THE SURFACE WATER BALANCE OF THE WOMBAT STATE FOREST, VICTORIA: AN ESTIMATION USING EDDY COVARIANCE AND SAP FLOW TECHNIQUES

Caitlin Moore, Jason Beringer, Darren Hocking, Ian McHugh, Peter Isaac Stefan Ardnt, Nina Hinko-Najera, Benedikt Fest, Julio Najera
What’s the purpose of this study?

The problem

- Global/regional climate change
- IPCC predictions for SE Australia (2007)
- Effects on water use/output from forest catchments

A solution

Measure water balance of forests:
- Eddy covariance
- Sap Flow
- Remote sensing
- Catchment water balance

Who cares

- Forest managers and planners
- Catchment management authorities
- Local residents/land managers
Wombat State Forest

- Near Daylesford, Central Victoria
- Covering 70,000 ha
- Temperate climate zone at an elevation of 713 m asl
- Long term average maximum daily temperature ~ 18 °C + range of 3-44 °C
- Declared a state forest in 1871
- Disturbances: Fire and harvesting
The Trees of Wombat State Forest

a) *Eucalyptus obliqua* (L’Herit) – Messmate Stringybark
b) *Eucalyptus radiata* (Sieber ex DC) – Narrow-leafed Peppermint
c) *Eucalyptus rubida* (Deane & Maiden) – Candlebark

(Brooker 2006)
Methods

ET
Plant transpiration
Soil evaporation
Canopy interception
Measured using

Meteorological Variables
Solar radiation/air temperature/wind speed & direction/humidity/pressure
How each affects

Transpiration
Trees
Measured using

Surface Water Balance of the Wombat State Forest
Contribution of E. obliqua & E. radiata to

Eddy Covariance
Contribution of forest processes to

Flux Tower Instrumentation
E. radiata
E. obliqua
Wombat’s Water Balance

- Total rainfall from August 2010 to August 2011 at Wombat was 1296 mm – A wetter than average year (av. 844 mm)
- Total evapotranspiration (LE flux) was 648 mm ~ 50% of total rainfall

Cumulative precipitation (P) and Evapotranspiration (ET) from Wombat State Forest
Wombat in the bigger picture

Annual precipitation vs. Evapotranspiration for forests globally

Coefficients:
- $b[0] = 108.8$
- $b[1] = 0.464$
- $r^2 = 0.756$

$n=165$ (modified from Baldocchi & Ryu 2010).
Global probability distribution of annual ET for forests

Mean global water use for forests is 503 ± 338 mm yr⁻¹ (Baldocchi & Ryu 2011)

Daily water use values for different forest types

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Climate</th>
<th>Water Use (mm day⁻¹)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaved Deciduous</td>
<td>Temperate</td>
<td>1.47-1.67</td>
<td>(Wilson and Baldocchi, 2000)</td>
</tr>
<tr>
<td>Broadleaved Evergreen</td>
<td>Temperate</td>
<td>2.49-4.03</td>
<td>(Leuning et al., 2005)</td>
</tr>
<tr>
<td>Broadleaved Evergreen</td>
<td>Tropical</td>
<td>3.0-3.75</td>
<td>(Fisher et al., 2009)</td>
</tr>
<tr>
<td>Savanna Woodland</td>
<td>Tropical</td>
<td>1.4</td>
<td>(Hutley et al., 2000)</td>
</tr>
<tr>
<td>Savanna Woodland</td>
<td>Semi-arid</td>
<td>1.04</td>
<td>(Baldocchi et al., 2004)</td>
</tr>
<tr>
<td>Coniferous Evergreen</td>
<td>Temperate</td>
<td>1.07-1.47</td>
<td>(Grunwald and Bernhofer, 2007)</td>
</tr>
<tr>
<td>Coniferous Evergreen</td>
<td>Boreal</td>
<td>0.1-3.5</td>
<td>(Arain et al., 2003)</td>
</tr>
<tr>
<td>Broadleaved Evergreen</td>
<td>Temperate</td>
<td>0.74-2.81</td>
<td>This study</td>
</tr>
</tbody>
</table>
Preistley-Taylor Coefficient

- Calculation of the Preistley-Taylor coefficient ($\alpha$) provides a useful index for comparing the evaporative control of different forest types (Komatsu 2005).
- $\alpha = \frac{E_{eq}}{ET}$
- High leaf area, ample soil water supplies and a large photosynthetic capacity can increase this ratio (Baldocchi & Ryu 2010).

### Priestley-Taylor coefficients for forest types around the world

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boreal Broadleaved Deciduous</td>
<td>1.09</td>
<td>-</td>
</tr>
<tr>
<td>Temperate Broadleaved Deciduous</td>
<td>0.851</td>
<td>0.147</td>
</tr>
<tr>
<td>Tropical Broadleaved Evergreen</td>
<td>0.824</td>
<td>0.115</td>
</tr>
<tr>
<td>Temperate Broadleaved Evergreen</td>
<td>0.764</td>
<td>0.181</td>
</tr>
<tr>
<td>Temperate Coniferous</td>
<td>0.652</td>
<td>0.249</td>
</tr>
<tr>
<td>Boreal Coniferous Evergreen</td>
<td>0.550</td>
<td>0.102</td>
</tr>
<tr>
<td>Boreal Coniferous Deciduous</td>
<td>0.530</td>
<td>0.084</td>
</tr>
<tr>
<td>Wombat State Forest (this study)</td>
<td>0.990</td>
<td>-</td>
</tr>
</tbody>
</table>

(Baldocchi & Ryu 2010).
Sap Flow

• Average daily water use (L day\(^{-1}\)) was 19.7 and 13.8 for *E. obliqua* and *E. radiata*, respectively.

Mean (±SE) daily tree water use (L day\(^{-1}\)) at WSF for 23 days
Variables influencing sap flow

- Daily tree water use followed the trend in daily total precipitation, with a MLR revealing solar radiation, VPD, wind speed and air temperature each had a significant effect on tree water use.
Outcomes

- In a climatically wet year, the Wombat State Forest output approximately half of the annual rainfall sum.
- Eddy covariance measurements conform with the expected range for temperate forests around the world.
- Sap flow measurements reveal the contribution of individual trees and species to the total water use of the forest.
- The WSF was more likely to be energy limited, rather than water limited, during the period of measurement.

Future Directions

- Continue measurements in order to capture a wider range of climatic variability; i.e. wet, dry and average years.
- Findings can be used to provide a dry sclerophyll component to climate/vegetation models or validate remote sensing measurements.
Acknowledgements

• Project partners Monash University (Jason Beringer) and the University of Melbourne (Stefan Ardnt)
• ARC LIEF “MEGA – Mobile Ecosystem Gas-exchange Analyser for Australian Landscapes (LE0882936)
• Jason Beringer – Honours supervisor
• Nina Hinko-Najera (data QA/QC for Eddy covariance)
• Kara Rasmanis/Reza Amiri (figures)
• Everyone who helped with fieldwork!!
References