Seasonal variation in recharge and water and carbon balances of Banksia woodland on Gngangara mound

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http://www.ozflux.org.au/monitoringsites

CSIRO Oceans and Atmosphere

OzFlux

TERN Terrestrial Ecosystem Research Network
Local context – groundwater supply is under stress

- Drying climate is reducing stream flows to dams and recharge to aquifers
- Perth’s increased dependence on groundwater and seawater desalination
- Banksia sand-plain woodland is the major cover on the recharge area for Australia’s most important water resource
- Internationally significant wetlands under threat from warming and drying climate, and increased water demand.
- Long-term groundwater monitoring shows decline in aquifer storage at 50GL/yr  NPV ~ $10^9 based on next available water source (sea-water desalination)
The site has been selected because south-west Western Australia has had a major climate shift since the early 1970s with a major reduction in rainfall.

**Last quarter century winter rain as % of previous 75 years**

![Image of rainfall map showing decrease in recent years](image-url)
Because of reducing dam inflow, we have increased reliance on groundwater.

In 1975 it was 5% now 50%

*P. pinaster* plantation

Water supply bores

Urban area
The basis of the technique is to close the balances of energy, water and carbon for a ‘Control Volume’.

\[ R_n + A = I E + H + G \]

- \( R_n \): net radiation
- \( E \): evaporation
- \( A \): advected energy
- \( I E \): latent heat
- \( H \): sensible heat
- \( G \): heat storage

\[ P = E + R + Q + DS \]

- \( P \): precipitation
- \( R \): recharge
- \( Q \): surface flow
- \( DS \): change in water storage

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Site selected with Noongar approval ...

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The Gnangara/Gingin site

- Elevation 50m AHD
- Banksia woodland
- Tree height ~7.5m
- Leaf Area Index ~0.8
- Biomass (est.) 38t/ha DM
- Coarse sand
- $K_{sat}$ ~5-50 m/day
- DBD=1.35g/cm³
- Tower instruments at 15m
- Piezometers and soil moisture also 500m east and west

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It has a conveniently located Dept of Water piezometer with a long-term record.

Graph showing water level (m AHD) from Aug/76 to Aug/16 with a peak in Aug/84 and a notable increase in water level following Recharge following Wildfire, 1986.

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Instruments – eddy covariance

Average wind

4-component radiation (+ net rad)

Digital camera

turbulent fluxes

- soil moisture x46 (3)
- groundwater level x 3
- soil and water salinity from 3 nests of sampling piezos
- 3x3+ 1x8 Neutron tubes
- (Plus Wind at 10, 7, 2m Ta,rh at 10, 7, 4, 2m)
<table>
<thead>
<tr>
<th>INSTRUMENT TYPE</th>
<th>Make</th>
<th>Model</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open path CO2, H₂O</td>
<td>LI-Cor</td>
<td>LI-7500</td>
<td>15m</td>
</tr>
<tr>
<td>3D Sonic anemometer</td>
<td>Campbell Scientific</td>
<td>CSAT3</td>
<td>15m</td>
</tr>
<tr>
<td>Air temperature</td>
<td>Vaisala</td>
<td>HMP155</td>
<td>1m, 15m</td>
</tr>
<tr>
<td>Air relative humidity</td>
<td>Vaisala</td>
<td>HMP155</td>
<td>1m, 15m</td>
</tr>
<tr>
<td>Net radiometer</td>
<td>Kipp and Zonen</td>
<td>CNR1</td>
<td>15m</td>
</tr>
<tr>
<td>Wind speed and direction</td>
<td>Gill</td>
<td>Windsonic4-L 2D sonic</td>
<td>15m</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Hydrological services</td>
<td>CS701</td>
<td>2 x 0m &amp; 2m</td>
</tr>
<tr>
<td>Soil Heat Flux plate (2 replicates)</td>
<td>Middleton</td>
<td>CN3 Huksflex</td>
<td>-0.05m each of 3, 3 self calibrating</td>
</tr>
<tr>
<td>Soil temperature averaging probe (2 replicates)</td>
<td>Campbell Scientific</td>
<td>TCAV</td>
<td>-0.02 ± 0.05m each of 2</td>
</tr>
<tr>
<td>Soil temperature thermistor</td>
<td>Campbell Scientific</td>
<td>CS107</td>
<td>-0.10, -0.20, -0.40, -0.80, -1.80m</td>
</tr>
<tr>
<td>Soil water content reflectometers</td>
<td>Campbell Scientific</td>
<td>CS616 (x4)</td>
<td>-0.1 (x4), -0.2 (x2), -0.4 (x4), -0.8 (x2), -1.6 (x4)m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CS650 (x2)</td>
<td>-2m, -4m (x2), -6m (x2), -8m</td>
</tr>
<tr>
<td>Soil moisture (method 1)</td>
<td>HydroInnova</td>
<td>COSMOS</td>
<td>100m south-east of tower</td>
</tr>
<tr>
<td>Soil moisture (method 2)</td>
<td>Campbell</td>
<td>Neutron probe</td>
<td>Every 25cm from the surface to 12m, 3 holes</td>
</tr>
<tr>
<td>Watertable</td>
<td>Piezometer, In-situ pressure transducer</td>
<td>Troll 500</td>
<td>-15m, 3 piezometers, one at site, one 400m east and west</td>
</tr>
</tbody>
</table>
Instruments include

Cosmos - cosmic ray moisture monitoring and nested piezometers
Eddy covariance flux instruments

- Neutron probe tube to 6m
- Neutron probe tube
- Cosmos
- Soil moisture monitoring
  - TDR, SW Pot’l
  - 10, 20, 10, 20
  - 40, 80, 40cm
  - 160cm
  - 2m
  - 4m
  - 7.5m
  - 6m
  - 8.0m
  - 8m
  - 8.5m

(Wind, Ta, rh 10, 7, (4), 2m)

1 km
Soil moisture profiles around the COSMOS

Volumetric Soil Moisture Content

Depth (m) vs. Volumetric Soil Moisture Content

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Soil moisture trends at COSMOS

6hr average soil moisture content

Soil moisture content (cm³/cm³)

-0.04  0  0.02  0.04  0.06  0.08  0.1  0.12  0.14


- Calibration
- COSMOS
- Franz UCF
- COSMOS TDR
Soil moisture trends at COSMOS

6hr average soil moisture content

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Soil moisture storage, rainfall and evaporation

6hr average soil moisture storage

- **RAIN mm**
- **450 Water Storage in top 450cm Franz**
- **COSMOS storage mm**
- **Cumulative Rainfall**
- **Cumulative Evap**

![Graph showing soil moisture content, rainfall, and evaporation over time from 9/Feb to 30/Apr.](image-url)
Energy and carbon fluxes at Gingin
Flux data over *Banksia woodland*

- **Net radiation**
- **Sensible heat**
- **Latent heat**
- **Carbon flux**

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Progressive water balance

Soil water storage

Cumulative Precip
Cumulative Evap
Carbon assimilation efficiency: Carbon flux vs evaporation
Carbon assimilation and water use (Evap)

Daily rate relative to the average
Carbon assimilation efficiency in the Banksia

![Carbon assimilation efficiency graph](image)

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Carbon assimilation efficiency in the Banksia

- Carbon assimilation efficiency
  - Relative to mean

- Less than average assimilation
- More than average assimilation
Water fluxes and soil moisture at Gingin

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Water fluxes and soil moisture at Gingin

- Total Evaporation (mm)
- Rainfall (mm)
- Rainfall
- Evaporation
- Moisture storage

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## 2012-2015 water and carbon balance

<table>
<thead>
<tr>
<th>Year</th>
<th>Rain</th>
<th>Evap</th>
<th>Carbon</th>
<th>Carbon/Rain</th>
<th>Carbon/Evap</th>
<th>Recharge ~(Rain-evap)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>321</td>
<td>582</td>
<td>-1688</td>
<td>-5.3</td>
<td>-2.9</td>
<td>-261</td>
</tr>
<tr>
<td>2013</td>
<td>538</td>
<td>587</td>
<td>-2148</td>
<td>-4.0</td>
<td>-3.7</td>
<td>-49</td>
</tr>
<tr>
<td>2014</td>
<td>589</td>
<td>575</td>
<td>-2827</td>
<td>-4.8</td>
<td>-4.9</td>
<td>14</td>
</tr>
<tr>
<td>2015*</td>
<td>516</td>
<td>402</td>
<td>-1542</td>
<td>-3.0</td>
<td>-3.8</td>
<td>114</td>
</tr>
</tbody>
</table>
Conclusions

• Gingin COSMOz running since May 2011
  OzFlux station ~running since October, 2011

• For the first time evaporation is being measured at approaching “management scale” and recharge to the groundwater calculated in near real time

• Recharge is variable in season and year

• Carbon assimilation is highly dependent on season and year

• Collaboration welcome
THANK YOU

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