Can silvicultural treatments improve the water economy?:

Jerry Vanclay
Southern Cross University, Australia
JVanclay@scu.edu.au
Trees use water

Clouds form over forest

Atmosphere holds little water

MODIS/Terra satellite data, April 2006
Spatial prediction of mean annual runoff reductions (from the MAYA model)

THE IMPACT OF FOREST PLANTATIONS ON WATER YIELD, A STATEMENT CLARIFYING KEY SCIENTIFIC ISSUES

This statement presents agreed outcomes of a meeting chaired by the Bureau of Rural Sciences on Friday 24/10/03 concerning scientific knowledge of the impact of forest plantations on catchment water yield. Eighteen representatives from a range of government and scientific agencies attended (listed below).

Preamble
Potential impacts of forest plantations on the quantity and reliability of water flowing into rivers and aquifers have been of concern in certain regions for some time. The issue has recently received media and political attention.

This statement aims to clarify key scientific issues on the impact of forest plantations on catchment...
Effects of afforestation on water yield: a global synthesis with implications for policy

KATHLEEN A. FARLEY,1,2 ESTEBAN G. JOBBÁGY1,2 and ROBERT B. JACKSON1,2

1Center for Global Change, Duke University, Durham, NC 27708, USA; 2Department of Biology and Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC 27708, USA. 1Grupo de Estudios Ambientales – IMASL, Universidad Nacional de San Luis & CONICET, San Luis 5700, Argentina

Fig. 1. Changes in stream flow and annual renewable water as a function of plantation age, and the relative abundance of renewable water by country. Changes in stream flow in mm (A) and proportion (%) (C) as a function of plantation age. (D) Changes in annual renewable water (annual stream flow in mm divided by annual precipitation). (B) Average renewable freshwater (mm) versus mean annual precipitation (mm) by nation. The lines define 10%, 20%, and 30% renewable water as a percentage of MAP. See (12).

Trading Water for Carbon with Biological Carbon Sequestration

Robert B. Jackson,1* Esteban G. Jobbágy,1,2 Roni Avisar,3 Somnath Baidya Roy,3 Damian J. Barrett,4 Charles W. Cook,1 Kathleen A. Farley,1 David C. le Maitre,5 Bruce A. McCarr,6 Brian C. Murray7

*Corresponding author.
Is age causal or just correlated?

What else might be correlated with age, and more likely to be causal?
Transpiration estimates for Lismore vegetation made with Penman-Monteith equation

The ASCE-EWRI standardized reference ET equation based on the Penman-Monteith equation (eqn. 13) for a hypothetical crop with typical data from Table 1 (Walter et al., 2002) is given as

\[ ET_{s0} = \frac{0.408 \, A(R_n - G) + \frac{C_n}{T + 273} \, U_2 \left( e_s^o - e_a \right)}{\Delta + \gamma \left(1 + C_d \, U_2\right)} \]

where \( ET_{s0} \) is the standardized reference crop evapotranspiration (\( ET_{0s} \)) or a tall reference crop (\( ET_{rs} \)) in units based on the 24-hr day or mm hr\(^{-1}\) for an hourly time step [time units on \( R_n \), evapotranspiration rates], \( C_n \) is the numerator constant for the time step, and \( C_d \) is the denominator constant for the reference crop type and \( U_2 \) is the relative humidity %.
Penman-Monteith equation shows us that evapo-transpiration depends largely on:
1. Wind speed
2. Humidity (within boundary layer)
3. Canopy roughness

½ transpiration in ⅓ of days when wind >13 km/hr
Windbreaks and Shelterbelts
Would windbreak trees like these reduce unproductive transpiration?

Or would there be no overall gain?
Enhanced water use efficiency in a mixed *Eucalyptus globulus* and *Acacia mearnsii* plantation

David I. Forrester, Swaminathan Theiveyanathan, John J. Collopy, Nico E. Marcar

“Transpiration may be less in mixture”

“For every 1 m³ of water transpired *E. globulus* trees in mixtures produced 87% more aboveground biomass than those in monocultures…”

“All treatments were well coupled to the atmosphere (about 0.25 in all treatments)”
Stomatal response to light

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Maximum stomatal conductance

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<th>Species</th>
<th>Δαt</th>
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Figure 2. Application to China. (a) (b) and (d)
Figure 3: Comparison of forest structure in (A) old growth and (B) regrowth mountain ash stands.
Figure 5. Correlation coefficient ($r_{uw}$) at canopy top ($z/h_c = 1$) from the field experiment at $x/h_c = -6, 0, 3.5$ and $14.5$ and from the wind tunnel at selected points.

How to neutralise this ‘hard’ edge of many plantations?

Wind speed & turbulence peaks here, at 4-10 times stand height

Low wind speed in mid-canopy and below

Figure 1.7: Three characteristic zones for smooth terrain to forest transition
Firebreak not less than 10 m wide; Trees pruned to 5 m along firebreak.
Research needs:
Benefit of ‘internal windbreaks to reduce effective wind speed…
… wind tunnel and field studies …
Modify transpiration through atmospheric decoupling of canopy?
… what is ideal canopy structure?
How is transpiration affected by turbulence near forest edges?
… wind tunnel and field studies …
Modify turbulent transpiration by softening edges of plantations?
- with hedges on wind-exposed edges?
- by thinning and pruning edges?
… field studies …
*Plus species-site matching, tree breeding, …*
Caveat

No ‘silver bullet’: Match silviculture to site:

High transpiration in polders

Low transpiration in catchments

No ‘free lunch’: Energy balance will change
Figure 9: Comparison of forest structure in (A) old growth and (B) regrowth mountain ash stands.
Hydrological cycle.

Units are thousand cubic km for storage and thousand cubic km/year for exchanges.

Atmospheric moisture residence times and cycling: Implications for rainfall rates and climate change
Kevin E. Trenberth, National Center for Atmospheric Research, Climatic Change, 1997
The analysis shows an annual mean recycling ratio of the percentage precipitation coming from a scale of 1000 km (adapted from Trenberth 1999b).
Total column of water vapour in atmosphere, averaged throughout April 2006

About 20 mm

±4 mm/day from forests is a big contribution …
Clouds form preferentially over native vegetation

T.J. Lyons
School of Environmental Science, Murdoch University,
Murdoch, WA 6150, Australia

Abstract: The replacement of native vegetation for agriculture leads to significant changes in land surface characteristics, such as albedo, surface roughness and canopy resistance. These land surface changes induce changes in the atmospheric boundary layer. It is shown that in Western Australia, this change in surface
Fig. 8. Changes in average maximum and minimum daily flows for the Citarum river basin, West Java, Indonesia, between 1923–1939 and 1962/1963–1984/1986 (after Van der Weerd, 1994).
Review

Managing water use from forest plantations

Jerome K. Vanclay *

School of Environmental Science and Management, Southern Cross University, PO Box 157, Lismore 2480, NSW, Australia

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ABSTRACT

Tree plantations have developed a reputation for excessive water use, with age commonly used as an explanatory variable to predict water loss – but many factors have the potential to affect plantation water use, and few of these alternatives have been considered. Changes in forest cover may be correlated with other environmental changes that may affect precipitation, transpiration, and runoff, indicating that more thorough investigation is required in both field and simulation studies. Several factors influencing water use by plantations are amenable to management control, so there is scope to design and manage forest plantations deliberately for water use efficiency. Research is needed to elucidate the relative contributions of forests and grasslands to atmospheric moisture; the influence of vegetation on the distribution of rainfall; the effect of air turbulence from plantation edges, firebreaks and streamlines; the potential to modify atmospheric coupling of forest plantations through plantation design, including the use of mixed species plantations, and by softening hard edges by thinning and pruning plantation edges.

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Forest edges and the soil-vegetation-atmosphere interaction at the landscape scale: the state of affairs

Arthur W. L. Veen
Department of Physical Geography, University of Groningen, PO Box 14, 9750 AA, Haren, The Netherlands

Wim Klaassen
Department of Physical Geography, University of Groningen, PO Box 14, 9750 AA, Haren, The Netherlands

Bart Kruijt
Department of Physical Geography, University of Groningen, PO Box 14, 9750 AA, Haren, The Netherlands

Ronald W.A. Hutjes
Department of Physical Geography, University of Groningen, PO Box 14, 9750 AA, Haren, The Netherlands

Although the soil-vegetation-atmosphere exchange of momentum and heat is fairly well understood for many types of homogeneous surfaces, the disturbances created by transitions of one surface type to another remain to be analysed more fully. This is especially true for the impact which a large transition such as the forest edge has on the average fluxes in a small-scale heterogeneous landscape with forest. Recently acquired experimental evidence appears to some extent contradictory and at variance with conventional concepts.

Key Words: forest edges • momentum fluxes • energy balance • land surface heterogeneity • advection • area averaging of fluxes.

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