LP130100731: Mimicking natural ecosystems to improve green roof performance

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LP130100731 Aims:

1. Assess whether ecosystem mimicry can improve green roof stormwater retention and water quality.
3. Develop new green roof substrates to improve water and nutrient retention.
4. Validate experimental findings on a full-scale green roof.
5. Model green roof thermal and hydrology performance with different substrate and plant combinations under different rainfall and climate scenarios.

We have 4 months left on the grant.
Students

Zhanna Grebenshchykova, (Uni of Bordeaux internship) *The nutrient removal performance of vegetated roofs: quantification of an optimal fertilisation regime* (Experiment 2)

Andrew Pianella (PhD) - The thermal performance of green roofs in South-East Aust
Zheng Zhang (PhD) - Improving green roof hydrologic performance by increasing functional diversity
Joerg Werdin (PhD) - Can biochar improve green roof hydrological performance in hot and dry climates?

Influence of plant composition and water use strategies on green roof stormwater retention

- Evaluated how plant water use strategies influenced evapotranspiration (ET) and stormwater retention;
- ET and retention were greatest in plants with high water use and drought tolerance
- Plant roots reduced retention and soil water content due to preferential flow;
- Preferential flow overwhelmed the influence of water use strategies.
Summary

<table>
<thead>
<tr>
<th>Water use strategies</th>
<th>Conservative</th>
<th>Plastic</th>
<th>Plastic</th>
<th>Plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferential flow</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Water use</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Limited</td>
</tr>
<tr>
<td>Retention</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Rainfall Retention

- Rainfall event size is the main driver of retention
- 100 mm deep green roof retained 84-95% annual stormwater because Melbourne has lots of small rainfall events
- Plant species:
  - have no influence on retention performance in small events
  - Influence retention via available storage before rainfall

\[
y = -0.07508 - 0.03757x + 0.01718x^2
\]

![Graph showing rainfall retention and plant species performance](image-url)
• Scoria substrate has the lowest thermal conductivity
• R-values of scoria and bottom ash higher than most green roof substrates studied overseas.
• Data used in green roof thermal models.

R-values of Green roof substrates - 10 cm deep, no plants

<table>
<thead>
<tr>
<th></th>
<th>SCORIA</th>
<th>BOTTOM-ASH</th>
<th>ROOFTILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-values [Km²W⁻¹]</td>
<td>Dry</td>
<td>Moist</td>
<td>Wet</td>
</tr>
<tr>
<td></td>
<td>0.805</td>
<td>0.332</td>
<td>0.293</td>
</tr>
<tr>
<td></td>
<td>0.735</td>
<td>0.295</td>
<td>0.236</td>
</tr>
</tbody>
</table>

Steady-state

- Scoria substrate has the lowest thermal conductivity
- R-values of scoria and bottom ash higher than most green roof substrates studied overseas.
- Data used in green roof thermal models.


Effects of plant selection on substrate temperature

- Four monoculture modules
- Mixed and unvegetated modules
- Three replicates
- Rainfall is controlled
- Scoria substrate

Lomandra longifolia  Dianella adixtia  Stypandra glauca
Sedum pachyphyllum  Mixture module  Unvegetated module

**Effects of plant selection on substrate temperature**

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>LAI</th>
<th>h (cm)</th>
<th>$\rho_{vis}$ (%)</th>
<th>$\rho_{IR}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lomandra longifolia</em></td>
<td>$3.3 \pm 1$</td>
<td>$35-45$</td>
<td>$26.5 \pm 2$</td>
<td>$23-54$</td>
</tr>
<tr>
<td><em>Stypandra Glauca</em></td>
<td>$1 \pm 0.1$</td>
<td>$65-75$</td>
<td>$7 \pm 2.5$</td>
<td>$26-39$</td>
</tr>
<tr>
<td><em>Sedum pachyphyllum</em></td>
<td>$2.5$</td>
<td>$15-18$</td>
<td>$10 \pm 2$</td>
<td>$11-38$</td>
</tr>
<tr>
<td><em>Dianella adixtia</em></td>
<td>$0.8 \pm 0.1$</td>
<td>$7-80$</td>
<td>$9 \pm 1$</td>
<td>$27-46$</td>
</tr>
<tr>
<td>Unvegetated</td>
<td>$6 \pm 1$</td>
<td>$10-18$</td>
<td>$26-39$</td>
<td>$23-54$</td>
</tr>
</tbody>
</table>

**Mixture**

- **LAI**: $1.3 \pm 0.1$
- **h**: $7-80$
- **$\rho_{vis}$**: $8.5 \pm 2$
- **$\rho_{IR}$**: $29-41$

*Results: Bottom Temperature Swings*

- Unvegetated modules have the greatest temperature variations;
- *Stypandra* has a performance similar to unvegetated modules due to scarce coverage.
- In this period, *Sedum* offers better insulation than *Lomandra* due to wetter substrate. However, annually *Lomandra* performs the best.
Temperature variation with green roof thickness

Control

Substrate thermal profiles across the three experimental green roofs does not vary significantly in the top 50-80 mm
Heat flux through the roof

Peak heat fluxes of 34, 17, 12 W m\(^{-2}\) for the 100, 150 and 200 mm thick green roofs respectively.

Time delay of 3.5, 5 and 7 hours for the 100, 150 and 200 mm thick green roofs respectively.

Potential Annual Building Energy Savings

Energy simulations for 1-storey brick commercial building with concrete roof and set indoor temperature (21 C heating, 24 C cooling).
Energy Conclusions

- David Sailor’s green roof model has been modified and updated to South-East Australia weather to provide more realistic simulations;
- R values of substrates are low. Scoria is the highest of those tested
- Selecting high albedo and cover plants will improve thermal performance
- Green roofs consistently reduce and delay peak heat fluxes into the building with increasing substrate thickness.
- Scoria substrate and Lomandra longifolia in a 150 mm green roof provide the best green roof thermal performance in Melbourne of the combinations we tested.
- Potential energy savings: 65% heating and 35% cooling.

Can biochar improve green roof hydrological performance?

Joerg’s PhD structure

Research question chapter 2:
Can wood anatomical structure be used as a predictor for the water holding properties of biochar?
Wood biochar and its water holding properties

Research question
Can wood anatomical structure be used as a predictor for the water holding properties of biochar?

Experiment
Wood anatomical structure in relation to biochar water holding properties.

Data
Wood density- and anatomical structure (Silviscan and water displacement) biochar water holding capacity (WHC), matric suction curve, plant available water (PAW), field capacity (FC), bulk density (BD)

Output
Paper / Geoderma or Science of the Total Environment

Species and results

<table>
<thead>
<tr>
<th>Species</th>
<th>Radial fibre lumen diameter (µm)</th>
<th>Wood density Silviscan (kg/m^3)</th>
<th>Wood density water displacement (Kg/m^3)</th>
<th>Dry bulk density biochar (kg/m^3)</th>
<th>Water holding capacity (% v/v)</th>
<th>Plant available water (% v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. cypellocarpa</td>
<td>11.6</td>
<td>629.9</td>
<td>671.6</td>
<td>156.1</td>
<td>44.2</td>
<td>40.9</td>
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<td>E. delegatensis</td>
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<td>526.1</td>
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<td>E. divers</td>
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</table>

Table 1 Summary table of measurements taken for each of the different Eucalyptus species and their corresponding biochar type
Wood density is a good predictor for the amount of plant available water in biochar.

Wood biochar and its water holding properties

Academic Outputs


Plus three published conference proceedings
Recommendations for Industry

• Need to consider the effect of plant roots on water retention
• R values of substrates are small
  – No additional benefit deeper than 15 cm
• Energy savings
  – Up to 65% heating
  – Up to 35% for cooling
• The plants are very important: shade, albedo
• Biochar is a new useful substrate component