Green and White Roofs: The Urban Heat Busters

An Investigation of White and Black Roofs, Biodiversity, and Water Retention

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Abstract

- We proposed three questions about green roofs:
(A) What are the differences in retaining heat on black and white roofs? (B) What type of insect biodiversity exists on green roofs? (C) How much stormwater runoff can green roofs retain?
- First, black and white roofs were compared to see which retained less heat in the wintertime. Our conclusions were not as expected because it showed white roofs to be generally warmer than black roofs. Our analysis sent us back to question the manufacturer about the emissivity of the white material used.
- Second, we observed the insect biodiversity on green roofs. We monitored and collected ants, flies, and bees that begin to inhabit a green roof from initial planting to mature growth.
- Third, we calculated the percentage of stormwater that was permanently retained on the Con Edison green roofs. Our analysis showed that green roofs retained 30% of the stormwater.

Background

- The Urban Heat Island Effect refers to when cities are warmer than the surrounding rural areas due to the low albedo of the building materials used.
- Increasing the amount of vegetation in a city can lower temperatures because of its great ability to evaporate water. Since there is a wide availability of open rooftop space in NYC, vegetation has been placed on roofs, called green roofs, to cool down buildings and lower cooling costs.
- Another aspect of our project consisted of analyzing how efficient a white rooftop surface would be at reducing building temperatures. Since white surfaces have high albedos, they can reflect sunlight easily. This would inhibit white roofs from reaching the high temperatures of black roofs.
- Besides its energy reduction capabilities, biodiversity on green roofs were also studied. We observed how insects may benefit from green roofs spaces placed around the city.

White Roofs vs. Black Roofs

Problem: In the winter season, white roofs may provide a "winter heat penalty" where white roofs reflect sunlight and may raise building heating costs. The purpose of this study was to analyze the "winter heat penalty" effect further.

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Background: Black roofs have a low albedo which enable them to heat to temperatures higher than ambient air. White has a high albedo which enable white surfaces to be at temperatures lower than ambient air. With this knowledge, we hypothesized that white roof surfaces should be cooler than black roof surfaces.

Methods: The experiment took place on the Con Edison green roof in Long Island City. A separate section contained a black roof surface and half of this area was coated white. Surface temperatures of the two areas were recorded hourly over the 2008-2009 winter (DJF) season.
During the 2009-2010 winter, an additional black layer was placed on top of the black roof area and hourly temperature readings were taken.

Results:

Average 08-09 Black and White Hourly Winter Temperatures

	Average temperatures
Black Surface	-0.98°C
White Surface	-0.41°C
Difference	0.57°C

Average Winter 08-09 Nighttime (12am-4am) Temperatures

	Average Temperatures
Black Surface	-5.57°C
White Surface	-2.73°C
Difference	2.84°C

Average Winter 09-10 (12am-4am) Temperatures

	Average Temperatures
Black Surface	-1.18°C
White Surface	-0.93°C
Difference	0.25°C

Average Winter 09-10 Nighttime (12am-4am) Temperatures

	Average Temperatures
Black Surface	-5.02°C
White Surface	-3.01°C
Difference	2.01°C

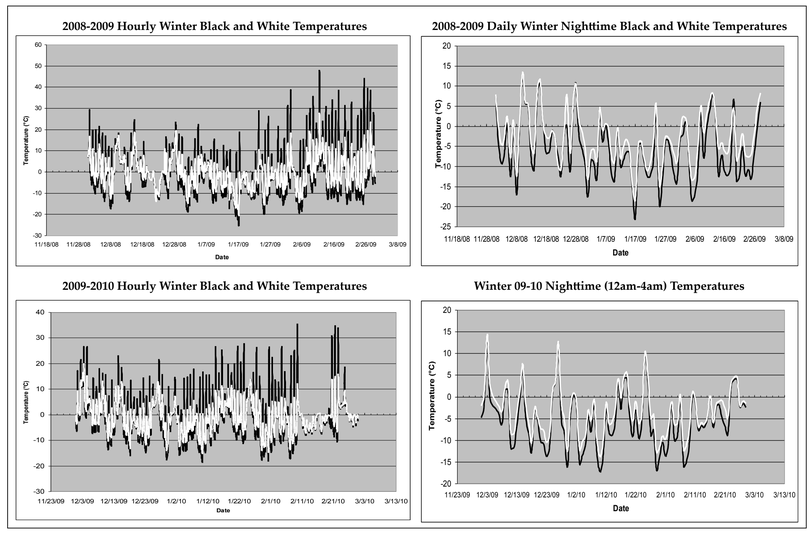
Ecological Biodiversity

Introduction: We studied insect communities of green roofs in NYC. It is a study of community diversity but includes a focus on pollinators. The goal is to survey the entomological diversity of green roofs.

Methods: The study includes 18 green roofs in all 5 boroughs of NYC. The three techniques used to study biodiversity were pan traps, which are small plastic bowls filled with soapy water, sweep nets and observations of specific plants.

Observations: The observations entailed watching pollinator friendly plants for 10-minute intervals. We also observed the insects that were collected in water filled bowls and noted the varieties of insects..

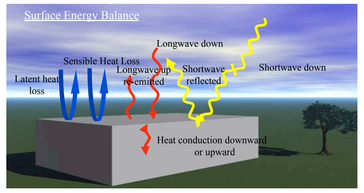
White Roofs & Black Roofs Continued



Water Retention

Problem: Storm water runoff causes adverse health effects by polluting a city's rivers and water supply. This contributes to the combined sewage overflow (CSO) effect which plagues waterways worldwide.

Objective: To calculate the latent heat emitted from a green roof. Latent Heat is the surface heat loss during phase change from liquid to water vapor, equivalent to evapotranspiration. To calculate the percentage of stormwater that was permanently retained on the Con Edison green roof. The annual retention rates during 2009 were calculated.

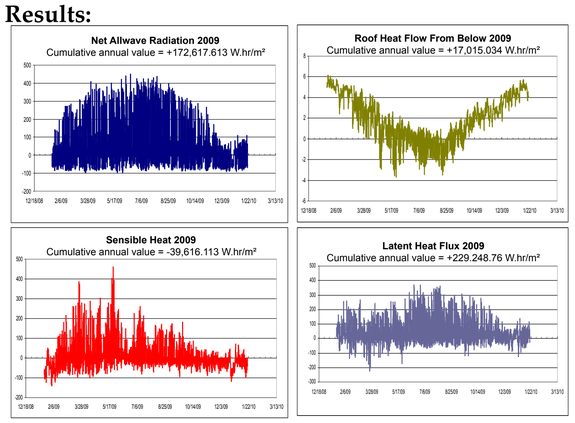


Methods:
A) The integrated energy balance equation is used to solve for latent heat flux:

$$\int(SW\uparrow + SW\downarrow + LW\uparrow + LW\downarrow)*dt = \int \text{Heat Conduction Below}*dt + \int SH*dt + \int LH*dt$$

B) Using the latent heat of vaporization coefficient allowed us to convert from a latent heat energy value to the mass of water evaporated.
Divide mass by density gives us the volume. Dividing this volume by integrated precipitation gives **percent** retention.
SUMMARY:
LH → mass of water evaporated → volume evaporated = RETENTION

Results:



Annual Percentage Water Retention	**30%**
Total '09 Rainfall on Green Roof (10,000 sq ft)	335,368 gallons
Annual Rainfall Retained	101,616.51 gallons
Annual Gallons Retained Per Square Foot	10.2 gal/sf

Conclusions and Future Work

We investigated three general areas of green roof research through various field work experiments:
(A) White and black roofs (B) Biodiversity of insects on roofs and (C) Water retention on the Con Edison roof.
(1) Surprisingly, white roof surfaces were 0.57°C warmer than black roof surfaces during the winter. Furthermore, we investigated the nighttime data and found the white roof surface to still be warmer and a greater temperature difference between the two surfaces. However, after we added a black layer on top of the black roof, we noticed that the difference in temperature between the white and black roofs decreased. In the future, we hope to investigate the emissivity of the white roof surface to account for the temperature differences.
(2) Additionally, we observed the biodiversity of insects on green roofs and found a wide variety of them on roofs around the city.
(3) Furthermore, our results showed that the Con Edison roof retained about 30% of the precipitation in 2009-10 or 10.2 gallons per square foot. This offers insight into the use of green roofs in the future. If the one billion square feet of rooftops in NYC were transformed into green roofs, we can potentially retain ten billion gallons of water annually from entering the CSO.

Sponsors:
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