



***Carbon Sequestration Potential
of our Urban Landscape***

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What lies beneath?

Illuminating the unseen nature belowground

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Urban greenery provides multiple environmental and social benefits.


Cities are disturbed ecosystems.

- ***Enhance urban aesthetics.***
- ***Provide open-spaces for recreation***
- ***Reduce water runoff***
- ***Increase water infiltration***
- ***Mitigate soil erosion***



-
- ***Cool local climate***
 - ***Remove airborne pollutants***
 - ***Offset greenhouse gas emissions***



A photograph of a lush green park. In the center, there is a large, dense bush with dark green leaves and some reddish-orange flowers. To the right, there are several tall palm trees. In the background, there is a line of trees and a blue sky with white clouds. In the foreground, there is a large, well-maintained green lawn. A few people are sitting on the grass in the distance to the right.

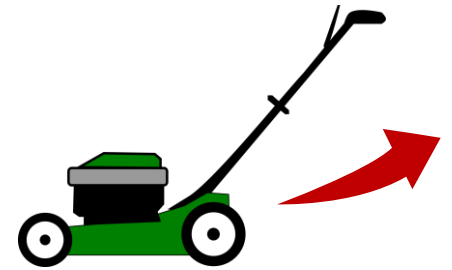
***Does urban greenery act
as sink or emission source
of atmospheric CO₂?***

CO₂ dynamics in a lawn

Mowing emissions

Photosynthesis

Soil respiration
(soil efflux)



Biomass productivity



Heterotrophic activity
Autotrophic activity

CO₂ production

Carbon storage



$$\frac{\text{Soil production} - \text{Soil respiration}}{\text{Soil CO}_2 \text{ storage}}$$

+

$$\text{Biomass productivity}$$

-

$$\text{Mowing emissions}$$

Total CO₂ removed from the atmosphere

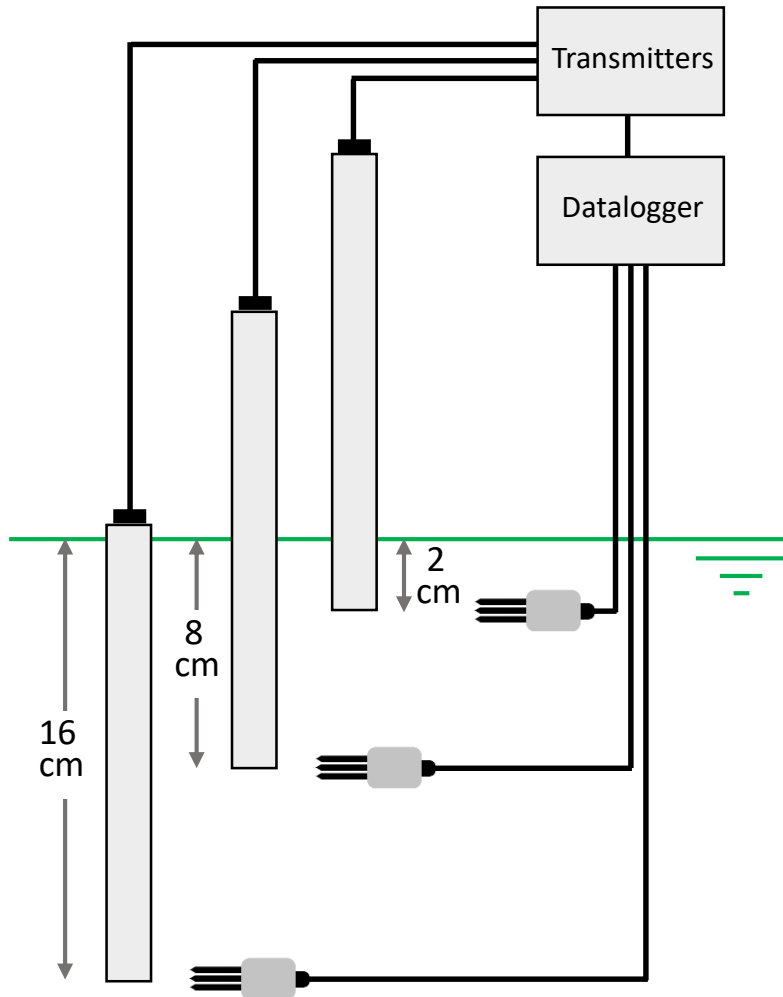


Soil respiration & CO₂ storage



*Telok Kurau, Singapore
Sep 2014 – Jul 2017*

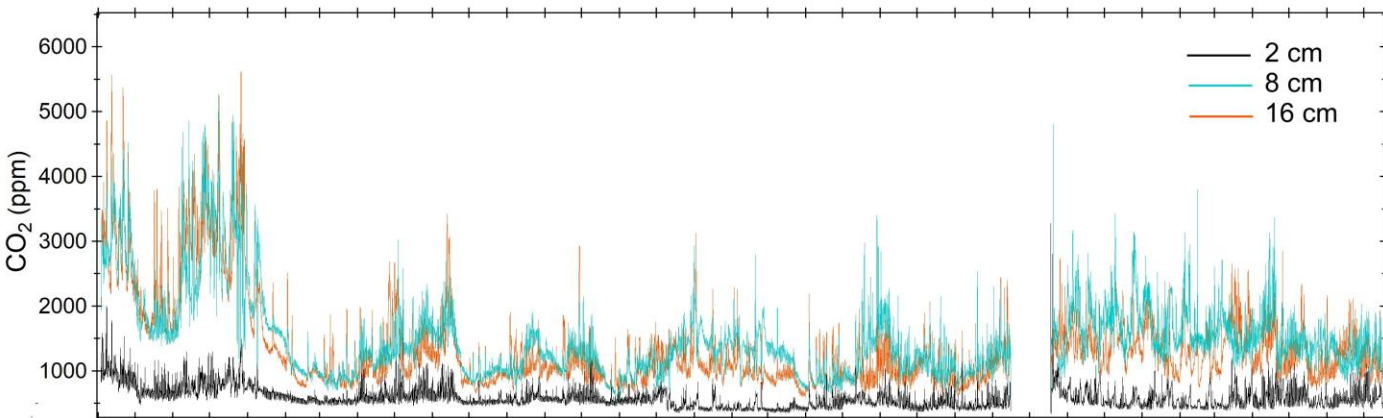
Soil respiration: flux gradient system



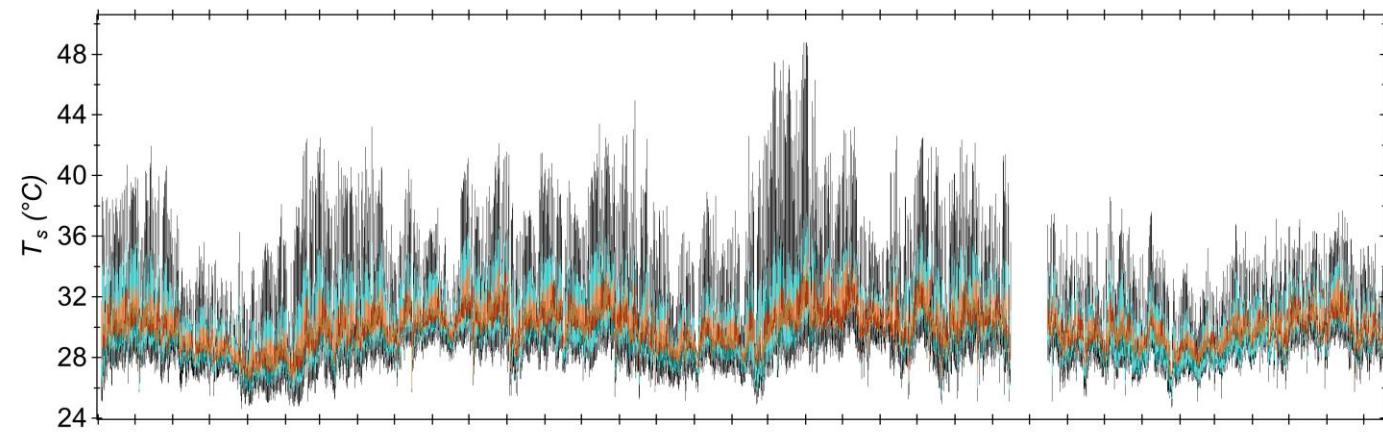
Solid-state CO₂ sensors
(Vaisala CARBOCAP
GMM222)



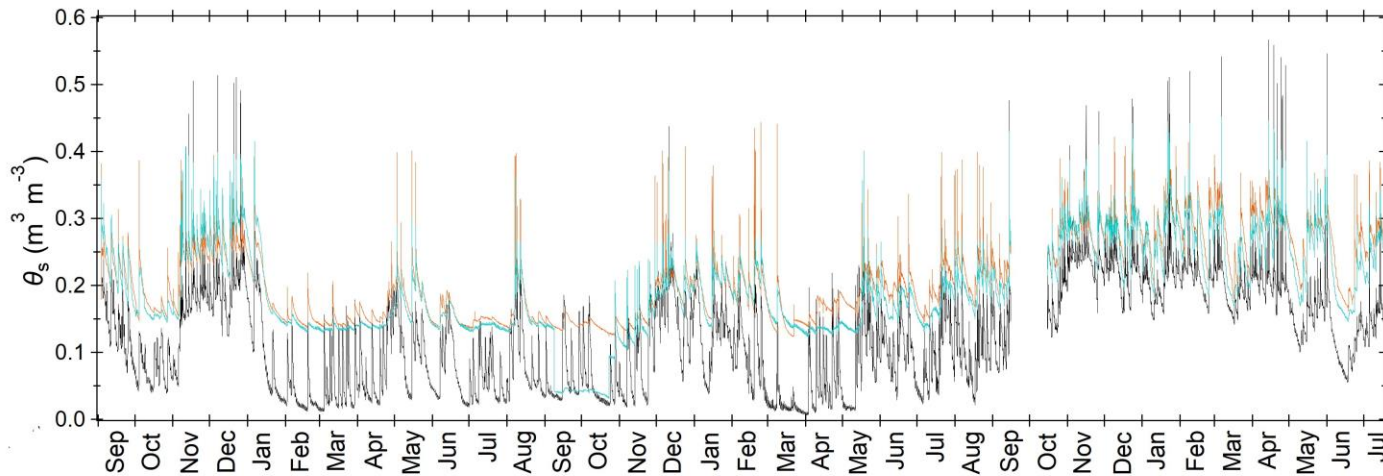
Soil Temp. & water
content (DECAGON 5TM)



CO₂



Temperature



Moisture

Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul

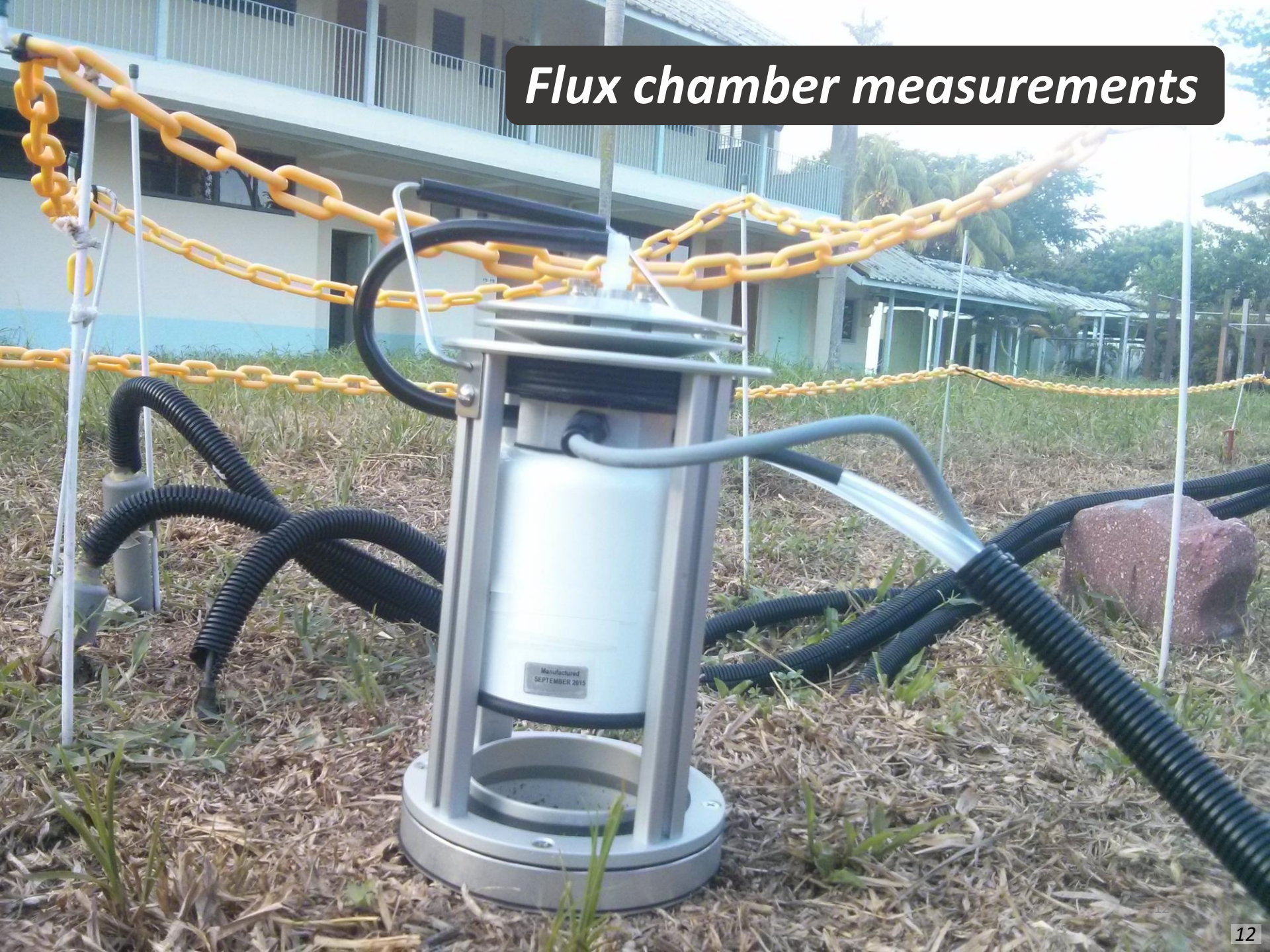
2014 2015 2016 2017

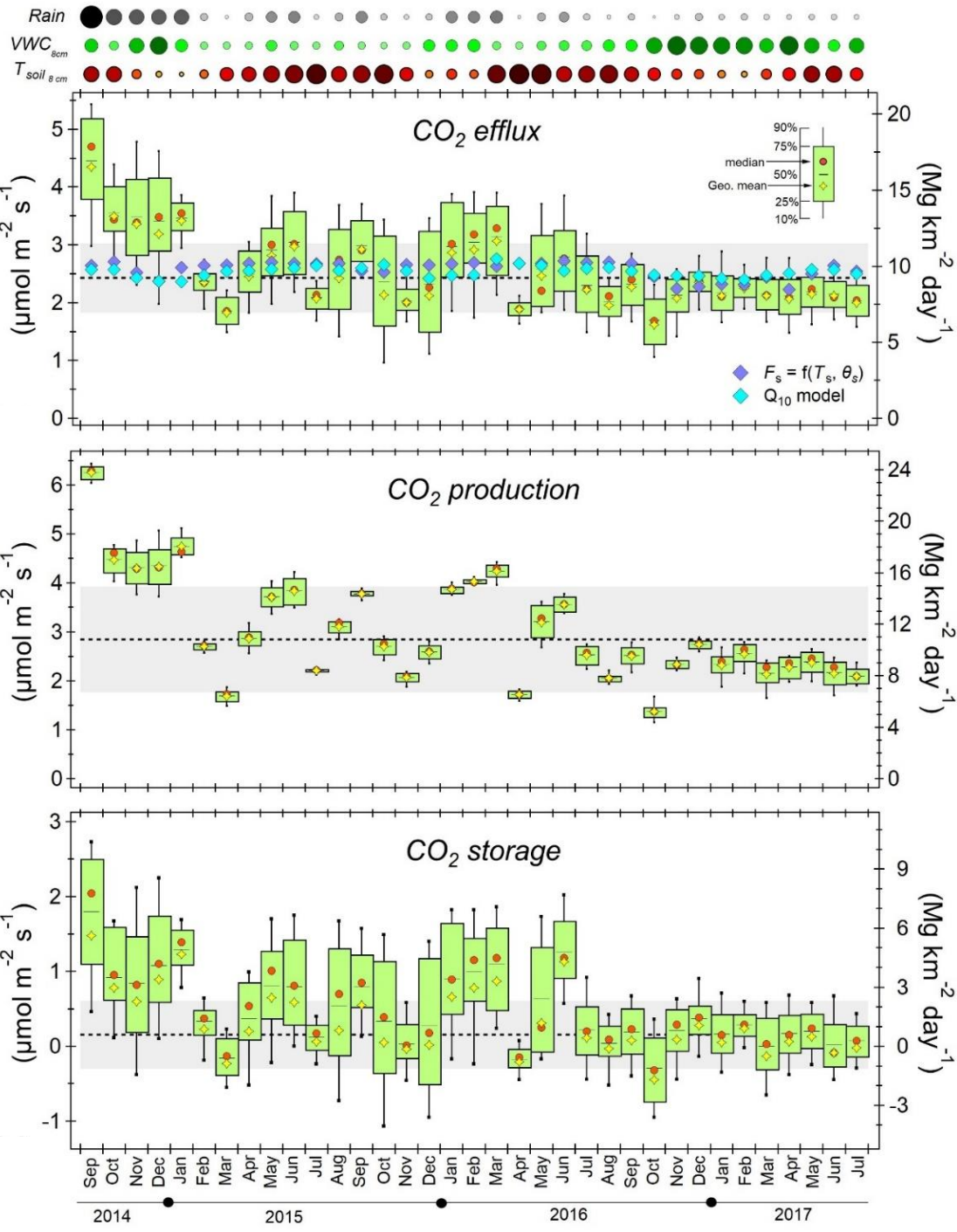


Soil characterization

- Soil texture {
 - % Silt
 - % Clay
 - % Sand
- Total Organic Carbon (TOC)
- pH
- Bulk density

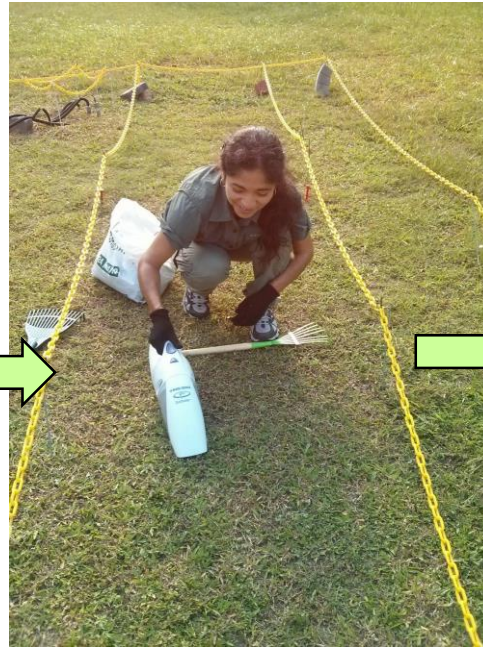
Flux chamber measurements





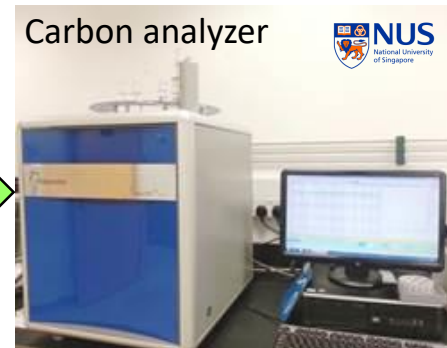
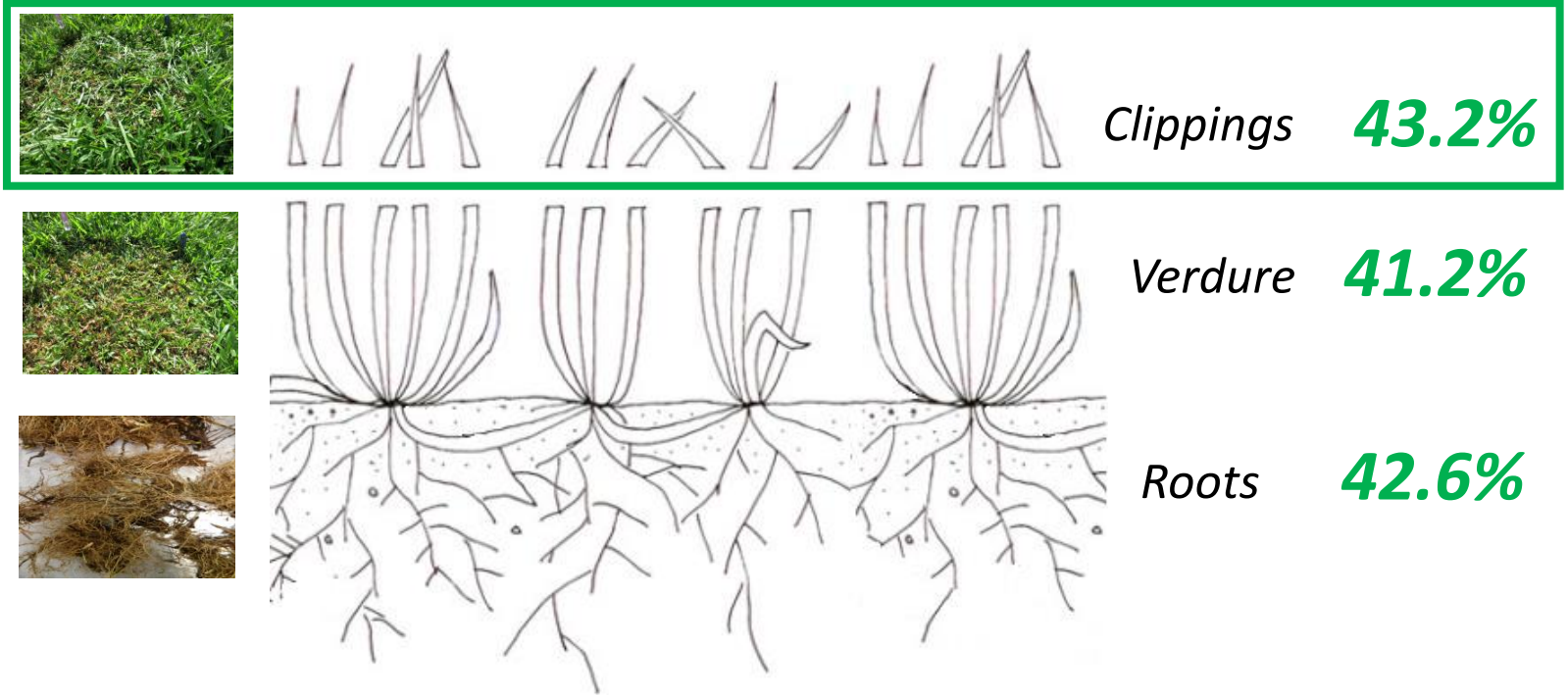
Monthly variations

Turfgrass biomass productivity

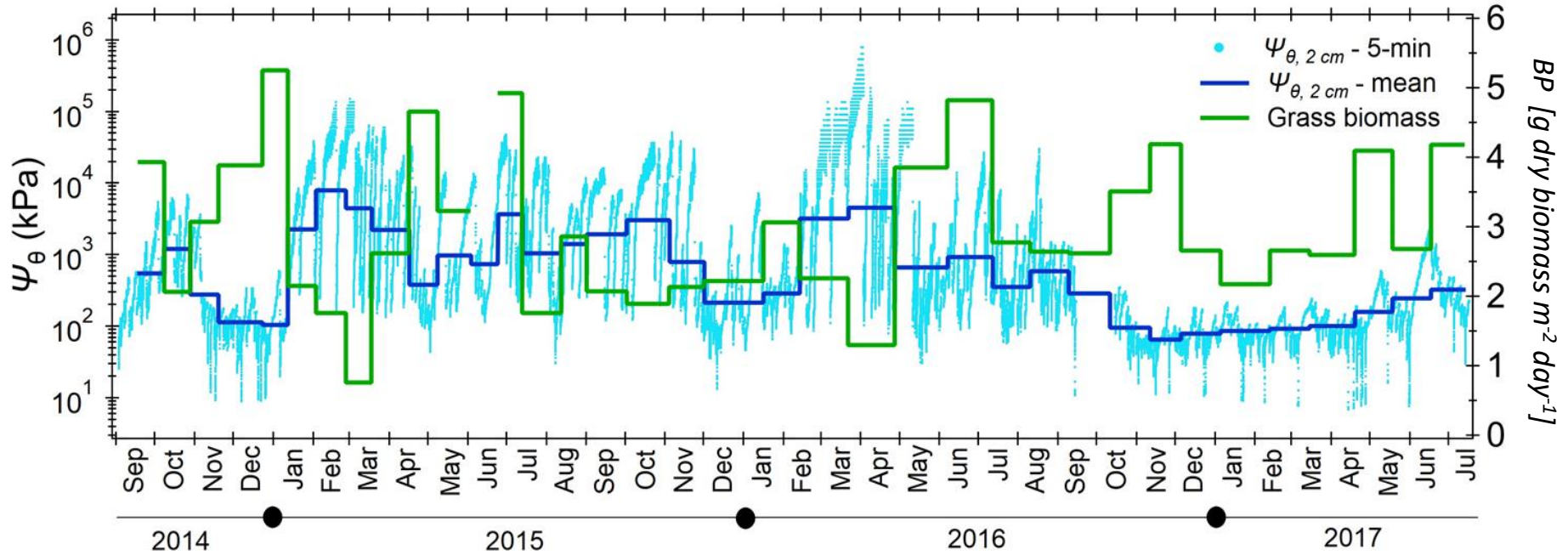


Clipping harvesting

Turfgrass carbon content



Grass biomass productivity



ψ_{θ} = moisture tension

$$\psi_{\theta} = 1.60 \times \theta^{-2.56}$$

θ = soil volumetric water content





Mowing emissions



Annual CO₂ emissions (ton km² yr⁻¹)

*The cleanest
machinery*



Mowing frequency	 Trimmer	 Push mower	 Lawn tractor	 Riding mower
Every week	78.2	82.6	70.1	28.0
Every 2 nd week	39.1	41.3	35.1	14.0
Every 3 rd week	25.6	27.0	22.9	9.2
Once per month	18.0	19.1	16.2	6.5



*The most
common*

Annual CO₂ flux (ton km⁻² yr⁻¹)

Soil CO₂ production - 4022

Soil respiration + 3370

Soil storage - 652

Biomass productivity - ~~1671~~

Mowing emissions + 27

+ 1671

Harvested
clippings
are burnt

Total flux - ~~2296~~

+ 1046



It is all about waste disposal management

During COVID-19 Circuit Breaker



After COVID-19 Circuit Breaker



Turfgrass impact per capita



Carbon footprint

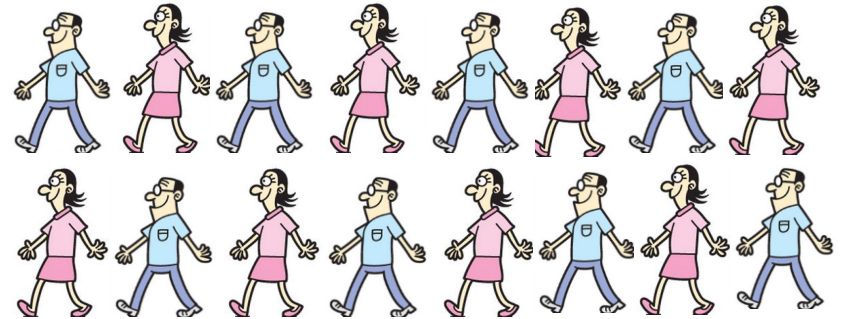
22 ton CO₂ yr⁻¹

Global Carbon Project, 2018.
<https://doi.org/10.18160/gcp-2018>

15% of urban surface is covered by turfgrass

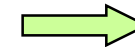
Gaw et al., Data, 2019.

CO₂ flux per km² of turfgrass



Sink

Ideal waste disposal management



Offset emissions of 16 people (344 ton yr⁻¹)



Source

Grass clippings are burnt



Add emissions of 7 people (157 ton yr⁻¹)

Turfgrass impact at city scale

- Energy consumption
- Industrial activity
- Waste incineration

48,560 Gg CO₂ yr⁻¹

National Environmental Agency, 2018.
Singapore's Fourth National Communication and
Third Biennial Update Report Under the United
Nations Framework Convention on Climate Change

112 km² covered by
turfgrass

Gaw et al., Data, 2019

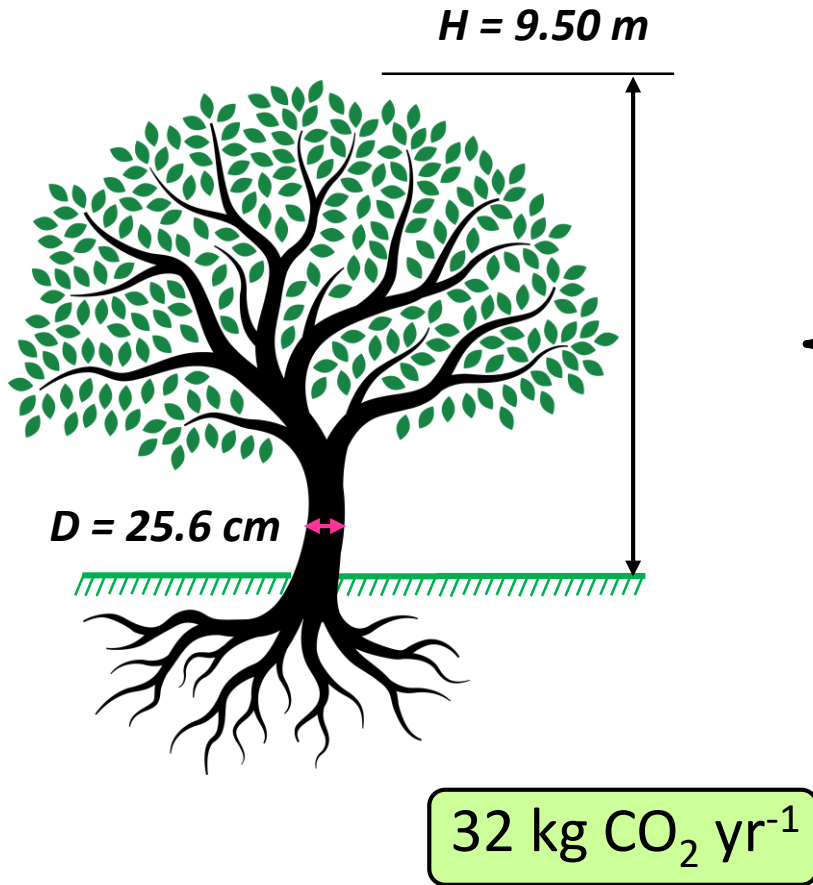
-257 Gg CO₂ yr⁻¹
*Ideal waste disposal
management*

-0.53%

+117 Gg CO₂ yr⁻¹
*Grass clippings
are burnt*

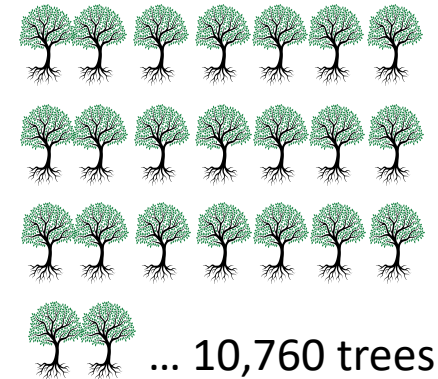
+0.24%

Turfgrass & trees



Ideal waste disposal management

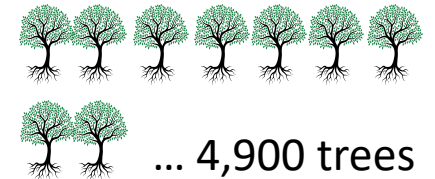
=



Grass clippings are burnt

=

Emission source



Considering 15% of urban surface covered by turfgrass

Turfgrass impact at neighborhood scale



ton CO₂ km⁻² yr⁻¹



15% turfed landscape

-344

or

+157



3,500 woody trees per km²

-136



1,900 palm trees per km²

-27

*Ideal waste
disposal
management*

-507

8% anthropogenic
emissions

*Grass clippings
are burnt*

-6

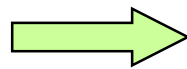
~0% anthropogenic
emissions



ONE MILLION TREES MOVEMENT

The One Million Trees movement aims to restore nature back into our city through the planting of more than a million trees across Singapore over the next ten years, as part of NParks' efforts to achieve our new City in Nature vision. Stay tuned to find out how you can get involved!

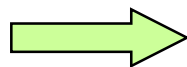
112 km² of vegetation with structure dominated by human management (without Tree Canopy)*



- 257 Gg CO₂ yr⁻¹

- 289 Gg CO₂ yr⁻¹

One-million trees (D = 25.6 cm, H = 9.5 m)



- 32 Gg CO₂ yr⁻¹

0.60% emissions at city scale

Offset emissions of 13,140 people

*Gaw et al., Data, 2019.



Take-home message

***Urban greenery
can act as a sink
for CO₂ with
an adequate
waste disposal
management.***

***However, it
won't offset
our emissions.***

References

Submitted to *Journal of Environmental Management*

Carbon dioxide dynamics in a residential lawn of a tropical city

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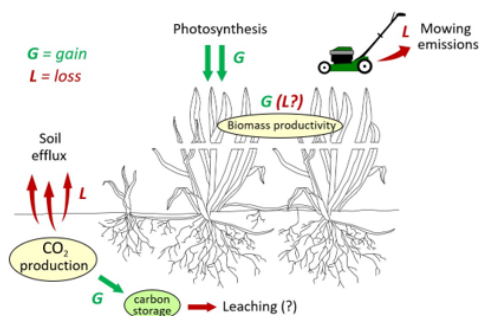
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Highlights:

- Urban lawns in the tropics can act either as a sink or as an emission source of CO₂.
- Belowground carbon accumulation was observed under steady state conditions.
- Warm and humid conditions increase biomass production and mowing frequency.
- If grass clippings are incinerated, the lawn acts as a net CO₂ emission source.
- Locally derived empirical models can be used to account for carbon stocks and fluxes.



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Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug



Carbon storage estimation of tropical urban trees by an improved allometric model for aboveground biomass based on terrestrial laser scanning

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^b Andlinger Center for Energy and the Environment, Princeton University, New Jersey, USA



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Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan



Research paper

Does urban vegetation enhance carbon sequestration?

Erik Velasco^{a,*}, Matthias Roth^b, Leslie Norford^a, Luisa T. Molina^c

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www.atmos-chem-phys.net/13/10185/2013/
 doi:10.5194/acp-13-10185-2013
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Atmospheric
Chemistry
and Physics



The role of vegetation in the CO₂ flux from a tropical urban neighbourhood

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