Landcare Research
Manaaki Whenua

Forest Hydrology Workshop

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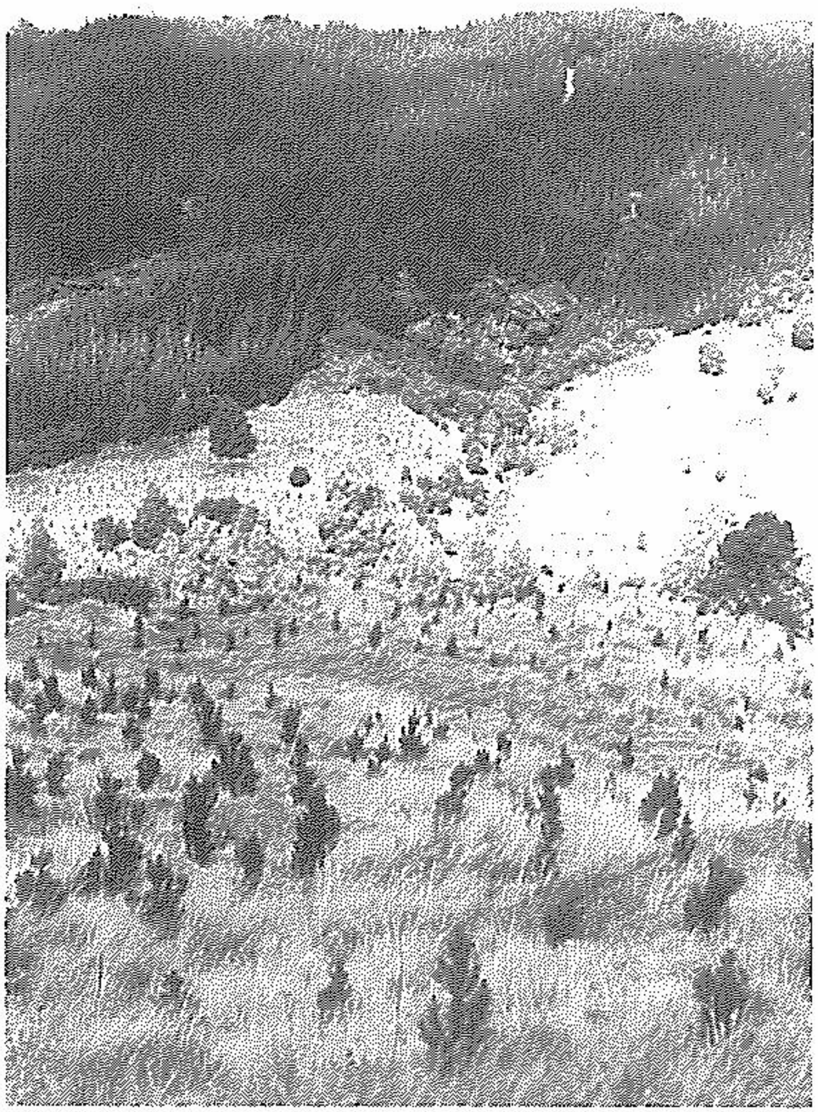
Land use change

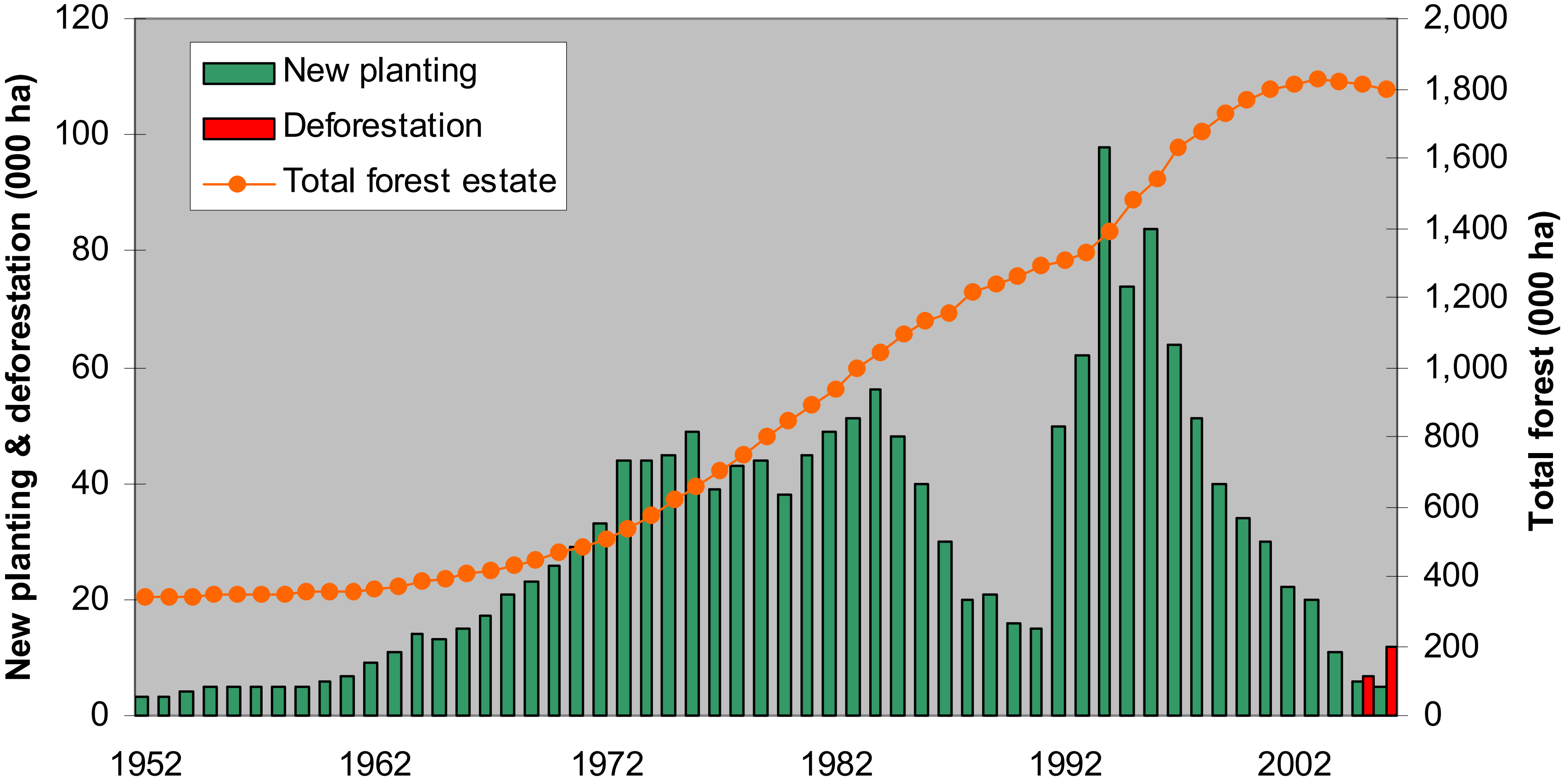


Floods & Droughts (1997)

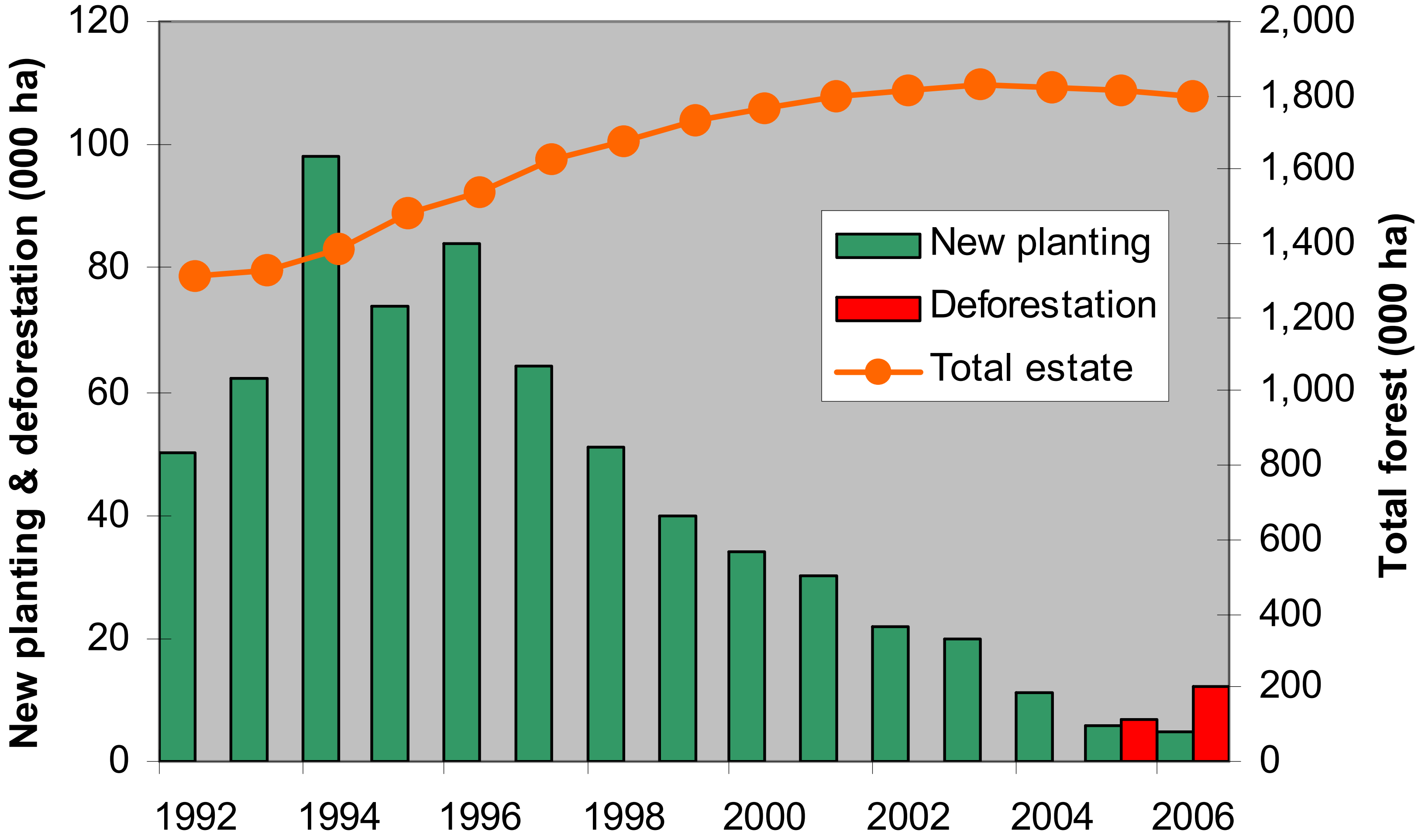
Figure 6.1. Conversion of dairy farmland to pine plantation, as shown here in Northland, is a common land-use change in New Zealand in the 1990s

Canterbury Plains
2006

Afforestation/deforestation 1952-2006



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

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

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

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
  - $\therefore$ 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

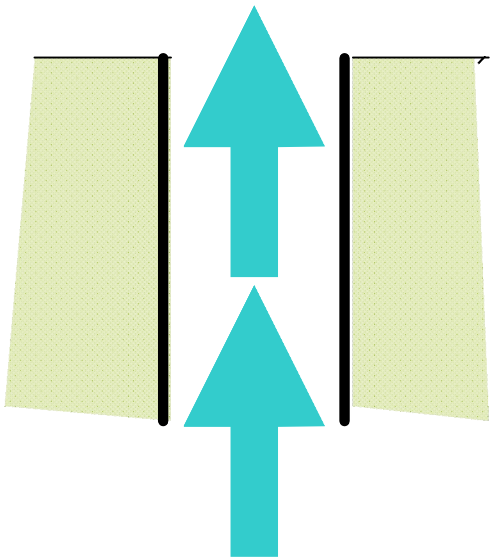
Transpiration

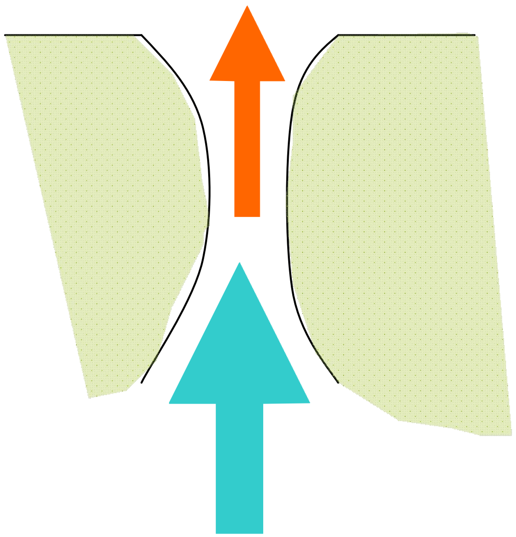
- Transpiration is water loss through the leaf (water extracted from ground by roots)
  - Annual transpiration similar trees & pasture
  - Pasture potentially higher
    - When soil wet pasture higher rates
    - Deeper roots can lead to longer period of transpiration under tall vegetation
    - Rooting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

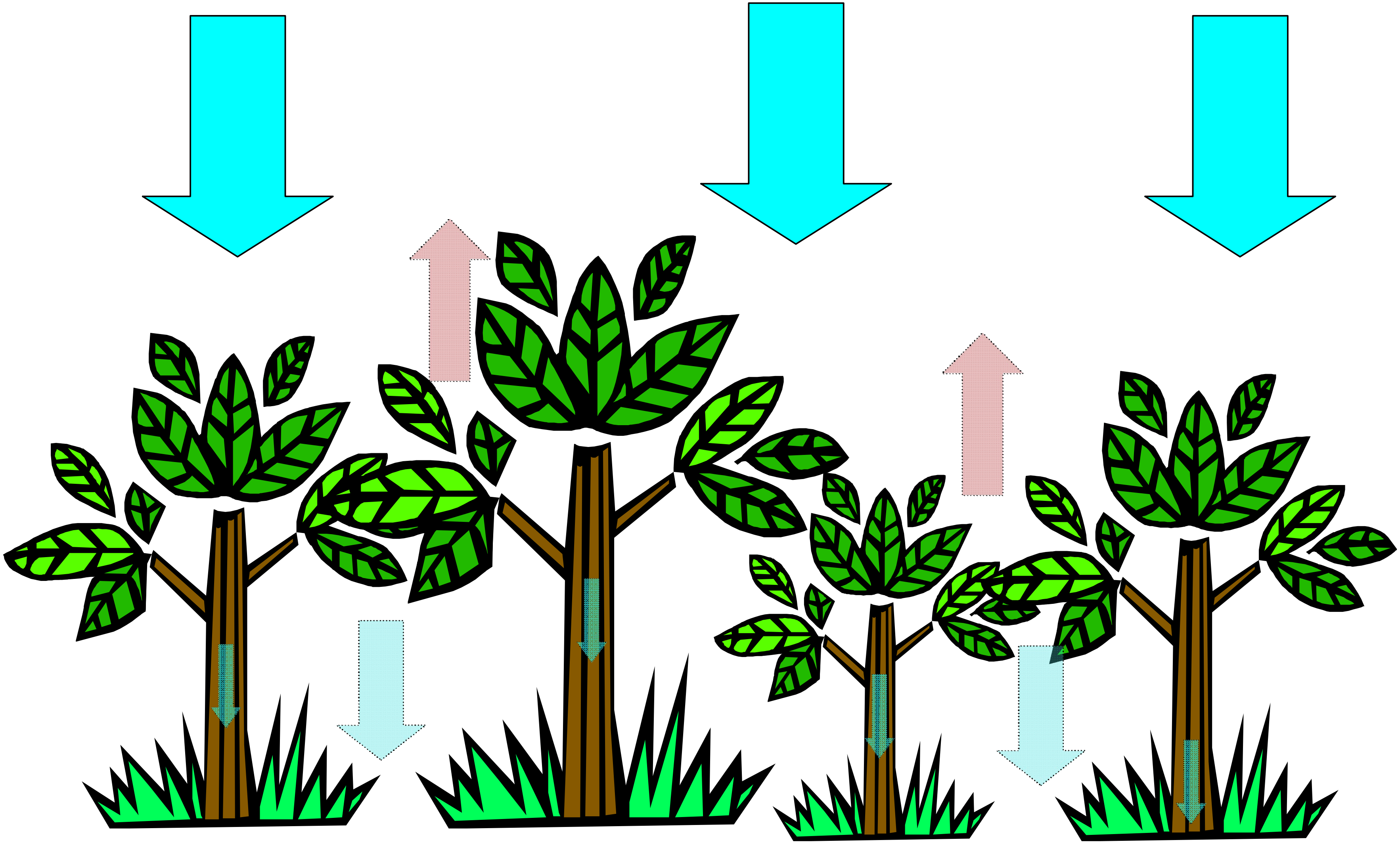
High evaporative loss

Soft sided stomata

Some forest species
Tall tussock

Lower evaporative loss

Interception loss

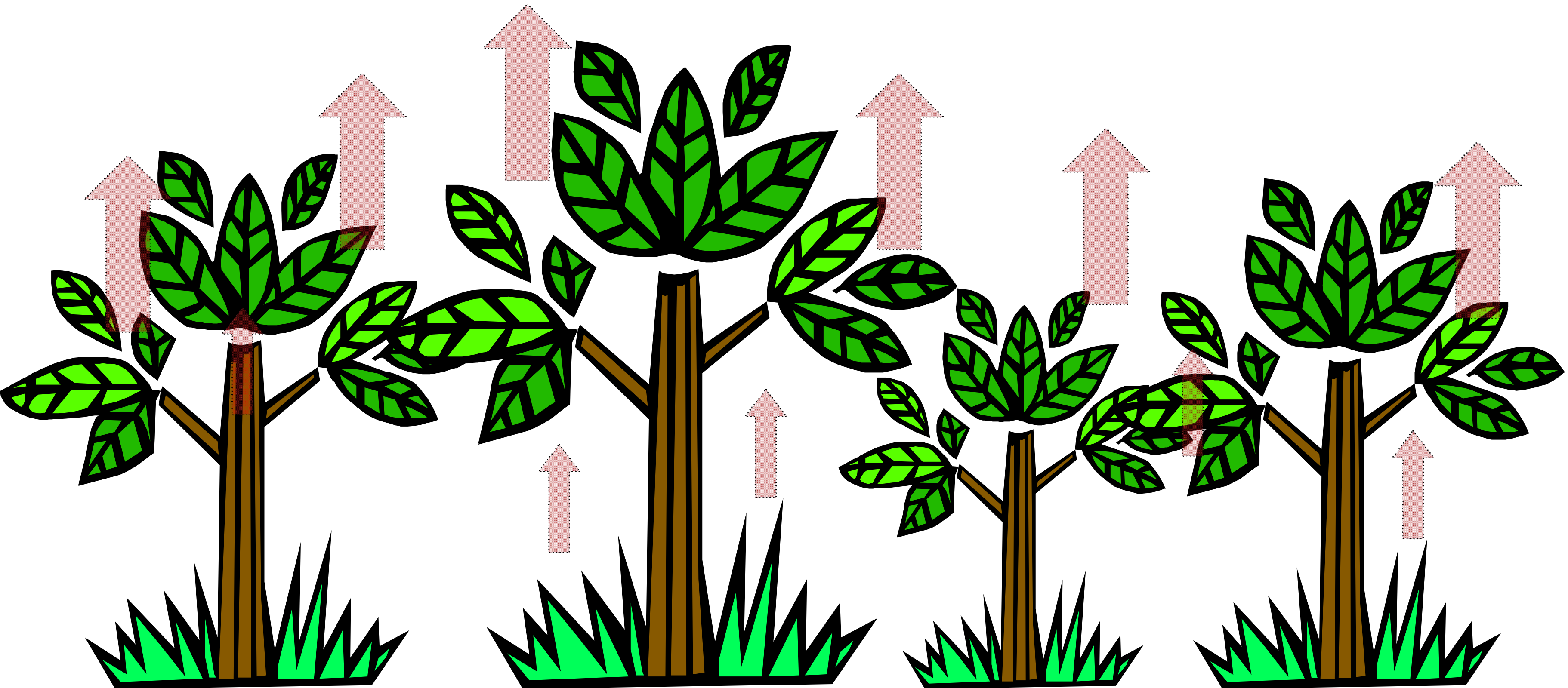


Interception loss

- 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

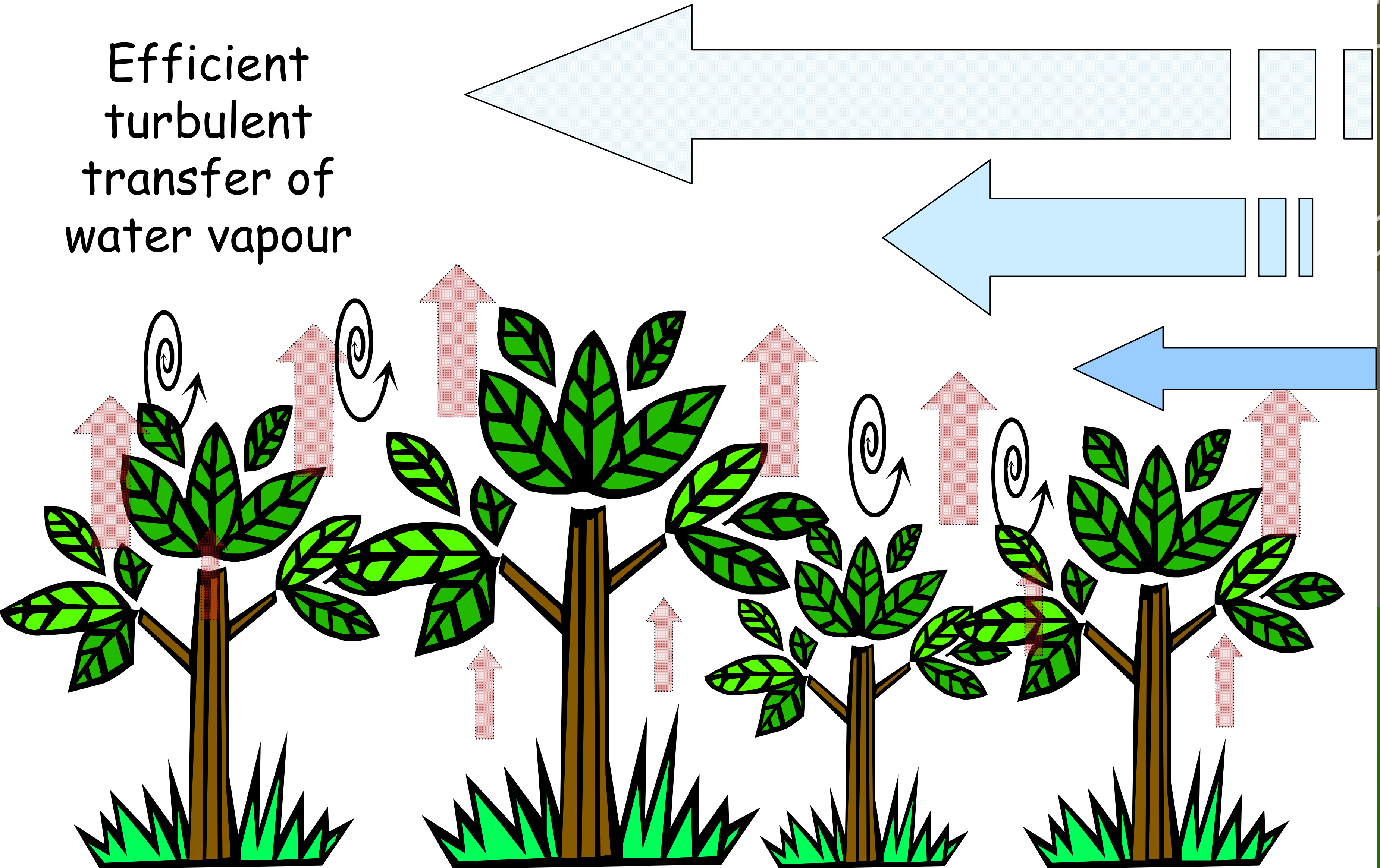
Why are trees so good at intercepting water?

Lots of intercepting surfaces (leaves/needles)



Why are trees so good at intercepting water?

Efficient turbulent transfer of water vapour

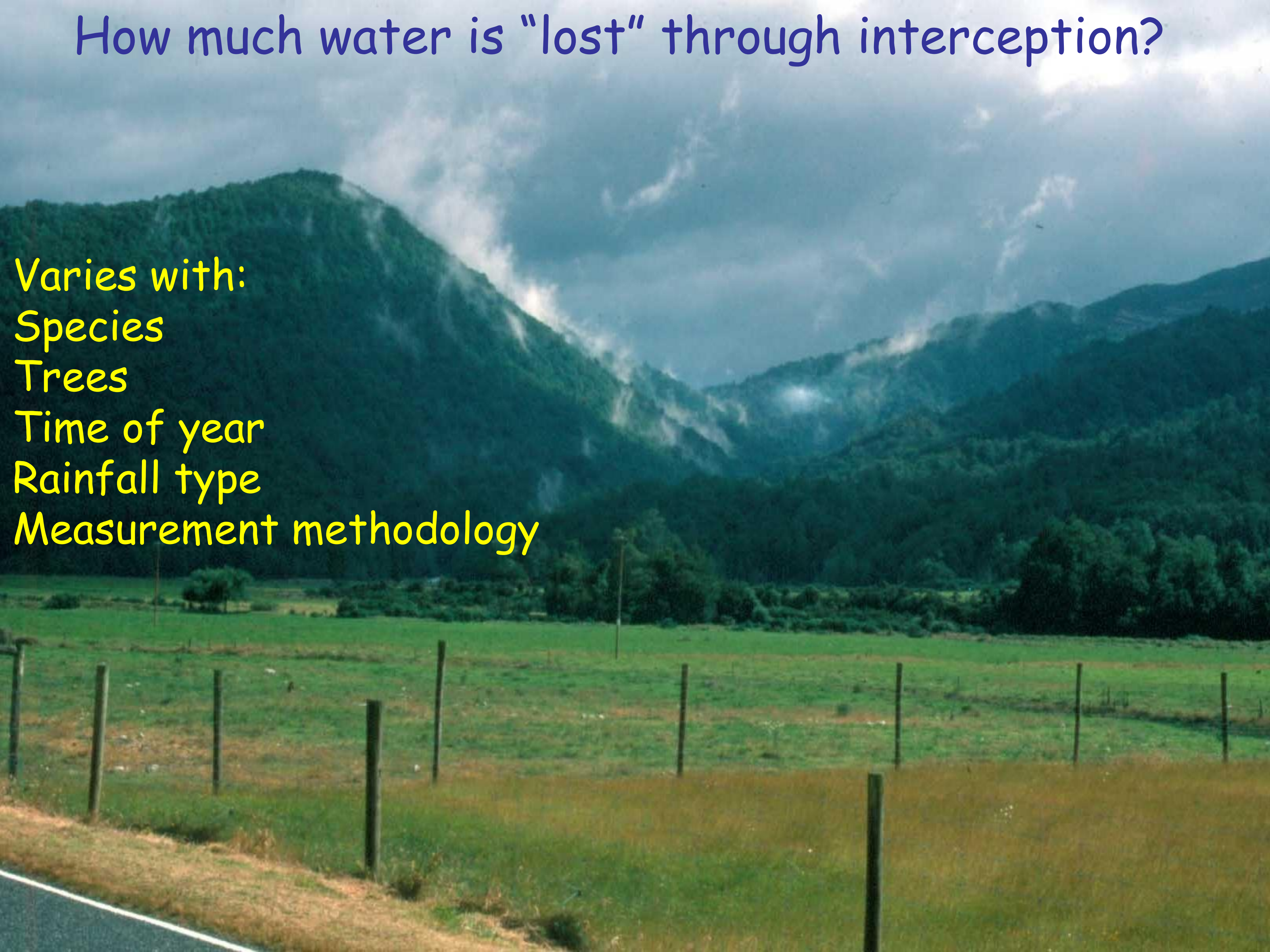


Why are trees so good at intercepting water?

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

Canopy cover	***Interception loss***
Pine forest (Australia)	5-26% per event
Oak (Denmark)	15% of summer rainfall
Kanuka (NI East Coast)	42% of annual
Pine forest (Canty plains)	33% of annual
Snow tussock	10-45% of monthly
Snow tussock	22% of annual

NZ figures summarised from Rowe et al (2002)

Pinus radiata	22% of annual in NZ *(35% max)*
Douglas Fir	29% of annual
Kanuka	42% of annual
Manuka	31-39% of annual
Snow tussock	10-45% of monthly
Snow tussock	22% of annual
Beech forest	26% of annual
Podocarp-beech	39% of annual
Kamahi	27% of total

Rowe, L.K., Jackson, R. & Fahey, B. (2002) Hydrological Effects of Different Vegetative Covers. Landcare Research Report LC0203/027 (available at http://icm.landcareresearch.co.nz)

Summary NZ figures - annual

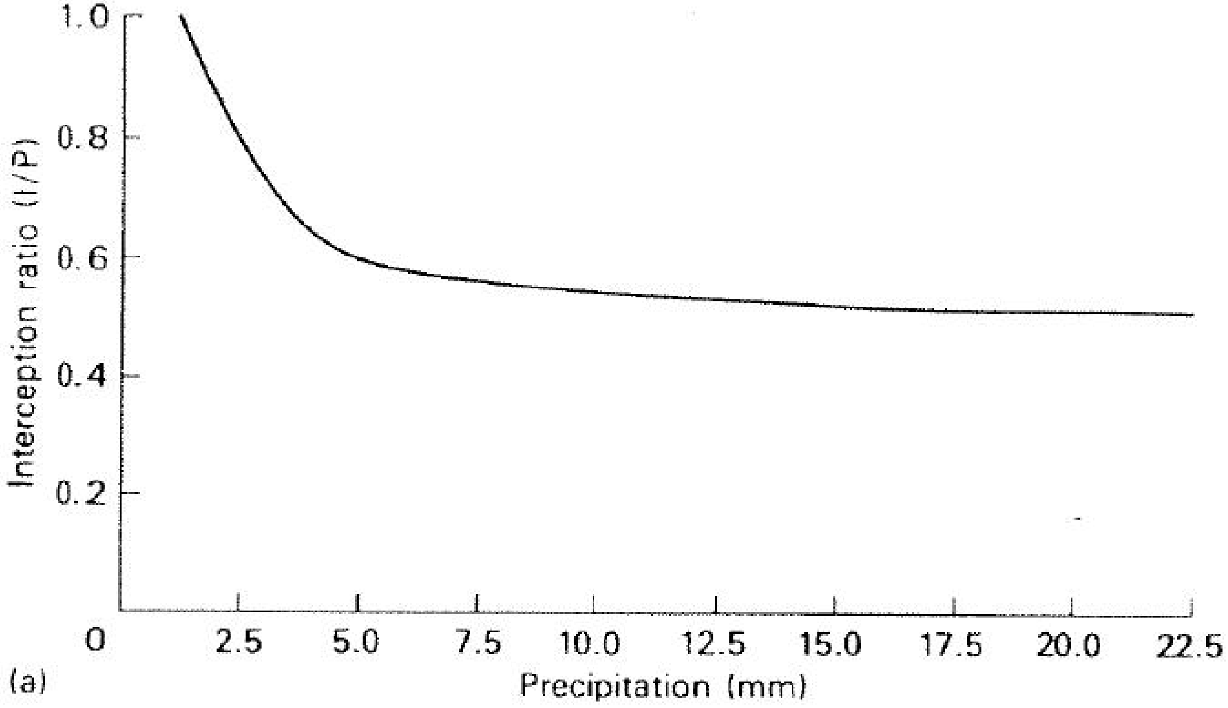
Canopy cover	*Interception loss*
Pinus radiata	22%
Douglas Fir	29%
Native forest	33%
Scrub (manuka/kanuka)	37%
Tussock grassland	21%

Caution with annual percentages

Climate an important factor

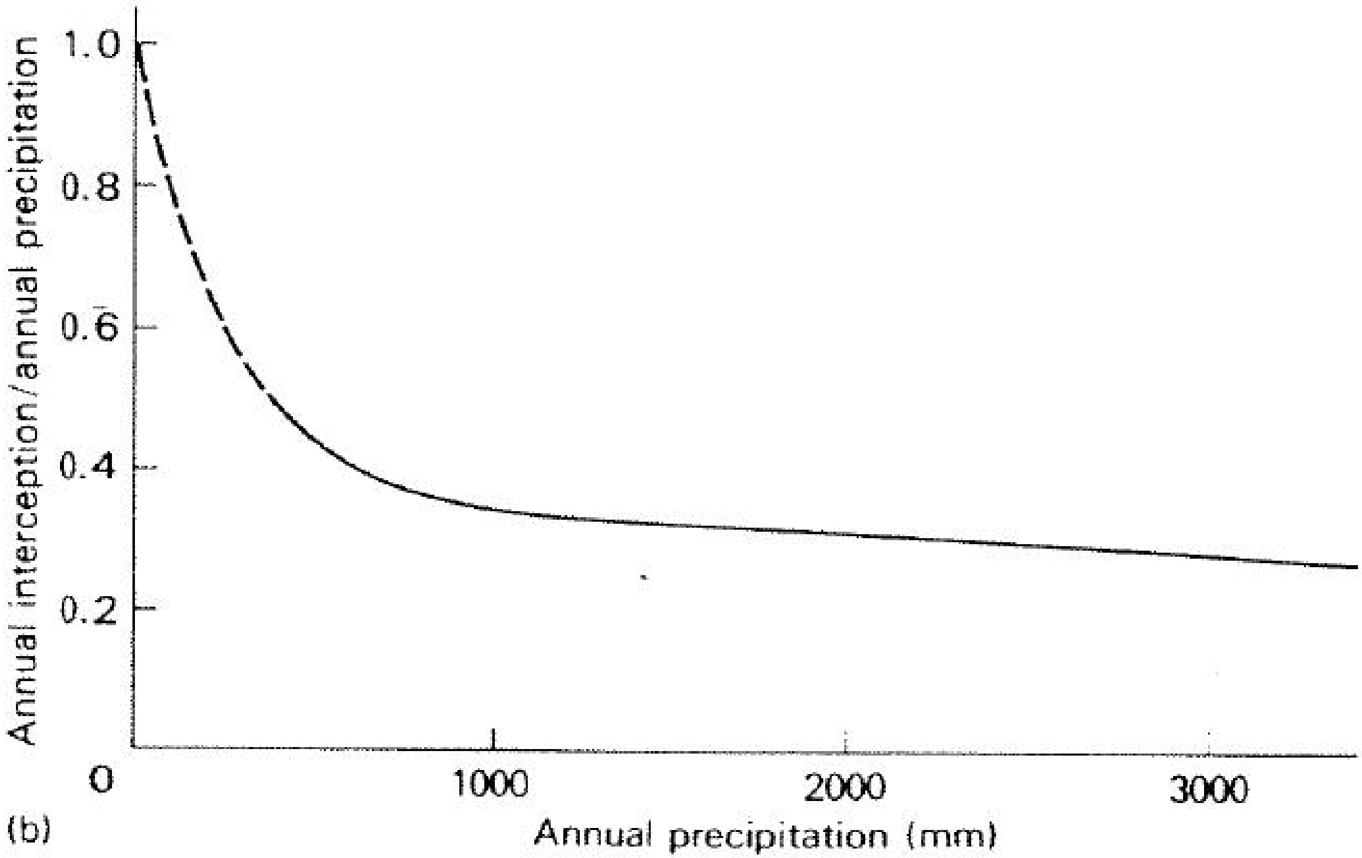
Rowe, L.K., Jackson, R. & Fahey, B. (2002) Hydrological Effects of Different Vegetative Covers. Landcare Research Report LC0203/027 (available at http://icm.landcareresearch.co.nz)

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)



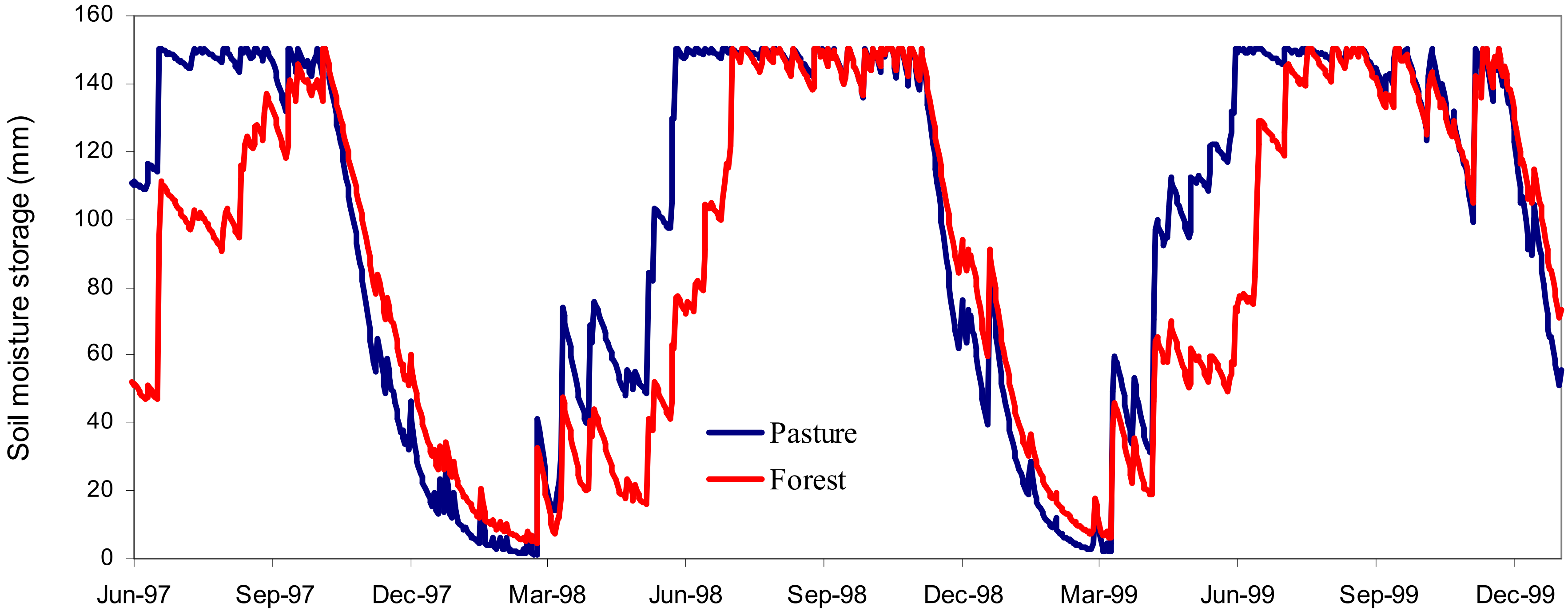
(b) Annual mean interception ratio and annual precipitation for a of British sites (based on an original diagram in IH, 1982).

Interception gain

- Reverse process
  - Rough canopy leads to condensation on needles?
  - Fog interception
- Known in NW
  - Important whe
    precipitation
  - Not believed t

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

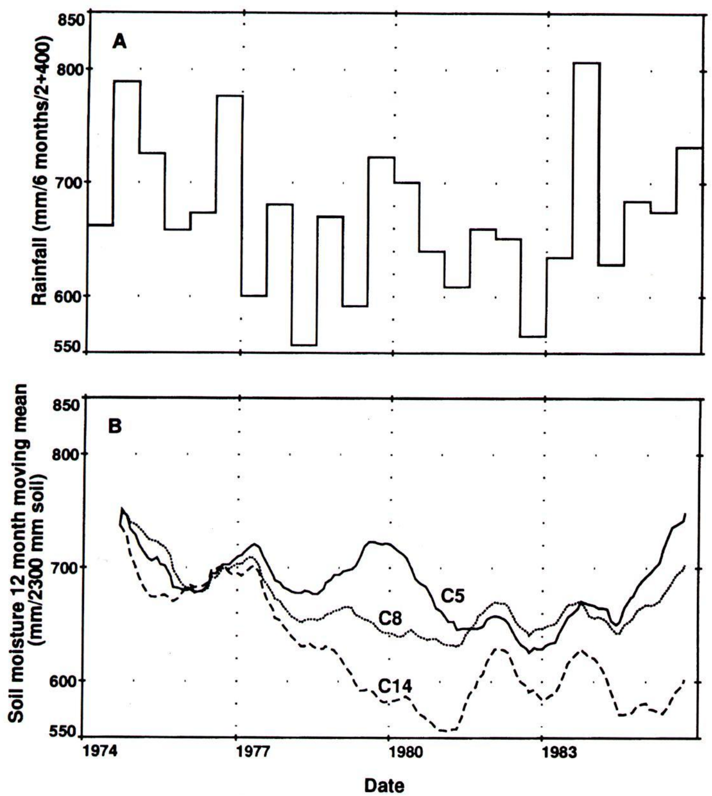


FIG. 6 — Relationship between 6-month moving average of rainfall (A) and 12-month moving mean of soil moisture depth (mm) in the top 2300 mm of soil from C5 (pasture) and C8 and 14 (pines)(B).

Water yield

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