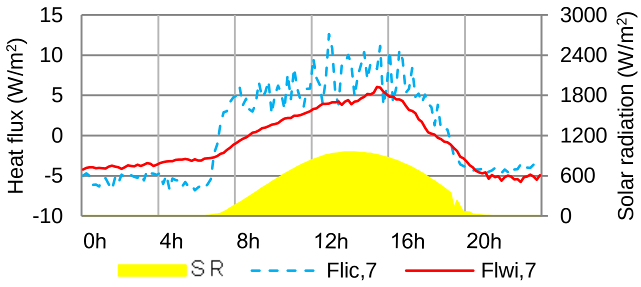

Figure 9 - Heat flux in the insulated area of the reference tray and the calculated heat flux of the insulation layer and solar radiation.

It is noticeable on Figure 9, that a solution with insulation (dashed line), at the end of the day for up to 12pm, is similar to a solution of a cover with an insulation layer, substrate and vegetation. During the daytime there is a maximum difference in the heat fluxes of 5W/m² (i.e. the flow through the solution with the insulating layer comes to be twice the flux through the solution with insulation, substrate and vegetation). From midnight until the sunrise there is a difference in the heat fluxes, which is lower than what observed during the day, the solution with the insulation layer allows a heat flux 3-4W/m² higher than the solution with insulation, substrate and vegetation.

Considering the entire day, the contribution of the substrate and vegetation on a green roof has a 41% impact. With this it can be concluded that a green roof only has thermal advantages during the daytime, while at night, its contribution is smaller, and at the end of the day is nonexistent.

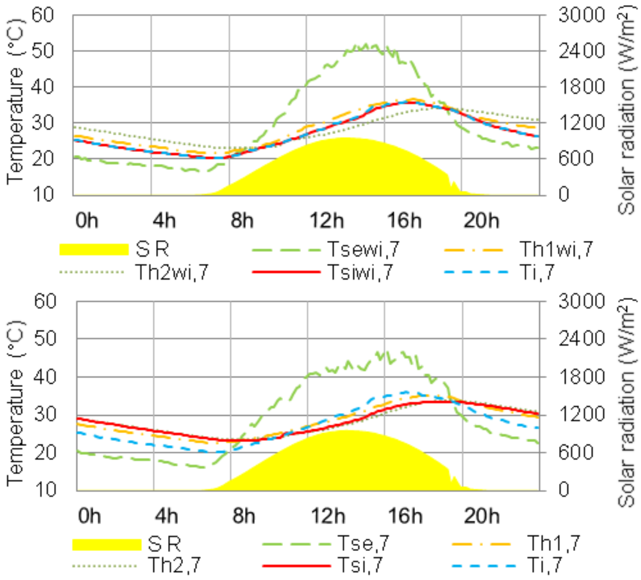

Figure 10 - Substrate temperature of the reference tray and solar radiation in the insulated area (top) and non-insulated area (bottom).

On Figure 10, it can be observed the influence of thermal insulation. The main difference between areas is the interior superficial temperature where in the insulated area it is almost the same as the interior temperature while on the non-insulated area it's similar to the temperature at height h2 (0cm). On the same Figure 10 it is noticeable that there is no influence of irrigation, as there is no type of break or unevenness in temperature at the time that it took place (08h00m).

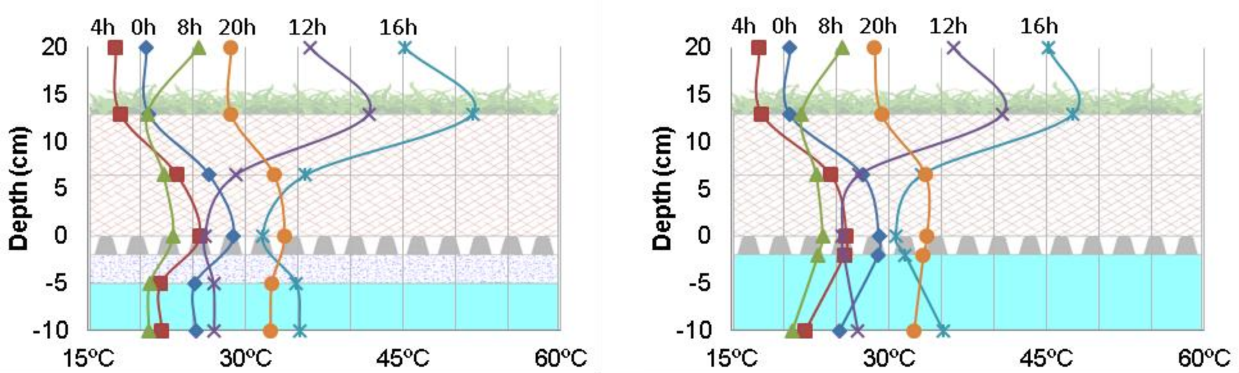

Figure 11 - Depth substrate temperature of the reference tray on different hours of the HD+: on insulated area (left) and non-insulated area (right).

Finally, through Figure 11 it is possible to check a large exterior temperature range and that it decreases in depth. However, the interior temperature presents a higher temperature range than the substrate so this confirms the existence of gaps in its surroundings, thus losing heat by ventilation.

5 Conclusions

This study is based on the experimental evaluation of the thermal behavior of a semi-intensive green roof. In the experimental campaign developed in ISA, temperatures were monitored for the 2015 summer season (interior and exterior ambient temperatures, superficial temperatures and temperatures throughout the soil depth), solar radiation, interior and exterior humidity and heat fluxes in four trays with different types of vegetation and substrate so as to be able to compare the thermal behavior in different combinations.
In regards to the comparison of the two substrates in use, the S1 substrate has a higher thermal conductivity as it presents an inner temperature 2°C lower (-5%) to the tray with substrate S2, during the day.
About the composition of each substrate, the main difference between them is the percentage of organic matter, in substrate S1 it has 73% against the 7% from the S2 substrate. According to Sailor (2008), a bigger percentage of organic matter leads to an increasing on the thermal conductivity on itself, thus meeting the same conclusion reached in this study. These results are associated with the fact that the substrate S1 has more clay then substrate S2, which is a sandy substrate, promoting the conductivity of the substrate S1.
For the plant species: the *brachypodium,* due to be ability to maintain its color and density during the summer, is a good ground shield against radiation; rosemary and lavender, being plants with a darker colors and are early in their development (i.e. being less dense), hence so favorable species were not found to protect a covering of solar radiation; moss could not be effective in protecting the soil because it was dry.
In addition to the constituents of the substrate, the type of thermal insulation and the chosen vegetation, there are other parameters that influence the thermal behavior of the roof. For example, sun exposure influenced by the nebulosity and in the choice of the vegetation factors like vegetation color and respective density.
Concerning irrigation, the conclusions drawn were that when using an efficient water management method with controlled amount of water, this does not influence the thermal behavior of the cover.
During periods where there is a reduction of the exterior temperature and a reduction in the daily accumulated solar radiation, it was concluded that a reduction of 30% and 40%, respectively, causes no significant change in the default behavior of the temperatures of the green covers. However, a reduction of this magnitude in the exterior temperature and in the daily accumulated solar radiation influences the heat flux through the cover during the day, causing a reduction of 60-80%, but does not affect the heat flux during the night. Associated to this factors, there was an average increase of interior humidity by about 20%.
In the analysis of the hottest day it was verified that the vegetation and the substrate have a contribution of approximately 41% in the reduction of the heat flux passing through the green roof on the insulated area throughout the day. However, in the beginning of the night time, the values of heat fluxes in both solutions are similar, and throughout the night until sunrise, it will be noticed a difference between the solution with the insulation layer and the solution of the roof with insulation, substrate and vegetation which is more efficient, during the daytime, on which the impact corresponds to a reduction in the values of heat fluxes by half when compared to the solution composed with insulation only.
By the day-type study also it was possible to compare the insulated area with the non-insulated area, which reported reductions of about 70% in heat fluxes because of the use of an extruded polystyrene foam insulation board with a thickness of 3cm.
Finally it was concluded that the exterior surface temperature had a large daily temperature range, and this was decreasing in depth due to the thermal inertia of the substrate.

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