WaterGUM

Water Green Urban Management

Green Technologies for Nutrient Management in Urban Stormwater

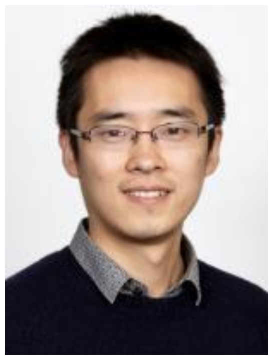
Kefeng Zhang

http://www.wrc.unsw.edu.au/water-green-urban-management-watergum

Green Technologies and Tools for Urban Water Management

Our WaterGUM Team

Prof. Ana Deletic
Team leader



Dr Kefeng Zhang

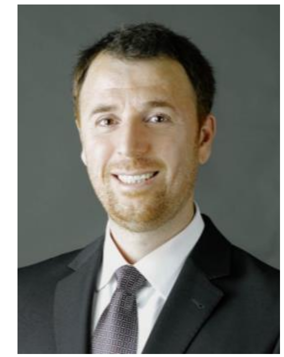
- Green technologies
- Stormwater
- Monitoring
- Validation
- Treatment models
- Quality Modelling

Dr Veljko Prodanovic

- Green technologies
- Stormwater
- Greywater
- Monitoring
- Quality Modelling
- Spatial Modelling

Dr Martijn Kuller

- Urban Planning
- Social Planning
- Spatial Modelling
- Quality Modelling



Dr Behzad Jamali

- Urban flooding
- Flood mitigation
- Flood risk analysis
- WSUD assessment

<u>Location</u>: WRC (Vallentine Annex – H22) Kensington Campus

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UNSW SYDNEY

Civil and Environmental Engineering


Planet is urbanizing at unprecedented rate!

Sydney, June 2016

Sydney in 2100?

And also Pollution!

Typical nutrient levels in stormwater:

TN: 0.6 – 7 mg/L

TP: 0.1- 1 mg/L

(Data From: *NRMMC-EPHC-NHMRC*)

Hawkesbury-Nepean River

TN: 0-5 mg/L (occasionally up to 30 mg/L at some sections)

TP: 0-0.8 mg/L

(Data From: *Hawkesbury Nepean River Environmental Monitoring Program: Final Technical Report, 2009*)

Could Blue-Green Infrastructure be the solution?

Nature Based Solutions - Europe

Water Sensitive Urban Design – Australia

Low Impact Development - USA

Sponge City - China

Could Blue-Green Infrastructure be the solution?

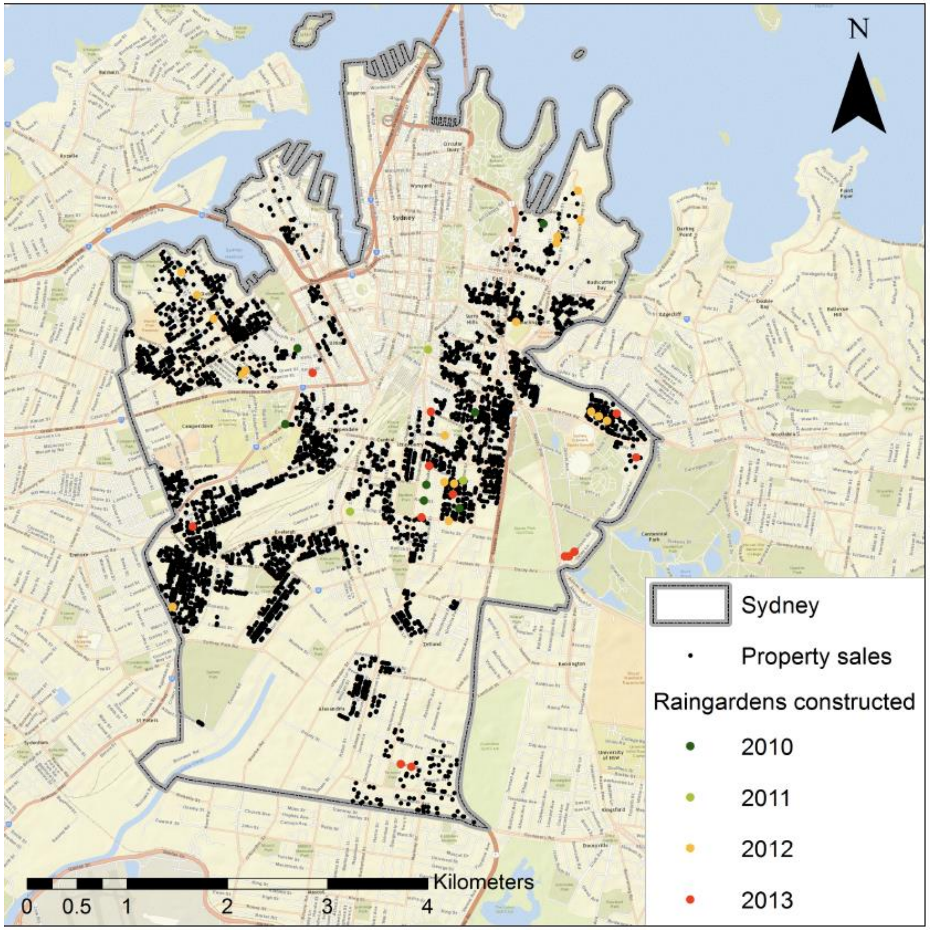
Environmental Benefits

- Pollution management
- Air pollution reduction
- Biodiversity protection

Direct Economic Benefits

- Water services: supply + flood protection
- Cooling
- Property value increase

Amenity value of raingardens in Sydney



- Hedonic model within a quasi-experimental framework
- Data
  - sales date, price, locations, and characteristics of **4,437** single family homes sold 2008 -2014
  - construction date and location of **41 intersections with rain-gardens**

Polyakov M, Iftekhar S, Zhang F, and Fogarty J, The amenity value of water sensitive urban infrastructures: A case study on rain gardens

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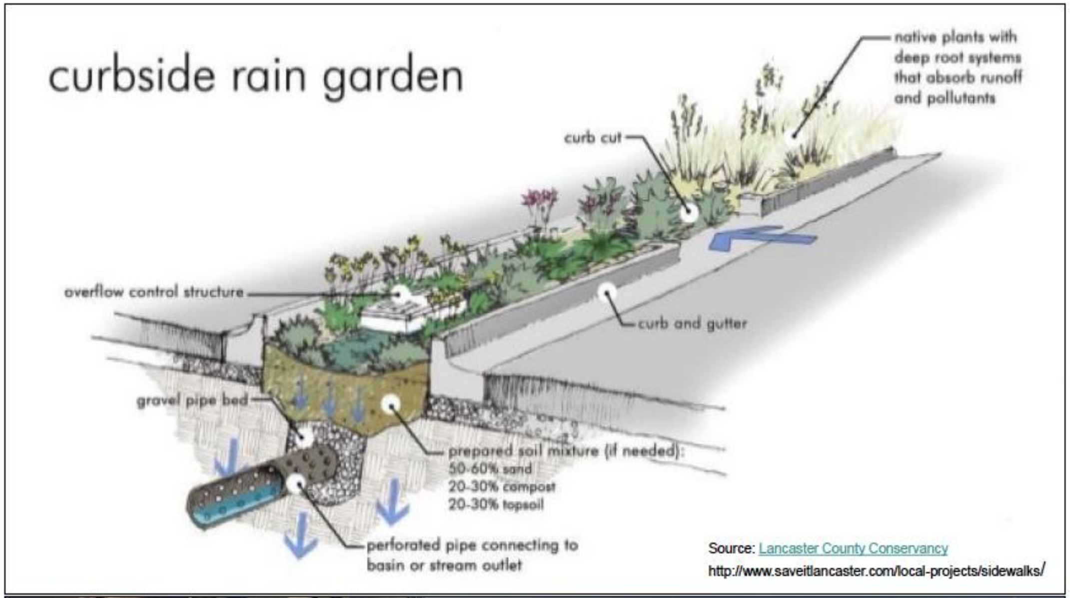
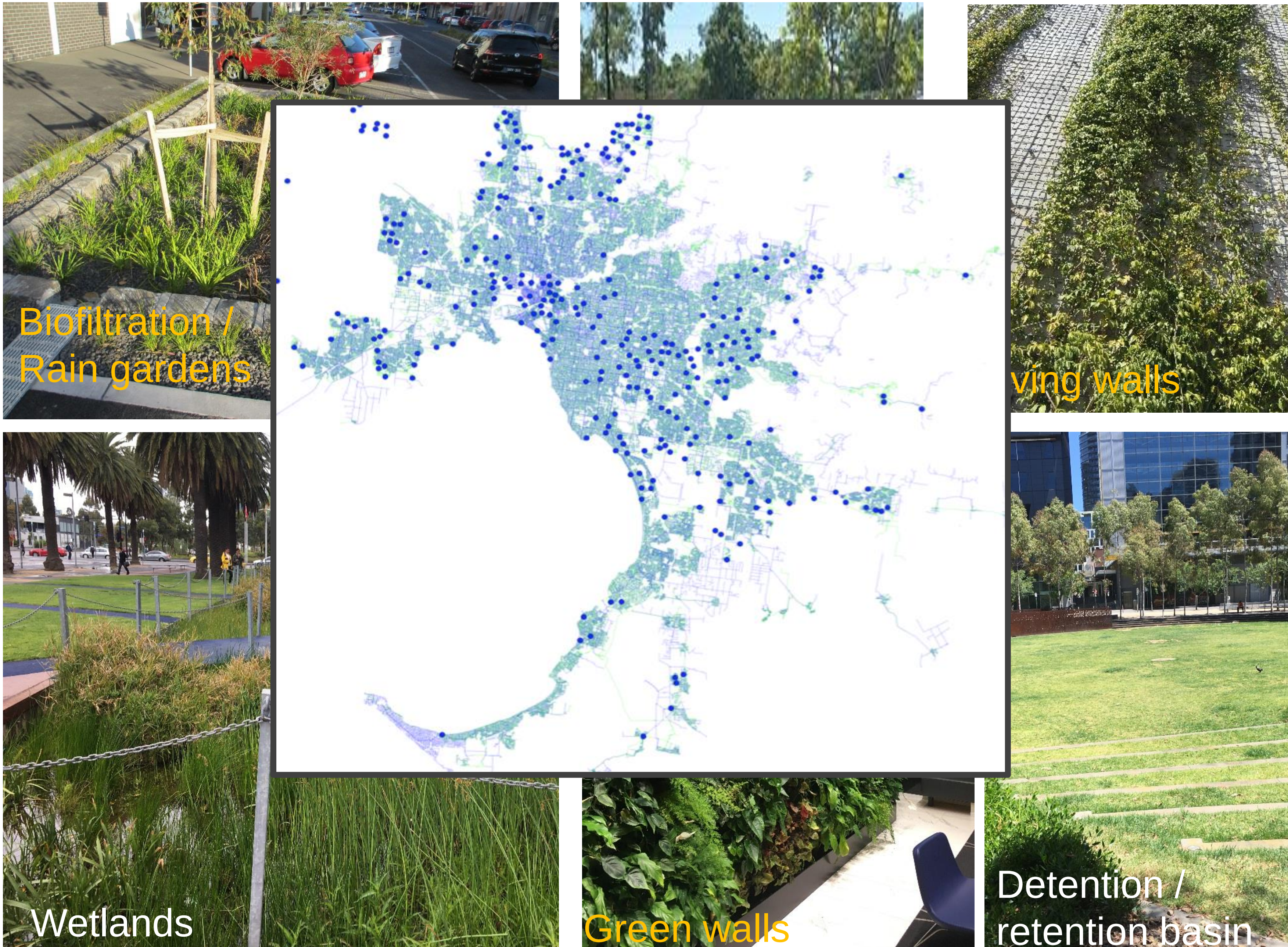
Amenity value of raingardens in Sydney: Results



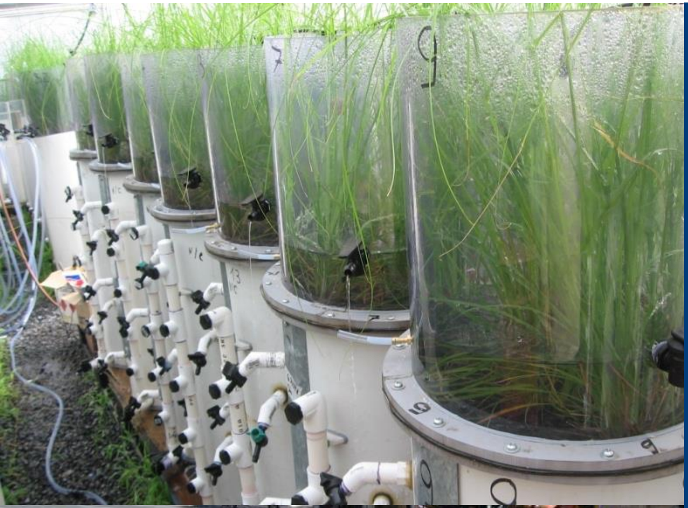
Polyakov M, Iftekhar S, Zhang F, and Fogarty J, The amenity value of water sensitive urban infrastructures: A case study on rain gardens

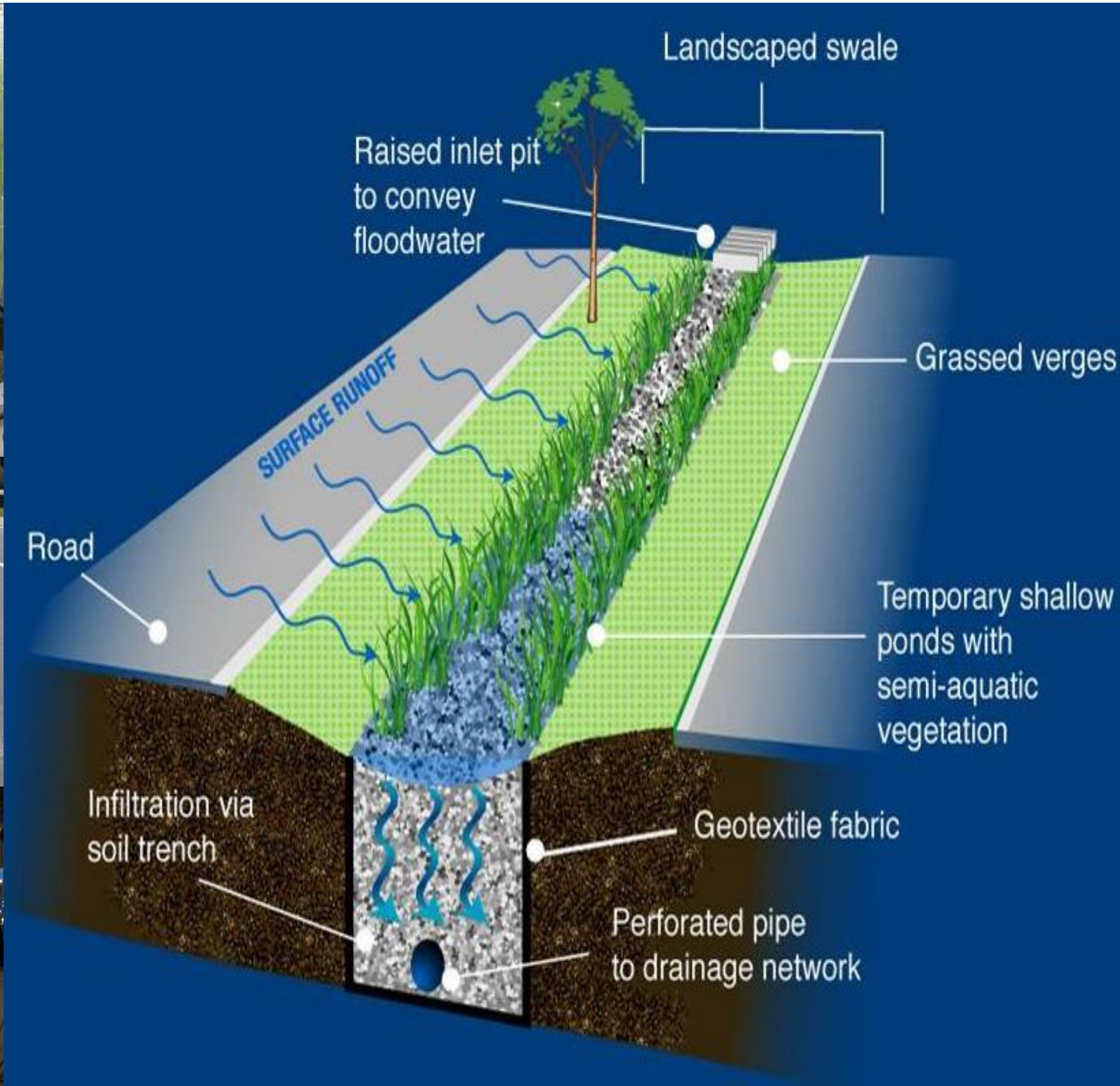
- Rain-gardens increased values of a median house
  - within 50 m - by **6% (AU$54,000)**
  - within 50 to 100m - by **4% (AU$36,000)**
- The aggregate increase in the value of houses around an intersection was **AU$1.5 mil**

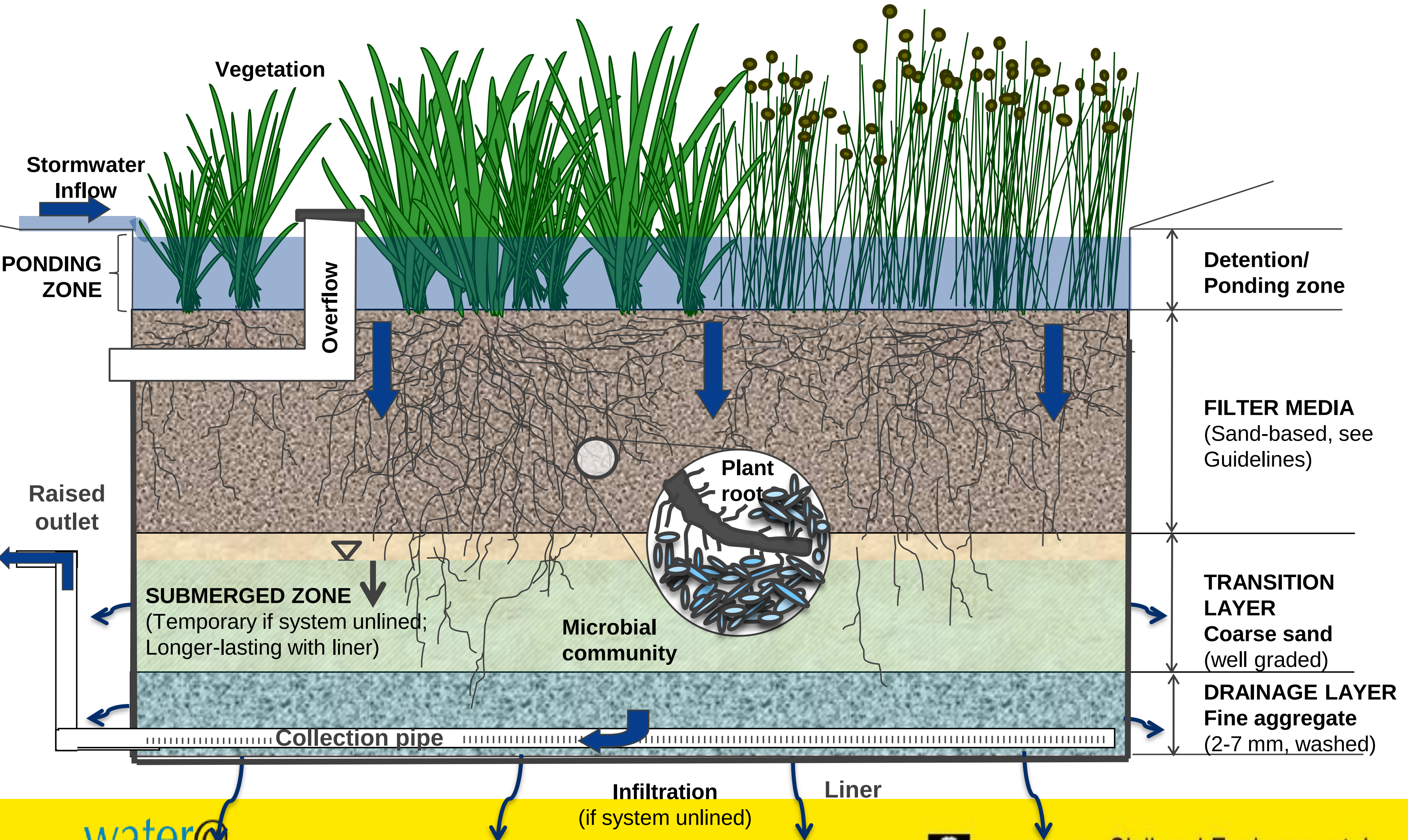
Green Infrastructure in Urban Areas



Stormwater Biofilters:
Rain Gardens and Bioretentions







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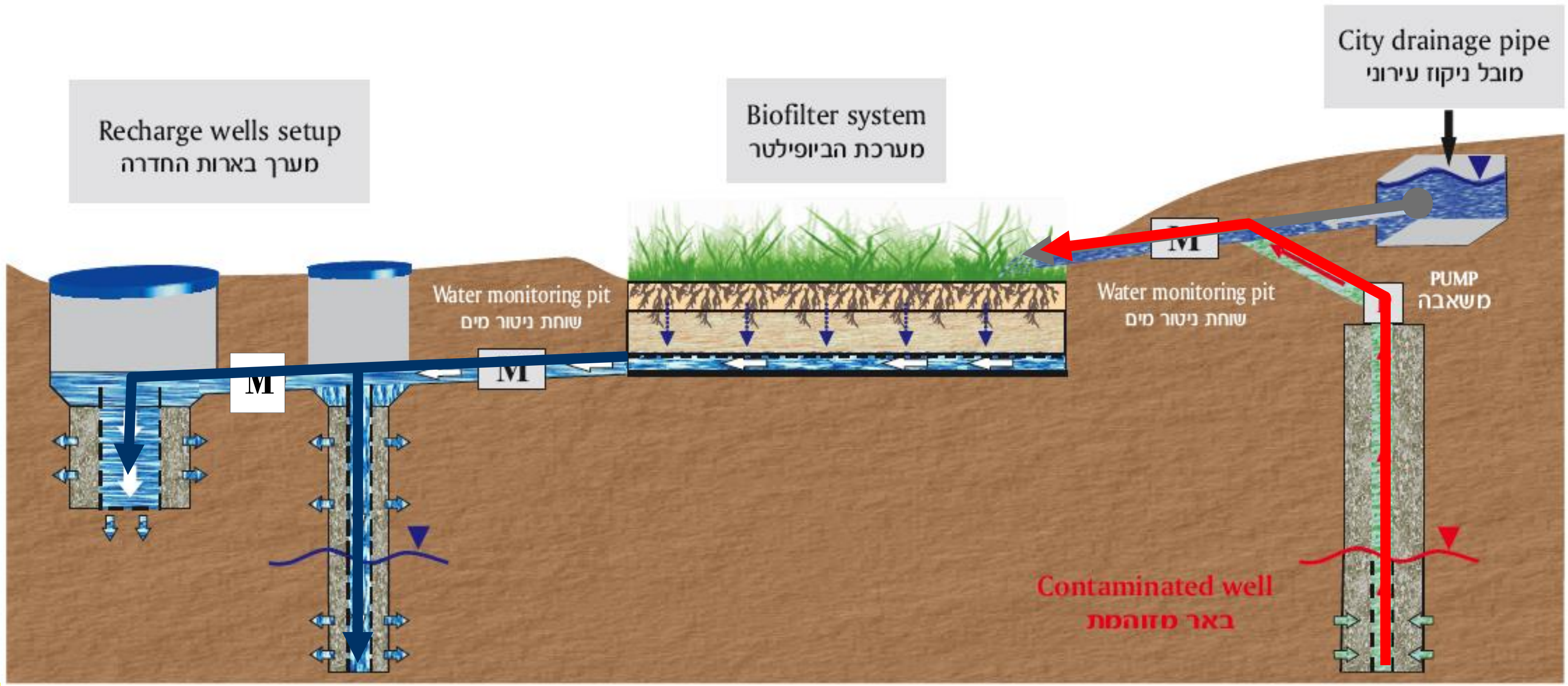
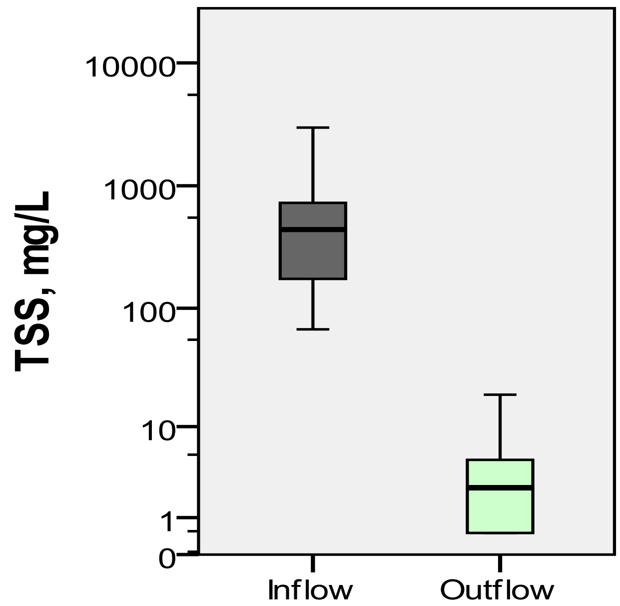
The first stormwater biofilter in Israel – Kfar Saba (2010)

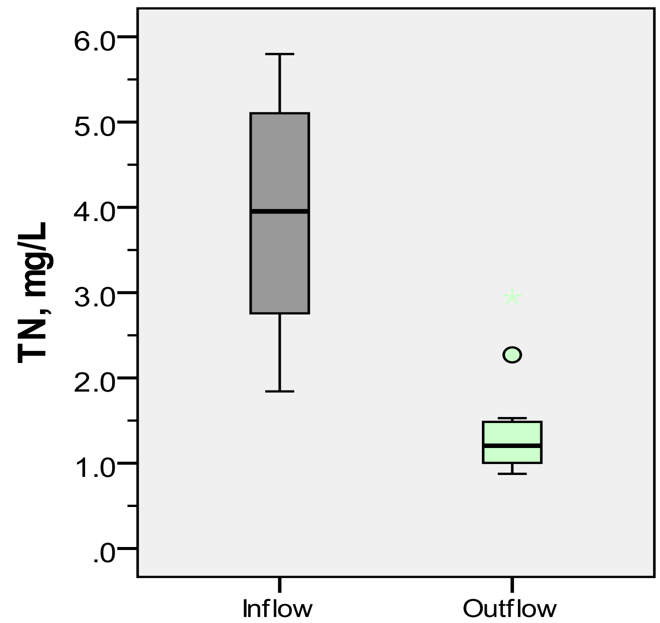
The first stormwater biofilter in Israel – Kfar Saba (2010)

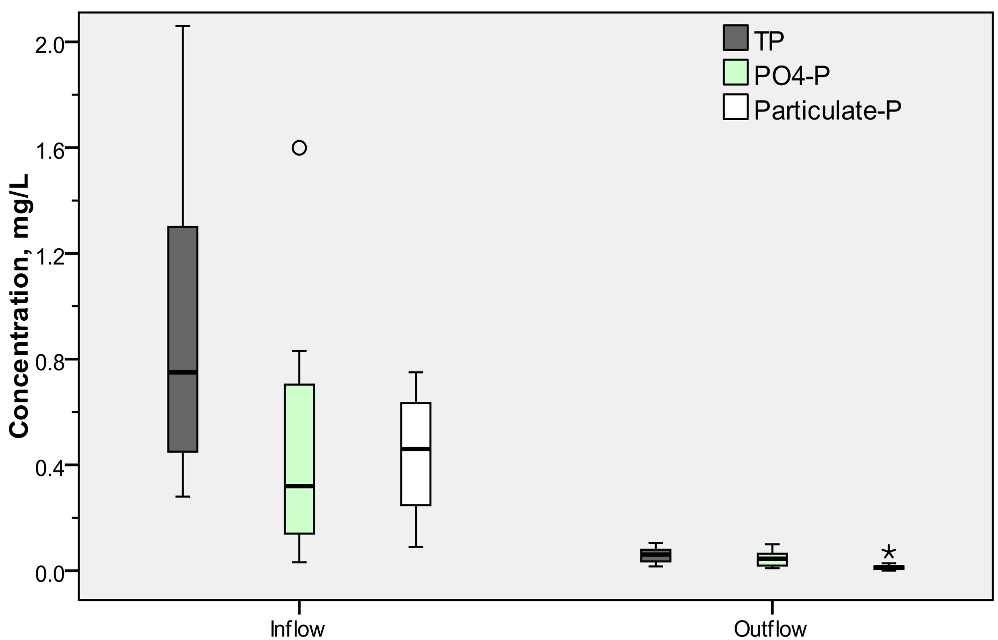
Kfar-Sava biofilter treats stormwater in wet months and groundwater in dry months

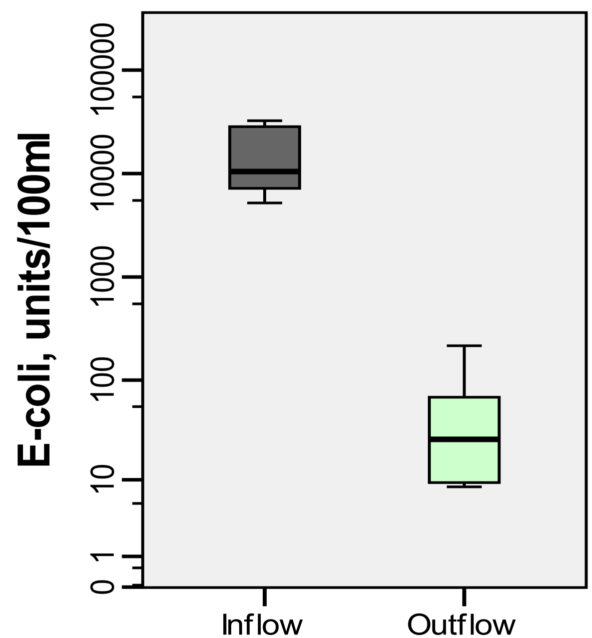


Monitoring of storm events









Designing to suit local conditions

Design to meet local objectives / needs / priorities

+

Local climate (Size and design)

Local pollutant characteristics

+

Local plants

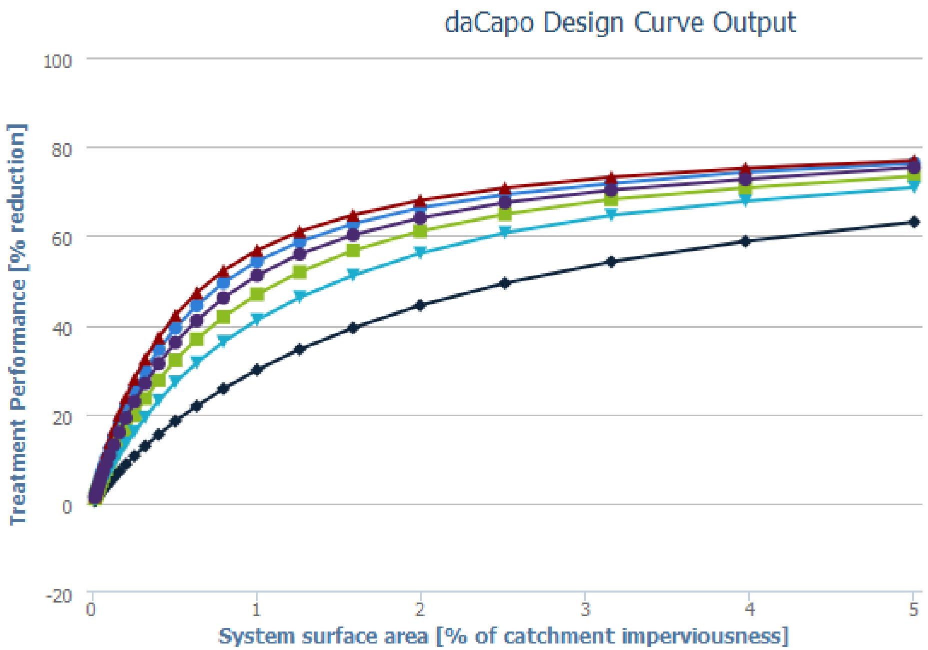
+

Local sources of media

Key design characteristics – Sizing

- Vital for treatment capacity and lifespan
- influenced hydraulic conductivity, ponding depth

Recommend size of ~>2% of impervious catchment area in Sydney for 45% TN and TP removal



Design curves (generated by MUSIC)

- ➢ **Oversized** – system too dry to support plant
- ➢ **Undersized** – system overwhelmed, clog earlier, flows bypass untreated

Key design characteristics – Media selection

Roles -

- Supports plant growth
- Dictates stormwater infiltration rate
- Provides physical and chemical filtration of pollutants

TABLE 2. Pollutant Removal Summary for Six Filter Media Types

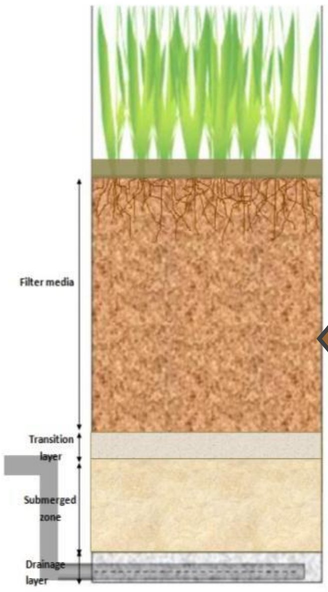
	TSS	TP	TN	TOC	Cu	Mn	Pb	Zn
	Event mean hydraulic loading (g/m²)							
	29	0.08	0.45	1	0.06	0.01	0.15	0.22
	Load Reduction (%)							
S	99 ± 1	97 ± 1	38 ± 1	59 ± 8	97 ± 1	94 ± 1	99 ± 1	99 ± 1
SL	93 ± 4	−65 ± 16	−18 ± 15	−103 ± 17	97 ± 1	−32 ± 54	99 ± 1	99 ± 1
SLH	92 ± 3	−143 ± 17	−37 ± 4	−146 ± 19	96 ± 1	−71 ± 19	99 ± 1	98 ± 1
SLVP	90 ± 3	−73 ± 15	−23 ± 12	−129 ± 22	94 ± 2	−26 ± 52	95 ± 2	96 ± 4
SLCM	92 ± 4	−409 ± 40	−111 ± 41	−178 ± 13	94 ± 1	−152 ± 100	97 ± 1	96 ± 1
SLCMCH	96 ± 1	−437 ± 50	−164 ± 14	−165 ± 5	93 ± 1	−178 ± 189	97 ± 1	96 ± 1

Load reductions are reported as the mean of three replicates ± standard deviation. Note: a negative load reduction indicates leaching of previously retained pollutants and/or native material.

Hatt, B. E., T. D. Fletcher and A. Deletic (2008). Hydraulic and pollutant removal performance of fine media stormwater filtration systems. *Environmental Science & Technology* ***42(7): 2535-2541.***

Key design characteristics – Media selection

Critical to follow requirements in Biofilter Guidelines for selection of media (Appendix C)



Filter media should have:

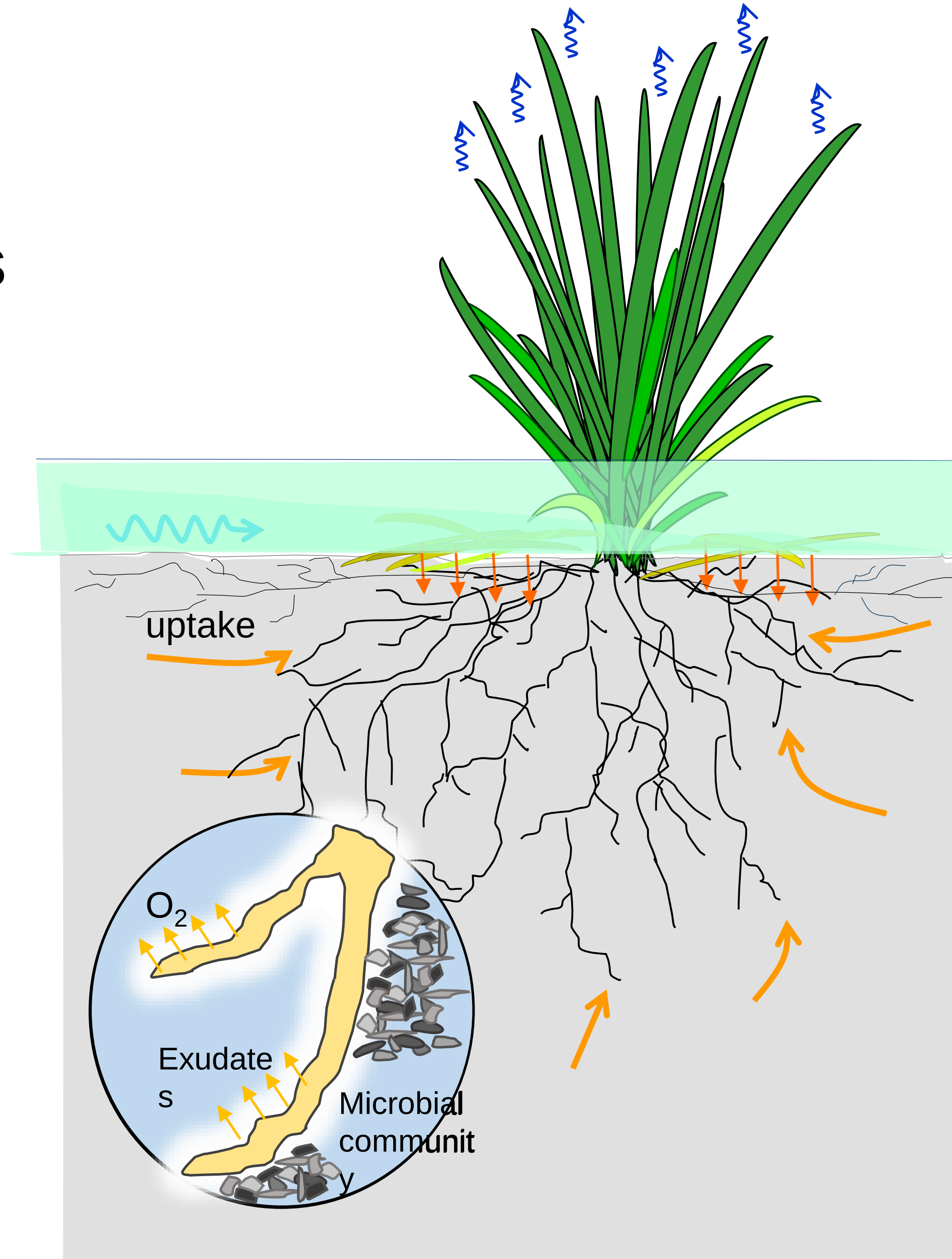
- **low level of nutrients,**
- **hydraulic conductivity of 100 - 300 mm/hr (up to 600 mm/hr for tropical climates)**
- **less than 3% fines (silt & clay)**

Why are **plants** important in biofilters?

Dr Emily Payne (Monash University)

Roles of plants in water treatment

- Nutrient uptake
- Conversion into organic forms
- Return via litter
- Provide carbon to drive microbial activity
- Oxygenate the rhizosphere
- Slow and disperse flow
- Stabilise the media
- Evapotranspiration loss
- Maintain infiltration



Effect on pollutant removal

Not significant for TSS, Heavy metals

BUT
Nitrogen removal performance

Poa sieberiana
Austrodanthonia caespitosa
Poa labilldieri
Soil only (+ moss)
Cyperus gymnocaulis
Gahnia sieberiana
Astartea scoparia
Velvetene
Hypocalymma angustifolium
Leptospermum continentale
Sporobolus virginicus
Dianella revoluta
Juncus pallidus
Allocasurina littoralis
Buffalo
Dianella tasmanica
Melaleuca incana
Poa poiformis
Gahnia trifida
Carex tereticaulis
Carex appressa
Juncus kraussii
Hakea laurina


Poa sieberiana
Austrodanthonia caespitosa
Poa labilldieri
Soil only
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Gahnia sieberiana
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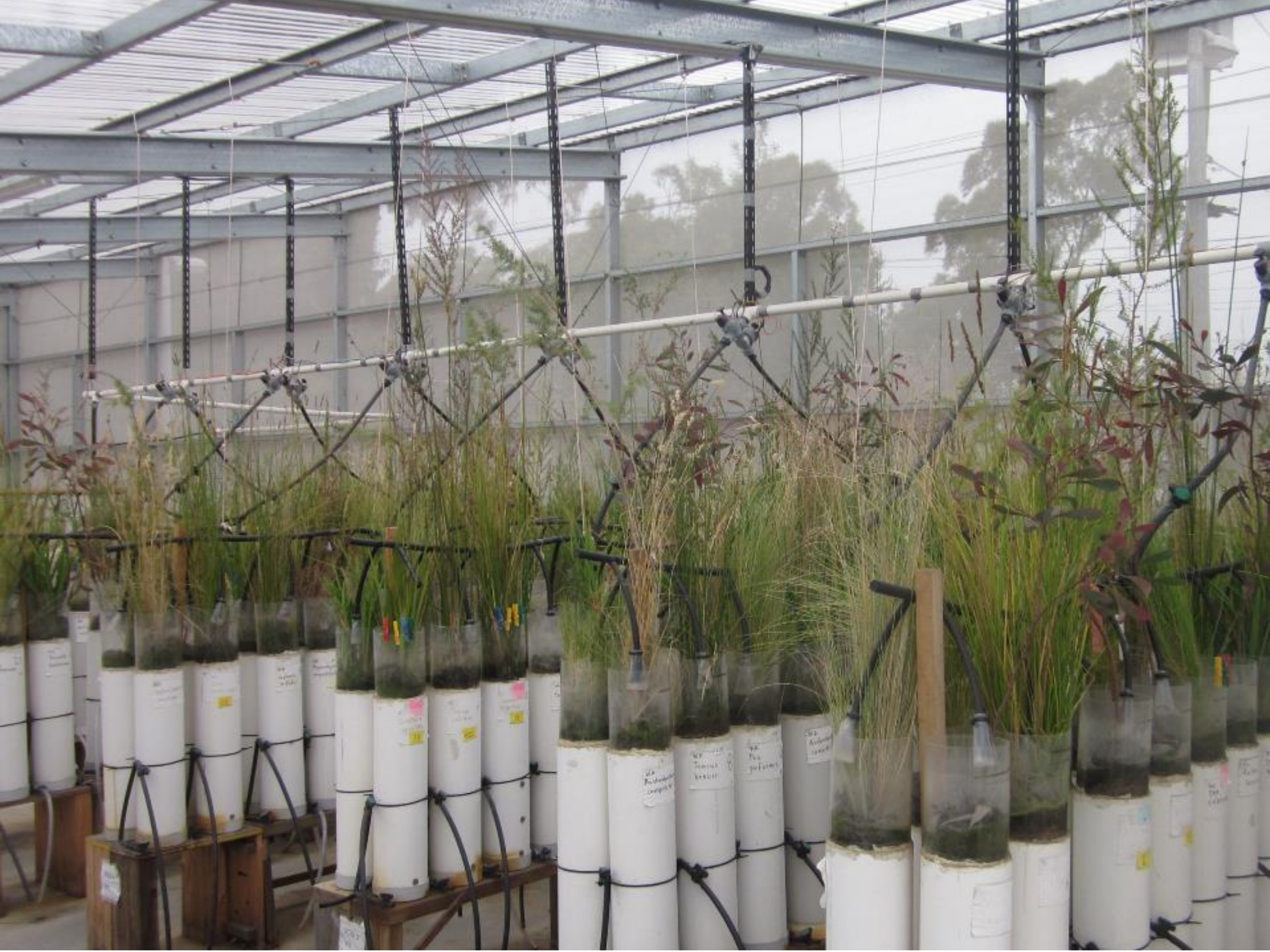
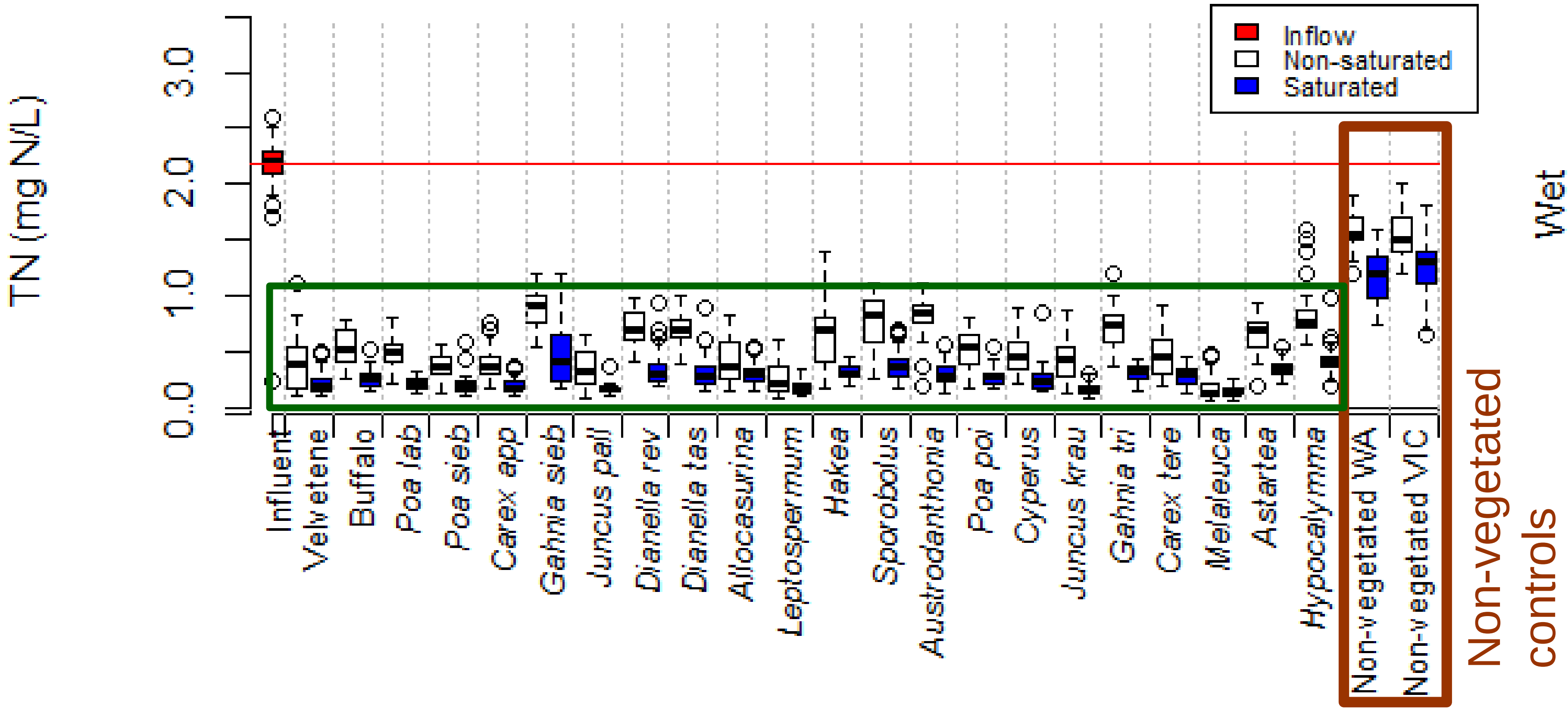


Total Nitrogen (TN)

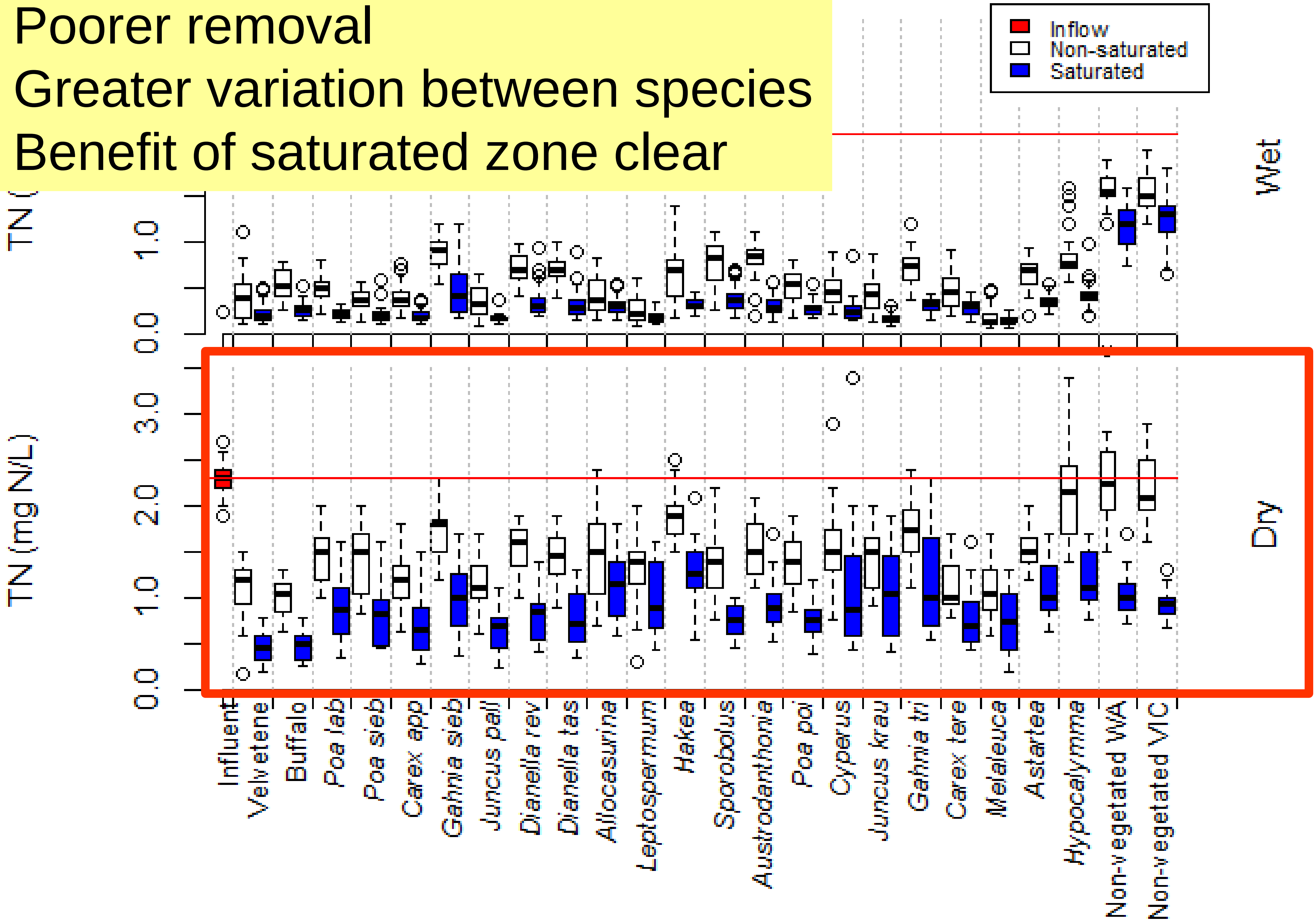


During wet conditions –

- All plant species perform relatively well – significantly more effect than non-veg
- Saturated zone reduces species variation

After drying…

Following drying –
Poorer removal
Greater variation between species
Benefit of saturated zone clear



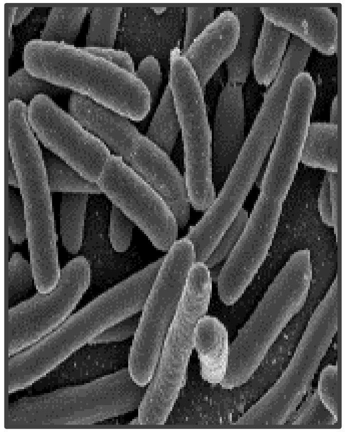
Where does the nitrogen go?

NO_3^-, NH_4^+

Assimilation

vs

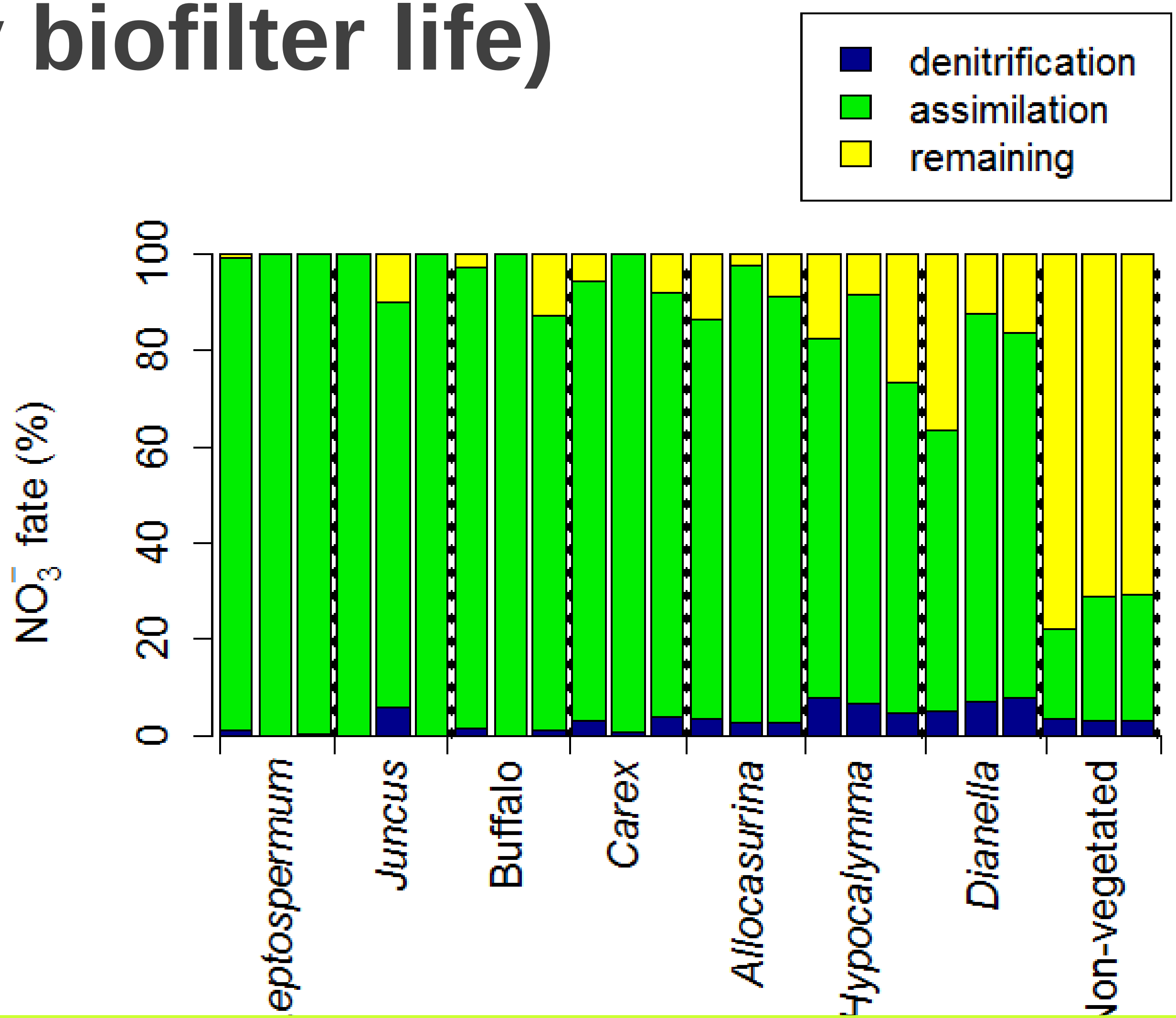
N_2, N_2O



NO_3^-

Denitrification

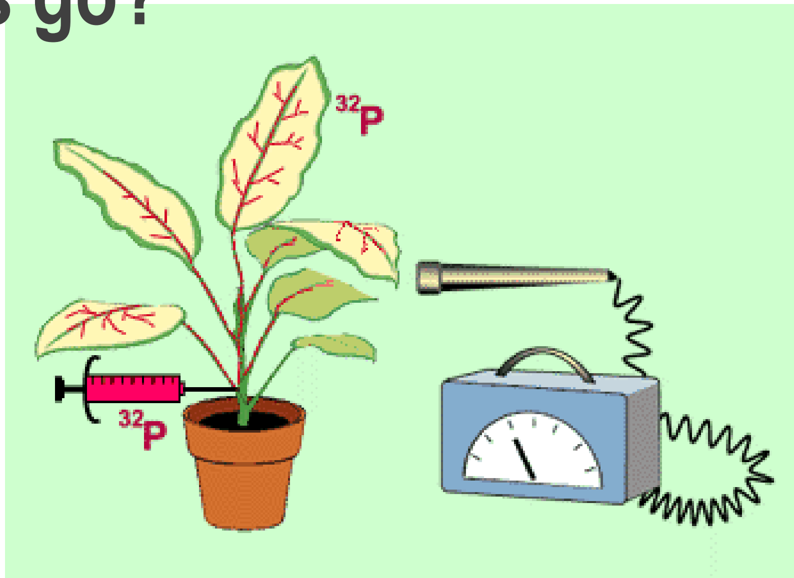
Division of incoming nitrate (early biofilter life)



- Most nitrate is assimilated
- Denitrification minimal at this stage

Where did Total Phosphorous go?

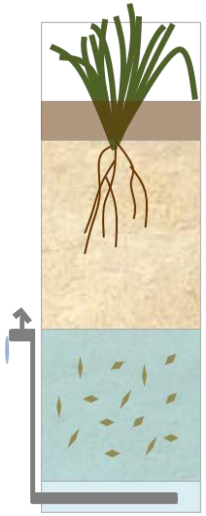
P tracer study



Objective: Determine the fate of dissolved P in greywater biofilters

Method

- Inject radioactive ^{32}P tracer (mixed with synthetic greywater) into 10 cm diameter biofilter columns
- 1 plant and 1 sand only treatment
- Measure P concentration and radioactivity in plant biomass and filter media after harvest

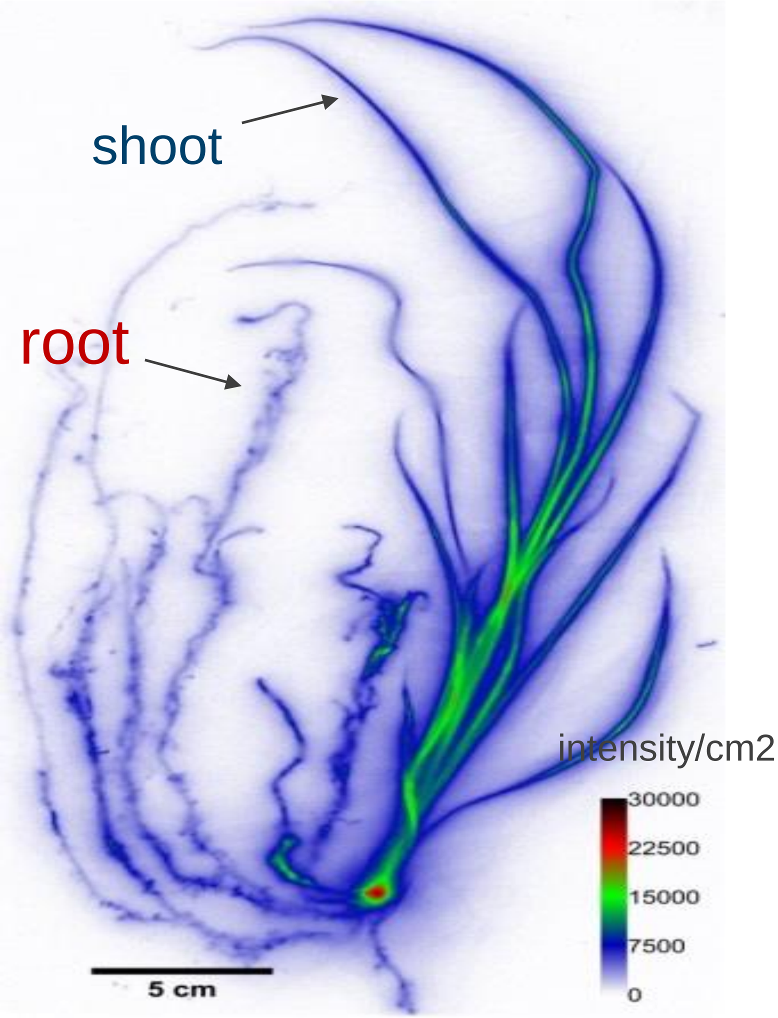


E.g. column profile

Where did Total Phosphorous go?

% of TP retained by

	Effluent	Shoot biomass	Root biomass	Media	Unaccounted for
Planted	1 ± 1	50 ± 7	14 ± 2	29 ± 6	6 ± 7
Unplanted	41 ± 1	n/a	n/a	48 ± 2	11 ± 3



Plants are the key!

Autoradiographs of ^{32}P distribution across a *Carex appressa* plant following three days of dosing with labelled solution.

Plant species selection for optimal nutrients removal

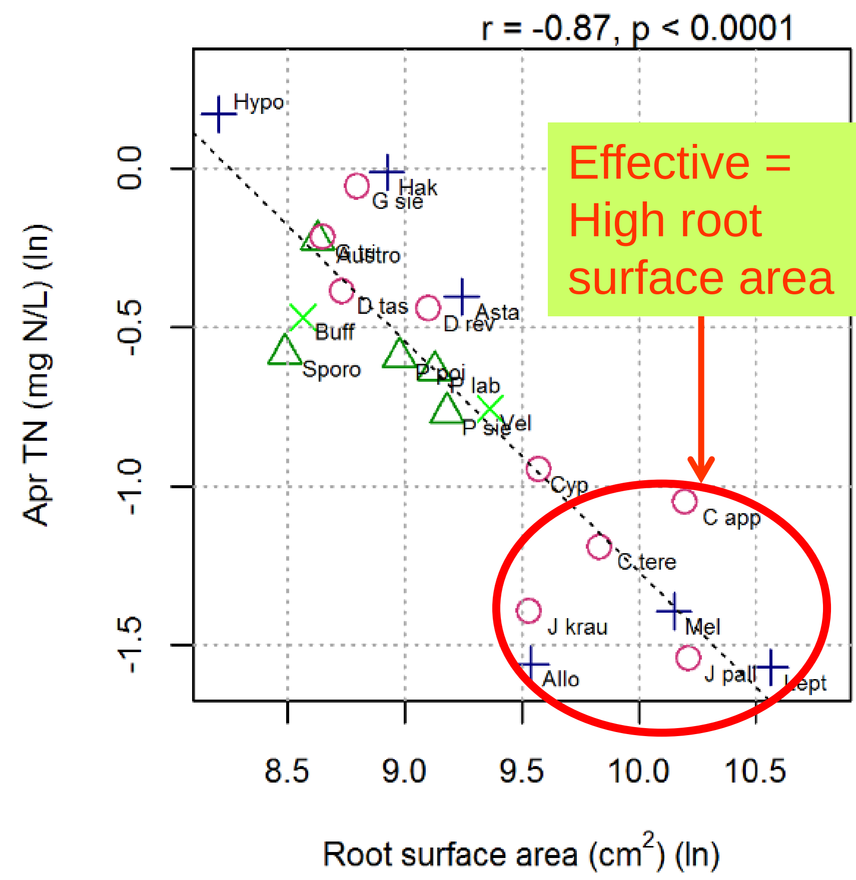
- **Some species perform relatively well in both wet and dry** (e.g. *Carex* spp., *Juncus pallidus* and *Melaleuca incana*)

…or consistently poorly (e.g. *Hypocalymma, Hakea* and *Gahnia* spp.)

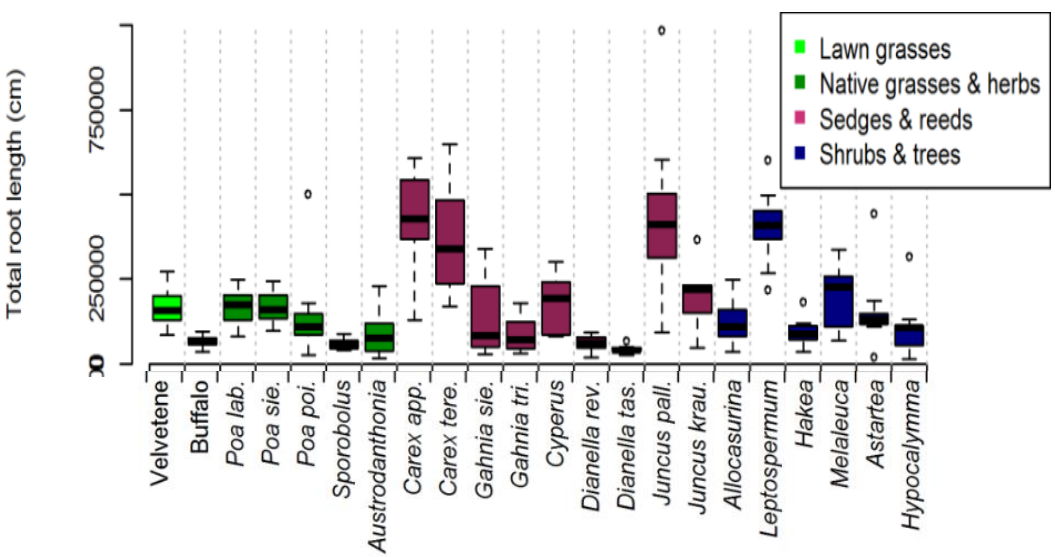
Relationships in wet conditions

- **Root characteristics** – high total length, surface area, mass and length of fine roots
- **High total biomass**
- Key process - **plant nitrogen uptake**

Performance vs. Root surface area



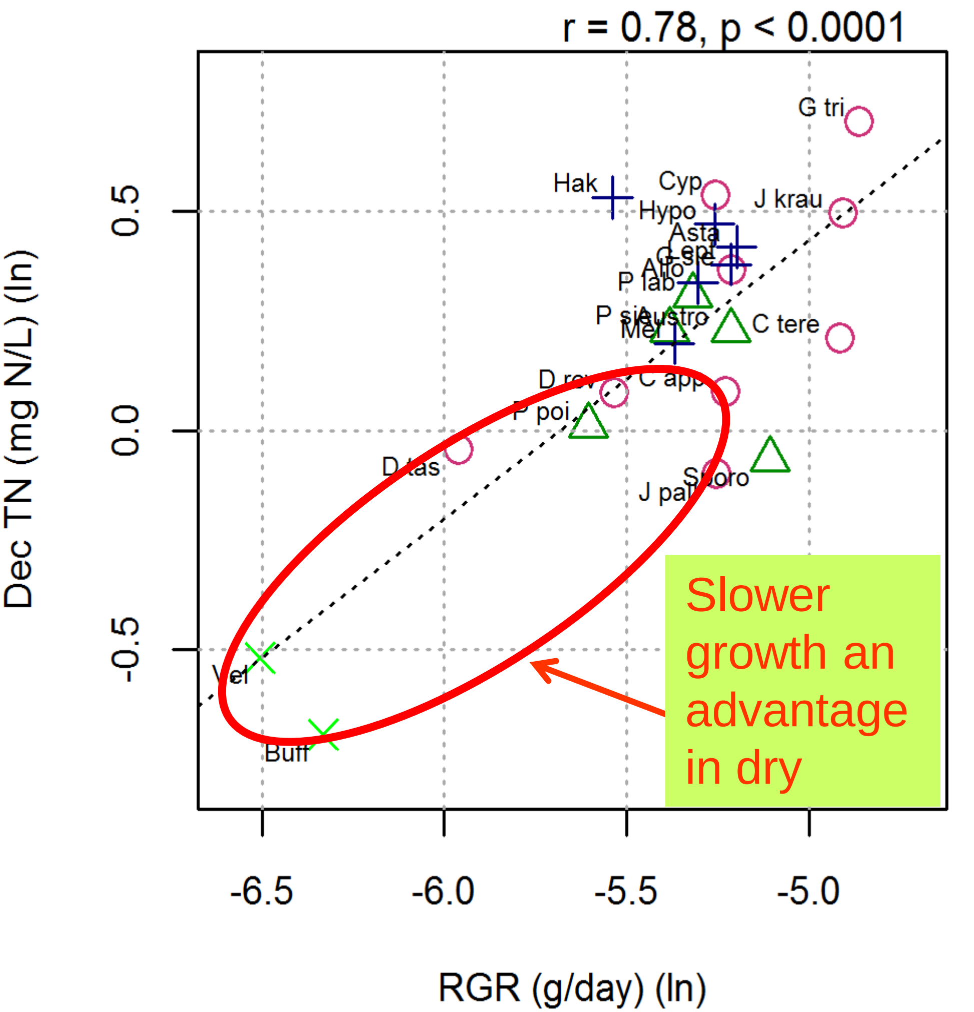
Total root length across species



Relationships in dry conditions

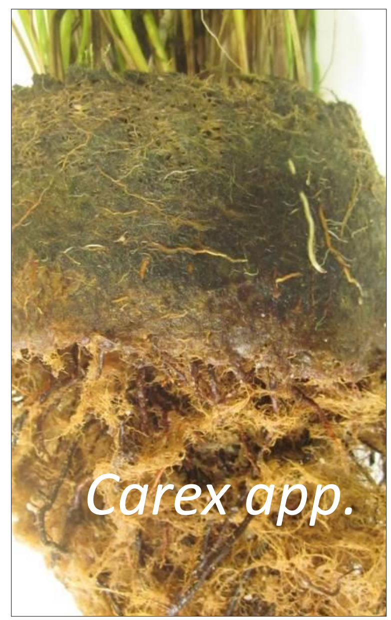
- **Drying** changed relationships with plant characteristics from the wet
- **Water conservation** critical
- Advantage to species with **lower growth and biomass**
- **Lawn grass** performance was promising but clogging and experimental limitations problematic

Performance vs. Relative Growth Rate



Effective plant species characteristics

Select species with **extensive and fine roots, high growth, high total plant mass**



- **Generally exclude** species with **thick roots or minimal root systems**, particularly small and slow-growing shrubs/trees

Dianella revoluta

Plant species selection guidelines

- **Similarity in broad plant type or general appearance is a poor guide** e.g. *Carex* vs.*Gahnia*

- **Species in same genus** expect to have reasonably similar performance (within similar climatic regions)
- **Compare species first to those of the same broad type** – compare apples with apples (e.g. grasses vs. other grasses)

Native grasses

Poa species
(Medium)

Austrodanthonia
(Poor)

Use a **mixture of species** – allows for ‘self-selection’

Include **at least 50% ‘effective’ species** – either tested or with effective characteristics (i.e. extensive root systems…)

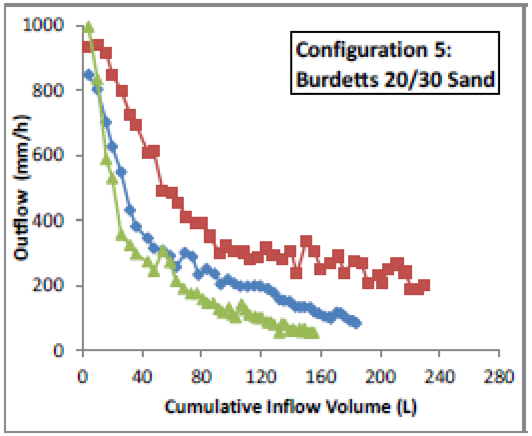
Lawn grass

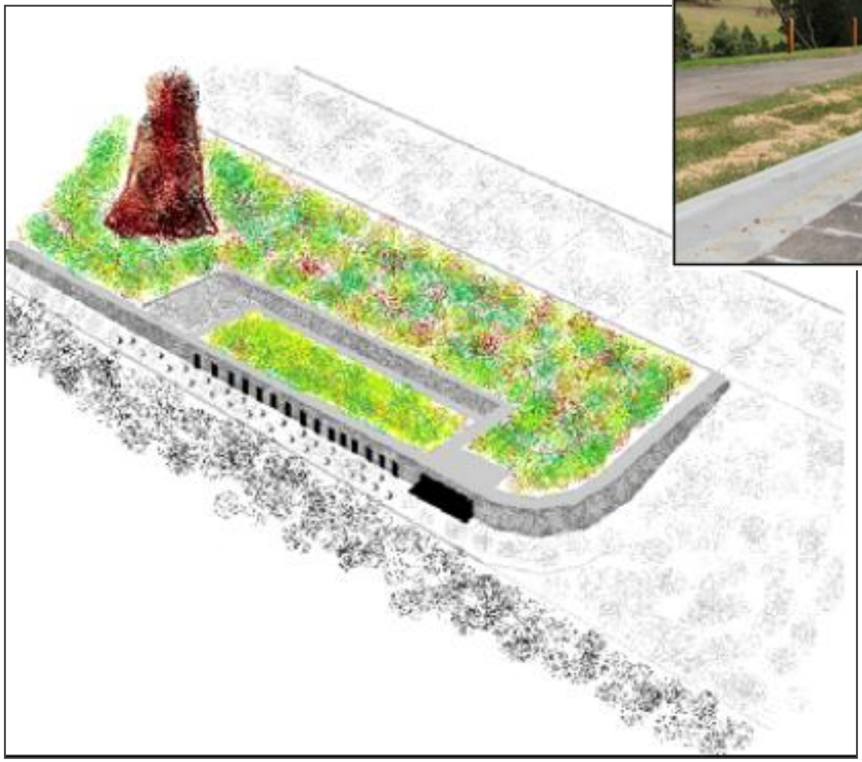
Promising, but need to consider:

- Clogging potential
- Mowing requirements
- Capacity to survive dry periods – evapotranspiration loss on a large scale
- Which lawn species to use - differ in shade tolerance, drought tolerance etc.

Zero Maintenance WSUD (ZAM WSUD)

City of Manningham, Melbourne





Walkable WSUD

Does not become a ‘litter collector’

Residents look after the system as part of the nature strip maintenance agreement

Plant & media Selection: Summary

- **Sizing the system correctly** to ensure the health of plants
- **Low nutrient media** critical
- **Nutrients removal** is sensitive to plant species selection
- Including a **saturated zone supports plants & function** across dry periods, allows denitrification, and buffers against poor plant choice
- **Different characteristics f**avourable in wet and dry periods
- Select species capable of **surviving in sandy media** with highly **variable inflows**
- Importance of an **extensive root system,** alongside **high plant biomass** BUT must be able to survive and **conserve water across dry** periods
- Include a **diversity of plant species**

2009 2015

***Adoption Guidelines for Stormwater Biofiltration Systems* (2015)**

Full Guidelines & separate Summary Report

Download from:

http://watersensitivecities.org.au/new-publication-adoption-guidelines-for-stormwater-biofiltration-systems/

Thank you!

Vertical Technologies – next generation of WSUD