Forest Hydrology Workshop

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Land use change

Figure 6.1. Conversion of dairy farmland to pine plantation, as shown here in Northland, is a common land-use change in New Zealand in the 1990s.
Canterbury Plains
2006
Afforestation/deforestation
1992-2006
Forest Hydrology

• Change has changed
  – Deforestation has replaced afforestation

• Fundamentally the same issues apply:
  – How much water comes from a forested catchment vs non-forested?
  – What is the timing of those flows?
    • Floods and low flows in particular

• New issues?
  – Nutrient cycling and losses in forested land
  – Active afforestation vs reversion
Forest Hydrology Processes

• How do trees affect hydrology?
• Transpiration
• Interception loss
• Interception gain?
• What does this mean for water yield?
Trees alter the water balance

\[
\text{Precip} - \text{Evap} - \text{Runoff} - \Delta Storage = 0
\]

\[
\text{Evap} = \text{Precip} + \text{Runoff} - \Delta Storage
\]
Evaporation

• Evaporation is a diffusion process
  – Available energy
  – Ability of atmosphere to absorb water vapour

• Evaporation from a vegetated surface is a mixture of:
  – Evaporation from soil
  – Transpiration (dry leaf evaporation)
  – Interception (wet leaf evaporation)

• Originally thought that wet leaf took available energy, suppressing dry leaf
  – \[ \therefore \text{net evaporation loss the same} \]
Trees and evaporation

• However water balance studies showed water loss with forests, e.g.
  – Wagon Wheel Gap, Colorado, (Bates, 1921)
  – Lancashire, UK, (Law, 1958)
• Rutter (1967) showed that wet leaf evaporation could be 4 times greater than dry leaf
  – Linked mechanism to transfer of sensible heat from higher in atmosphere
• Provided a mechanism to explain the water balance study results
  – Controversial theory at time
Transpiration

• Transpiration is water loss through the leaf (water extracted from ground by roots)
  – Annual transpiration similar trees & pasture
  – Pasture potentially higher
    • When soil wet pasture higher rates
    • Deeper roots can lead to longer period of transpiration under tall vegetation
    • Rooting depth is site specific
Transpiration & stomatal control

- Transpiration (dry leaf evaporation) can be controlled by plant physiology
  - Stomatal control
  - Exerted when the evaporative demand is high
    - N.B. not when soil moisture low
    - Drinking straw analogy
Hot dry atmosphere

Rigid sided stomata
Pasture species
High evaporative loss

Soft sided stomata
Some forest species
Tall tussock
Lower evaporative loss
Interception loss
Interception loss

• Water loss from water sitting on the leaf being evaporated
  – Horton (1919) early recognition of interception importance
  – Linked in to climate, tree form and rainfall type

• In New Zealand transpiration from pasture and forest are roughly equivalent
  – Therefore it is interception loss that causes greatest impact on water balance
Why are trees so good at intercepting water?

Lots of intercepting surfaces (leaves/needles)
Why are trees so good at intercepting water?

Efficient turbulent transfer of water vapour
Why are trees so good at intercepting water?

- Lots of intercepting surfaces (leaves/needles) = High potential storage of water in canopy
- Rough canopy = Efficient turbulent transfer of water vapour = High evaporative losses
How much water is “lost” through interception?

Varies with:
- Species
- Trees
- Time of year
- Rainfall type
- Measurement methodology
## Amounts of interception loss

<table>
<thead>
<tr>
<th>Canopy cover</th>
<th>Interception loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine forest (Australia)</td>
<td>5-26% per event</td>
</tr>
<tr>
<td>Oak (Denmark)</td>
<td>15% of summer rainfall</td>
</tr>
<tr>
<td>Kanuka (NI East Coast)</td>
<td>42% of annual</td>
</tr>
<tr>
<td>Pine forest (Canty plains)</td>
<td>33% of annual</td>
</tr>
<tr>
<td>Snow tussock</td>
<td>10-45% of monthly</td>
</tr>
<tr>
<td>Snow tussock</td>
<td>22% of annual</td>
</tr>
</tbody>
</table>
NZ figures summarised from Rowe et al (2002)

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinus radiata</td>
<td>22% of annual in NZ (35% max)</td>
</tr>
<tr>
<td>Douglas Fir</td>
<td>29% of annual</td>
</tr>
<tr>
<td>Kanuka</td>
<td>42% of annual</td>
</tr>
<tr>
<td>Manuka</td>
<td>31-39% of annual</td>
</tr>
<tr>
<td>Snow tussock</td>
<td>10-45% of monthly</td>
</tr>
<tr>
<td>Snow tussock</td>
<td>22% of annual</td>
</tr>
<tr>
<td>Beech forest</td>
<td>26% of annual</td>
</tr>
<tr>
<td>Podocarp-beech</td>
<td>39% of annual</td>
</tr>
<tr>
<td>Kamahi</td>
<td>27% of total</td>
</tr>
</tbody>
</table>

Summary NZ figures - annual

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<th>Canopy cover</th>
<th>Interception loss</th>
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<tbody>
<tr>
<td>Pinus radiata</td>
<td>22%</td>
</tr>
<tr>
<td>Douglas Fir</td>
<td>29%</td>
</tr>
<tr>
<td>Native forest</td>
<td>33%</td>
</tr>
<tr>
<td>Scrub (manuka/kanuka)</td>
<td>37%</td>
</tr>
<tr>
<td>Tussock grassland</td>
<td>21%</td>
</tr>
</tbody>
</table>

Caution with annual percentages
Climate an important factor

Interception loss (event)

3.2 (a) Interception ratio and storm precipitation in an area of tropical forest in Puerto Rico on data in Clegg, 1963.
Interception loss (annual)

(b) Annual mean interception ratio and annual precipitation for a range of British sites (based on an original diagram in IH, 1982).
Interception gain

• Reverse process
  – Rough canopy leads to condensation on needles?
  – Fog interception

• Known in NW Pacific states
  – Important where fog is a large part of precipitation
  – Not believed to be important in NZ
How does interception loss transmit into water balance?

- **Storage change**
  - Soil moisture storage
How does interception loss transmit into water balance?

• Storage change
  – Soil moisture storage
  – Doesn’t always recover over winter

**FIG. 6** — Relationship between 6-month moving average of rainfall (A) and 12-month moving mean of soil moisture depth (mm) in the top 2300 mm of soil from C5 (pasture) and C8 and 14 (pines)(B).
Water yield

- Interception loss and change in storage also transmit through into water yield reductions...

\[
\text{Evap} = \text{Precip} + \text{Runoff} - \Delta \text{Storage}
\]