AUSTRALIAN FLORA FOUNDATION

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Research Matters

Newsletter of the Australian Flora Foundation

No. 38, July 2023

Inside

Biosolar green roofs – achieving biodiversity outcomes and solar power on the same roof, at the same time

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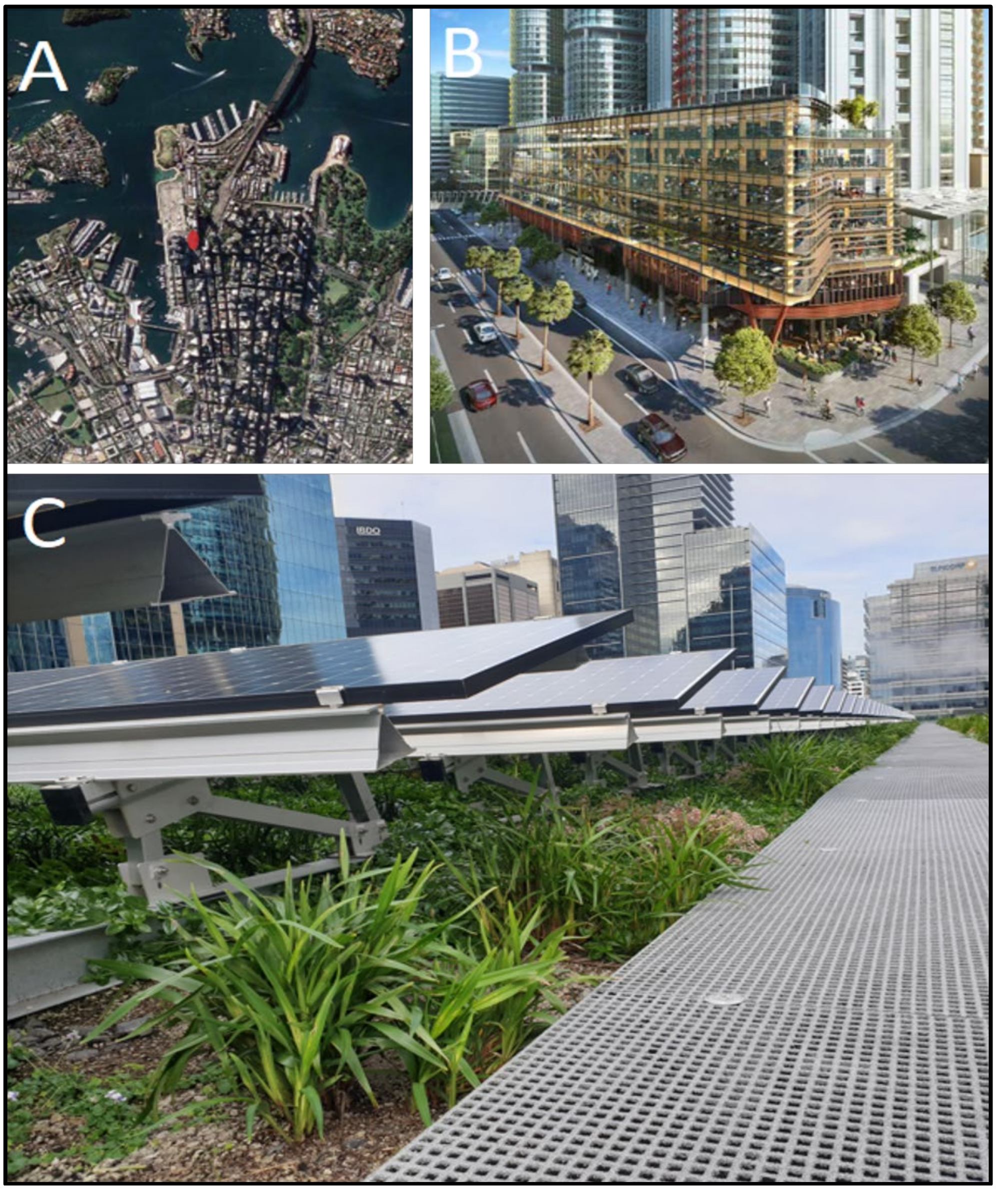
Introduction

Urban green spaces, such as parks and vegetation along roadsides, are readily recognisable examples of ecologically significant urban green areas. However, with growing human populations and limited space in cities, there is a rising trend for the adoption of space-efficient green solutions such as green roofs and green walls. While the ecological importance of residential and roadside vegetation is acknowledged in terms of supporting biodiversity, the impact of urban green roofs on biodiversity is still not well understood.

Additionally, green roofs play a role in regulating urban ambient temperatures, thereby enhancing the efficiency of solar panels by creating favourable conditions for energy production. There is a compelling correlation between the performance of photovoltaic panels (PV) and the negative impacts of rising ambient temperatures in their vicinity. What may come as a surprise to some is that as surfaces of solar panels heat up beyond 25°C, panel efficiency decreases. Green roofs have the potential to lower ambient temperatures around solar panels through evapotranspiration, thereby maximising the power output of PV systems.

Green roof studies

To date, many green roof studies have tested a single rooftop divided into 'green roof' and 'non-green roof' sections to measure differences in the effects of vegetation. However, studies using this design may be constrained by 'spatial confounding' due to the proximity of treatments leading to their effects influencing one another. Conversely, studies that use distinct buildings sometimes produce comparisons with limited validity due to the buildings being too far apart or too different in construction to be comparable. Further, most of the previous studies about removal of air pollutants by green roofs have assessed removal at the leaf scale, followed by modelling to generalise findings to an ambient scale. This is a process which has rarely been validated empirically.



Top left: (A) Map indicating the study site location (red dot) within the Central Business District of Sydney. Top right: (B) Architectural design of the Daramu House Building. Bottom: (C) View from the rooftop of the Daramu House Building looking southward and showing plant coverage around and underneath solar panels.

In this study, we aimed to determine whether established green roofs have greater abundance and diversity of organisms than conventional roofs. We investigated a Biosolar green roof – where a PV system is combined with a green roof – and compared it to a conventional roof containing only a PV system. We exploited a unique experimental design with the presence of a green roof as the sole variable. Our study sites were in the same geographic location and the buildings we used were the same height, size, and shape. We assessed avian, arthropod, and gastropod diversity across both roofs using motion-sensing camera traps at both macro- and micro-scales to quantify the biodiversity associated with urban green roof spaces. Further, plant community dynamics and succession were documented to investigate plant performance when influenced by shading due to the PV array.

Methods

The Biosolar green roof was located on top of the Daramu House Building in Sydney's Central Business District. Both the green roof and conventional roof were 1863.4 m^2, with 593.9 m^2 and 567.4 m^2 PV panel coverage, respectively. The green roof had a planted area of 1460.7 m^2 (78.4% total roof space), with PV panels covered 40.7% of the planted area. The green roof had a substrate depth of 120 mm and was irrigated with belowground hoses on a timer.

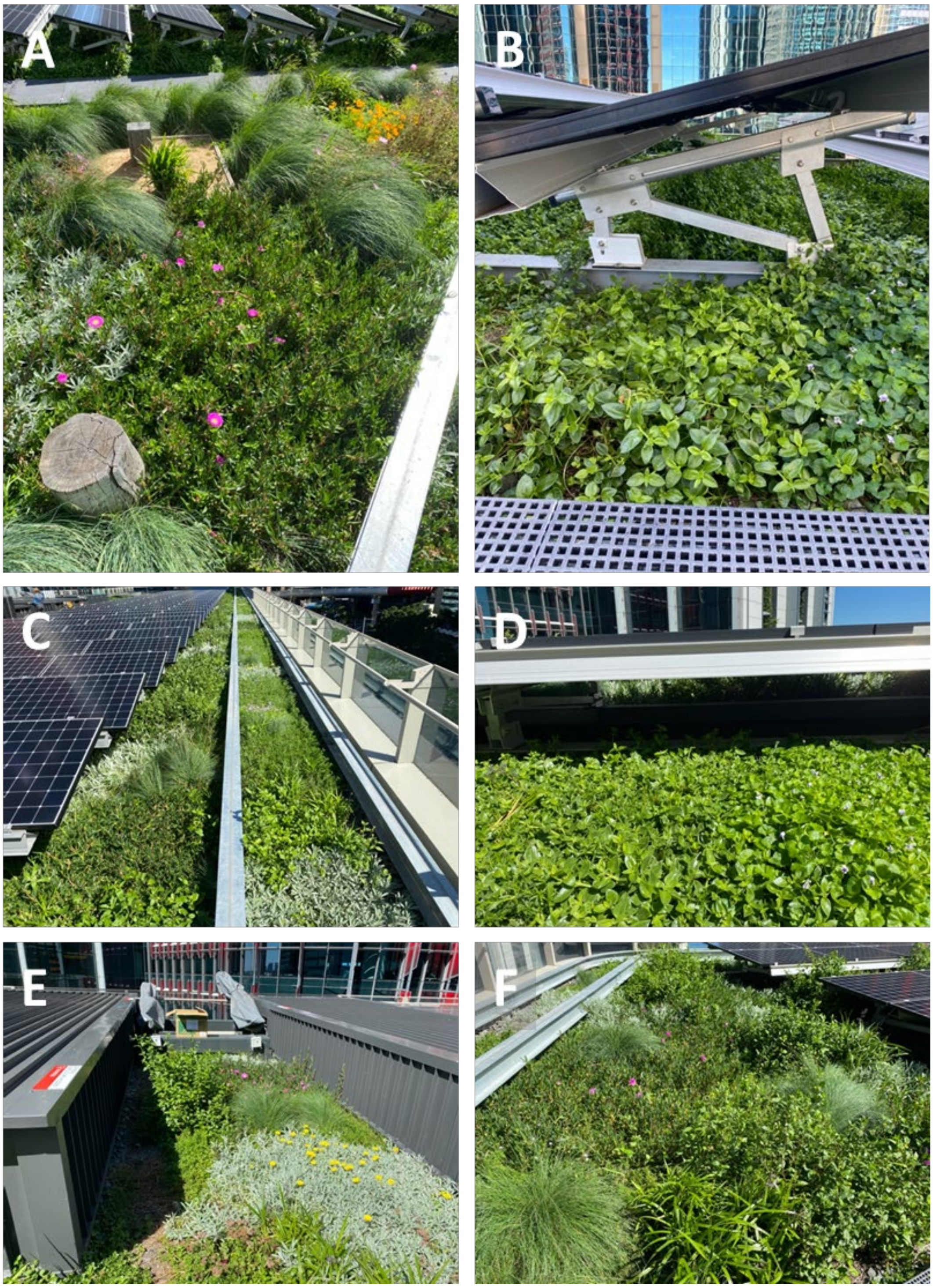
The Biosolar green roof was planted with a selection of native and non-native grasses and herbaceous plants (see table below). The plant assemblages were specifically selected to attract a diverse faunal community to the roof, with plants that would flower across all seasons.

Plant species	Common name	Spacing (plants/m^2)	Area (m^2)	Quantity
Under solar panels		5	615	
Viola hederacea	Ivy-leaved Violet			1542
Dichondra repens	Kidney Weed			1542
Around solar panels		10	248	
*Crassula multicava**	Fairy Crassula			496
*Aptenia cordifolia**	Baby Sun Rose			1488
Dianella caerulea	Blue Flax-lily			496
Open areas		10	595	
Dianella caerulea	Blue Flax-lily			745
Myoporum parvifolium	Creeping Boobialla			745
Brachyscome multifida	Cut-leaf Daisy			490
*Gazania tomentosa**	Silver Leaf Gazania			490
Goodenia ovata	Hop Goodenia			490
Poa poiformis	Coastal Tussock Grass			490
Themeda australis	Kangaroo Grass			490
Carpobrotus glaucescens	Pigface			490
				Total plants: 9994

*Indicates non-native species

Vegetation dynamics

Throughout the study period, we did vegetation surveys of the green roof to investigate the dynamics of vegetation growth and changes in the plant communities. In the open areas, there was minimal observable shift in the proportion of vegetation cover compared to the initial planted community. Each species in this section contributed an equal proportion to the overall vegetation cover on the green roof. However, in the 'Around solar panel' section, we observed the highest level of plant growth throughout the study period, with numerous species doubling in size since the time that they were initially planted. This growth is likely attributed to the deliberate selection of fast-growing vegetation for this section.



Top left: (A) An example of evenly distributed plant cover around solar panels. Top right: (B) Evidence of the succession of *Aptenia cordifolia* (Baby Sun Rose) and the dominance of this species beneath solar panels, minor cover of *Viola hederacea* also evident. Middle left: (C) Vegetation around solar panels along the outside of east section of the roof. Middle right: (D) Additional evidence of the dominance of *A. cordifolia* beneath solar panels and die back directly beneath the panels. Bottom left: (E) Relatively even cover of a range of species and marked increase in height in *Goodenia ovata* (Hop Goodenia). Bottom right: (F) Substantial height increases for the entire vegetation community.

The vegetation community that underwent the most changes where in the areas directly below and surrounding the solar panel arrays, especially with increases in the coverage of *Aptenia cordifolia*. This species emerged as the dominant plant within the vegetation community, occupying most of the space beneath and surrounding the solar panels, despite being initially planted in relatively low densities. The extent of this shift in the composition of the vegetation community was unexpected.

Dense plant growth under solar panels. *Aptenia cordifolia* (Baby Sun Rose), which was not originally planted under solar panels, is thriving in amongst *Viola hederacea* (Ivy-leaved Violet), *Dianella caerulea* (Blue Flax-lily) and *Dichondra repens* (Kidney Weed).

Measuring biodiversity

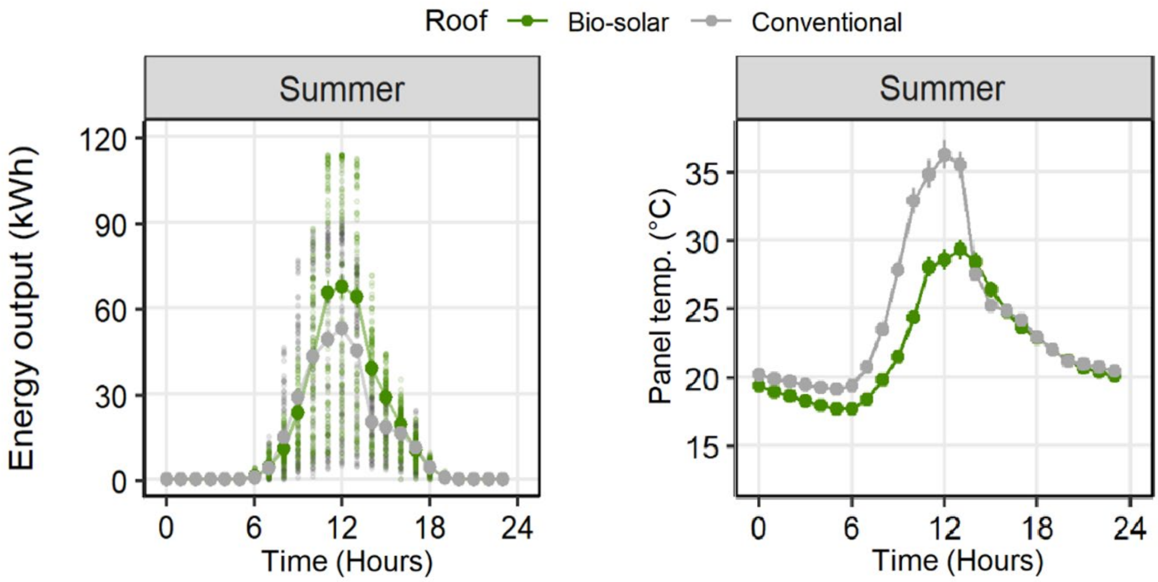
Environmental DNA (eDNA) metabarcoding surveys were done to assess and monitor green roof biodiversity. eDNA surveys involved collecting water run off samples from both the green and conventional roofs and processing samples on site using portable Smith-Root eDNA Citizen Scientist sampling equipment. The study compared biodiversity detected across the roofs using COI and 12S primers for the detection of eukaryotic species such as macroinvertebrates, fungi, and vertebrates (i.e., birds).

The results demonstrated the utility of eDNA metabarcoding to detect rooftop biodiversity, detecting a range of rooftop species and communities (i.e., algae, fungi) not evident using other survey methods. The method uses an easy-to-use citizen science workflow. eDNA results confirmed the presence of avian species observed using cameras and suggested that some other bird species visited the green roof but were not detected through other survey approaches.

The findings of this research extend beyond green roofs and have relevance to a broader range of ecosystems. Additionally, the study highlights the utility of eDNA metabarcoding and the potential for employing rapid, on-site workflows involving citizen scientists to advance the field of urban ecosystems research. This is particularly relevant as the use of eDNA sampling allows for a non-invasive and efficient method to assess species' presence and diversity.

Left and right: Handsome Jack Rojahn conducting eDNA sampling on the green roof site.

When measuring thermal effects, the green roof was able to reduce surface temperatures by up to 9.63°C and 6.93°C for the solar panels and roof surfaces respectively. There was also an average peak temperature reduction of 8°C on the green roof, which has substantial implications for thermal comfort. This reduction in temperature was then demonstrated experimentally to increase the solar performance of the photovoltaic panels on the roof, achieving a maximum increased output of 21-107 %, depending on the month. Additionally, performance modelling indicates that an extensive green roof in central Sydney can produce 4.5% more electricity at any given light level, averaged over the overall output.



Energy output from and surface temperatures of solar panels on a biosolar roof compared to solar panels installed on a conventional roof with no vegetation. During summer, the solar panels on biosolar roof are up to 5°C cooler in the middle of the day promoting greater energy output.

The results presented here are significant, both for the generation of sustainable energy, but also for demonstration that building owners/stakeholders should not have to choose between a green roof or a solar roof but can combine the two options and take advantage of the many benefits of biosolar green roofs.

Future research

Green roofs are a promising technology for creating more biodiverse, sustainable cities, however, there is still a long path to fully understanding their role in built environments. Future work could look to understand what behavioural and ecological traits make wildlife more likely to interact with novel green infrastructure and incorporate this knowledge into designing green roofs for biodiversity. Further, existing research has not been able to capture the effects of widespread implementation of green roofs to attract wildlife into cities across large scales. This is an important area of research as green roofs and other green infrastructure may alter the activity patterns of existing urban wildlife and may eventually attract non-urban species.

Further reading

Fleck R, Gill RL, Saadeh S, Pettit T, Wooster E, Torpy F, Irga P (2022) Urban green roofs to manage rooftop microclimates: A case study from Sydney, Australia. *Building and Environment* 209, 108673.