Assessing the multiple benefits of green roofs

Adam Bates,
Richard Greswell, Rae Mackay & Jon Sadler

School of Geography, Earth & Environmental Sciences, University of Birmingham

UNIVERSITY OF BIRMINGHAM

SWITCH Sixth Framework Programme (2002-2006)

Presentation outline

1. Overview
2. Green roof myths
3. Advantages of green roofs
4. Green roof use in SUDS (stormwater BMP's)
5. Summary & Conclusions

UNIVERSITY OF BIRMINGHAM

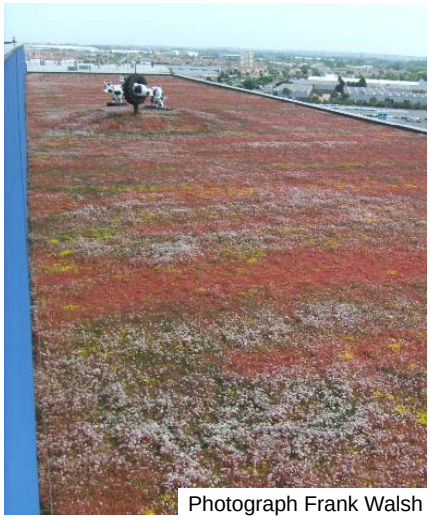
SWITCH Sixth Framework Programme (2002-2006)

Intensive green roofs

Cannon Street Station, London

Photograph livingroofs.org

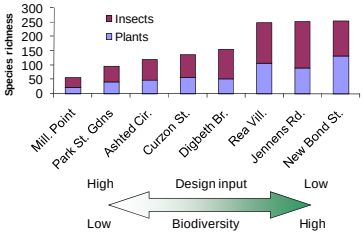
Extensive green roofs



Photograph Frank Walsh

Brown roofs

- An extensive green roof designed for biodiversity that emulates brownfield sites in an early stage of succession
- Why adopt brown roofs?
  - Often new developments on brownfield sites → more ecologically sustainable like for like replacement
  - In an urban context brownfields are associated with the highest no. of rare species & the highest diversity



Donovan *et al.* (2005)

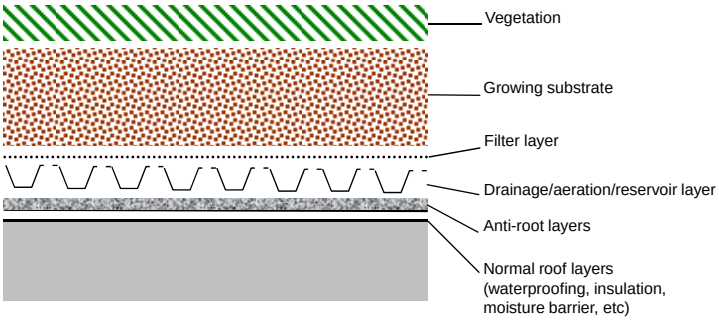
1. Introduction to green roofs

Brown roofs

UNIVERSITY OF BIRMINGHAM
SWITCH
Sixth Framework Programme (2002-2006)

Basic structure of all green roofs

- Whatever the type of green roof, the basic components of its structure are the same



Cost of green roofs

- Prices relatively over-inflated in the UK compared to Germany
  - Small economies of scale
  - Contractors unfamiliar with green roof installation, tend to err on the expensive side
  - Should fall as they become more mainstream
- Prices vary according to height, size of roof & if new build or retrofit
- Whole Life Cost of green roofs generally lower than 'standard roofs'
  - Carter & Keeler (2008) Journal of Environmental Management 87: 350-363
  - Wong et al. 2003 Building & Environment 38: 499-509
  - Clark et al. 2008 Environmental Sci. & Tech. 42: 2155-2161
- But… savings mainly based on the increased life expectancy of water-proofing membranes

	Conventional (£/m^2)	Shingle (£/m^2)	Paved (£/m^2)	Self build (£/m^2)	Biodiverse (£/m^2)	Sedum blanket (£/m^2)	Sedum plug (£/m^2)
Warm roof	55	70	75	95	105	120	125
Extra expense (£)		+15	+20	+40	+50	+65	+70
Percentage increase		27	35	73	91	118	127

From Bamfield & Fox-Davies

Green roof literature

- Green roof literature mainly
  - Not peer reviewed (conference proceedings, reports, manufacturers information)
  - Partial (e.g. paid for by green roof manufacturers, researchers charging consultancy fees, etc)
- Tendency to research the advantages of green roofs singly
  - Lack of appreciation that maximising one environmental benefit will usually trade-off against other environmental benefits
  - Most research on *Sedum* green roofs
- Green roofs therefore often seen as an environmental panacea

Myth 1: High Maintenance & leaks

- Maintenance
  - Differences of opinion but extensive roofs only require the same, or slightly more maintenance than a normal flat roof
    - Annual to biannual visits after the first year to clear drains and remove problem plant species (mainly *Budleja*)
    - Grass meadow green roofs will require annual to biannual mowing
- Roof leaks
  - Extensive green roofs require an additional roof protection layer to prevent damage to the roof by plant roots
  - Only badly installed roof water-proofing causes leaks, not green roofs
  - Green roof companies guarantee the water-proofing & will guarantee the plant survivability in standard systems

Myth 2: Loading

	Dunnet & Kingsbury	FLL
Crushed brick (1cm depth)	18kg/m^2	10-13kg/m^2
Pumice (1cm depth)	6.5kg/m^2	11-12kg/m^2
Expanded clay (1cm depth)	3-4kg/m^2	5-8kg/m^2
Topsoil (1cm depth)	17-20kg/m^2	16-19kg/m^2
Compost (1cm depth)		10-13kg/m^2
Sand (1cm depth)	18-22kg/m^2	
Egg-box drainage board 4cm depth (entire course)		19-21kg/m^2
Fibre matting (entire course)		20-50kg/m^2
Extensive plant growth (total)		10kg/m^2

- Extensive green roofs typically 80-170kg/m^2, intensive 300-1000kg/m^2
- But… designers often aiming to hold the roof down!
  - Gravel surface 90-150kg/m^2
  - Paving slabs 160-220kg/m^2

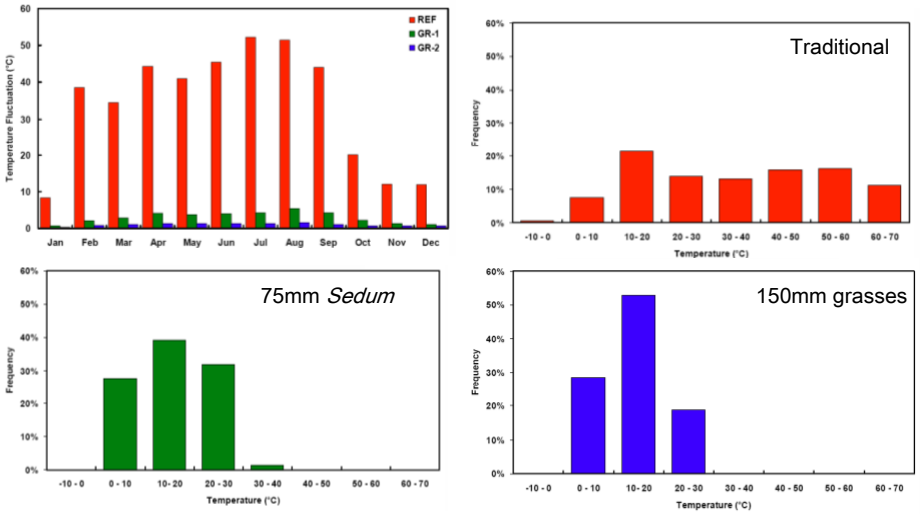
Myth 3: Aesthetics

- Unrealistic expectations
  - Choice of nomenclature
    - Green roofs rarely green
    - Rooftop gardens rarely garden-like
  - Glossy summer photographs
    - Time to establish
    - Die-back during dry periods, after seeding & in the winter
- Only ‘off the shelf’ solutions likely to have a reasonably consistent outcome
- Biodiversity/brown roofs particularly variable

Private advantages of green roofs

1. Enhanced longevity of roof water-proofing
   - Much lower temperature range under a green roof
     - Reduced expansion & contraction of water-proofing
     - Reduced out-gassing of roof volatiles
   - Protection from UV & mechanical damage (e.g. hail, walking)
   - A green roof is thought to at least double the longevity of roof water-proofing membranes
     - Guarantee of water-proofing is not extended
     - Will get similar benefits from an inverted warm-deck roof (where the insulation is on the outside)

Roof temperature fluctuations

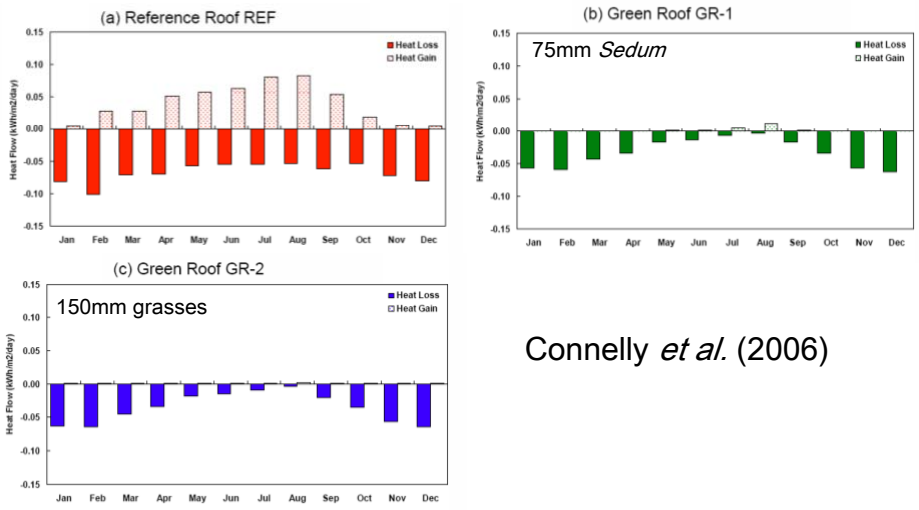


Connelly *et al.* (2006)

Private advantages of green roofs

1. Building insulation
   - Potential to keep buildings cool in summer & warm in winter
   - Function of amount & type of vegetation, substrate thickness & type, and substrate wetness → cannot ascribe simple R-values (or U)
   - Impact on well-insulated roofs is low
2. Improved environmental image (Ford, Barclays & GAP)
3. If roof accessible → improved psychological wellbeing of tenants/employees
4. Lower whole life costs compared to standard roofs
5. Hydrological
   - Reduction in necessary internal drainage capacity
   - Off-set potential groundwater building impacts?

Green roof insulation



Connelly *et al.* (2006)

Public advantages of green roofs

1. Urban cooling → combating the urban heat island effect (caution)
2. Habitat creation (caution)
3. Uptake of CO_2 → combating global warming
4. Lower release of CO_2 through reduced need for heating & cooling → combating global warming
5. Aesthetic value when roof over-looked
6. Removal of pollutants from rainfall (caution)
7. Removal of air pollutants

Hydrological function of green roofs

- Green roofs affect roof run-off by storage:
  1. Delaying the initial time of run-off
  2. Reducing the peak run-off
  3. Distributing the run-off over longer times
  4. Reducing the total runoff through enhanced evapotranspiration
- Meta-analysis of existing literature from Germany
  - Run-off mainly a function of roof depth
  - No effect of roof age, slope angle & length
  - Average run-off 80% of winter rainfall, 52% of summer rainfall

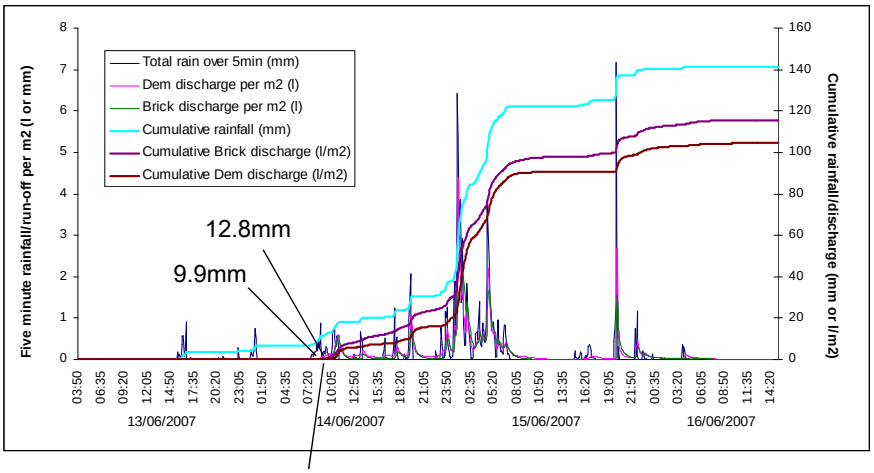
Birmingham Landscape

UNIVERSITY OF BIRMINGHAM

SWITCH

Sixth Framework Programme (2002-2006)

Hydrological function of brown roofs



Similar to a thin (~5cm deep) standard green roof

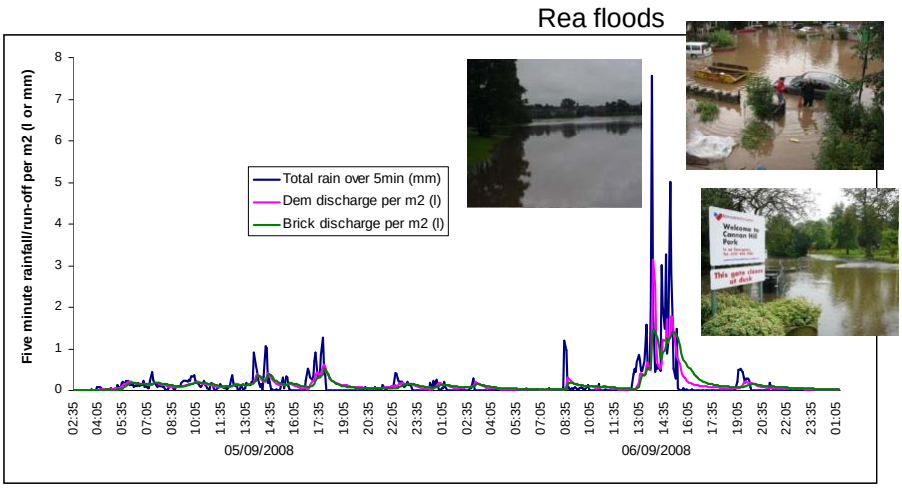
UNIVERSITY OF BIRMINGHAM

SWITCH

Sixth Framework Programme (2002-2006)

Hydrological function of green roofs

Rea floods

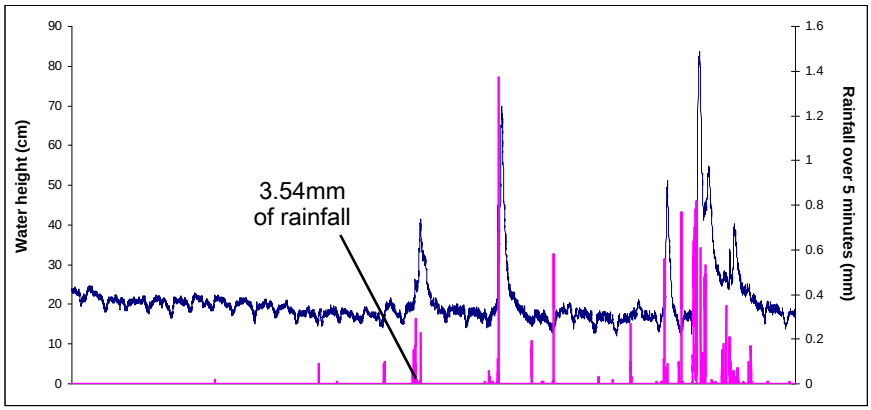


UNIVERSITY OF BIRMINGHAM

SWITCH

Sixth Framework Programme (2002-2006)

River Tame (10/2/08 – 14/3/08)



UNIVERSITY OF BIRMINGHAM

SWITCH

Sixth Framework Programme (2002-2006)

Summary

- Potential to move urban streams towards a more natural disturbance regime by reducing the magnitude of small disturbance events
- Effect on large storms is smaller, but can reduce the peak discharge for many events
- In heavily developed areas could be the only SUDS option → areas where green roofs have most potential to prevent localised flooding
- Cannot rely on green roofs alone, but considerable potential for use within an integrated system
- Possibility of using intensive green roofs on small sections of buildings & re-directing drainage from other sub-roofs onto it → much larger SUDS potential

Summary & Conclusions

- Green roof technology is advanced but tradeoffs not adequately recognised in perceived benefits.
- The relatively high capital cost of green roofs can be justified using LCA and the range of environmental gains
- Potential for use in SUDS, but do not provide a stand-alone solution
- Roof trials have generated very large data sets Analysis of the Birmingham roof data is ongoing.

Extensive green roofs

UNIVERSITY OF BIRMINGHAM

SWITCH

Sixth Framework Programme (2002-2006)