

Climate effects of afforestation: Carbon sequestration and changes in land surface albedo

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The amount of greenhouse gas in the atmosphere is a major driver of increased global temperatures. A positive greenhouse forcing (that is temperature increase) results from atmospheric CO₂ absorbing and reemitting more of the infrared radiation emitted by the surface. Forestation can help to mitigate this by slowing the rise of in atmospheric CO₂ concentrations through its uptake and storage as organic carbon. However the Earth's net radiative budget, and thus temperature, is also significantly determined by other biophysical factors such as surface albedo and evapotranspiration from plants.

The amount of incoming radiation from the sun that is reflected back out of the atmosphere, determined by the albedo of a surface, significantly affects the Earth's temperature. Highly reflective land cover surfaces like snow have very high albedo, reflecting much incoming radiation. In contrast forests absorb up to 95% incoming short wave radiation, and substantial amounts of infra-red radiation. Some of this energy is used by the trees for photosynthesis but a great deal is released as 'sensible heat' - raising the atmospheric temperature. Bare ground and crops have higher albedo, than forests.

The net temperature balance is further complicated by evapotranspiration effects. The incoming radiation is also partitioned into 'latent' heat which drives evaporation and transpiration in plants. Evaporation tends to produce cooling.

For forests to have a net benefit in mitigating climate change the temperature declines due to their removal of CO₂ from the atmosphere, and their increased evapotranspiration, must be greater than their heating effects through reducing the Earth's albedo.

A recent study predicting changes in the carbon cycle and climate undertook simulations involving continued anthropogenic carbon dioxide emissions and removal of forests in three different latitude bands (tropical, mid-latitude, and boreal)¹. Simulations showed that tropical forests cool the planet because of high carbon storage, high tropical cloudiness and increased cloudiness associated increased evapotranspiration, tropical forests. For mid-latitude forests, albedo-induced warming largely offsets carbon-induced cooling, with warming near the forest and cooling far from the forests. High latitude forests have a strong warming influence, largely due to the presence of dark forest canopies in regions that would otherwise be snow covered. The study concluded that on a global mean basis, albedo-based warming influences of forests approximately cancel their carbon-based cooling influences. The findings of this modelling exercise in tropical and high latitude regions are supported by earlier research². What is less certain is the total net effect of forest establishment on the net radiative balance in temperate regions, such as those that most of the forests in Australia occur on.

¹ Bala et al. (2006), Will afforestation strategies help mitigate global warming?, Eos Trans. AGU, 87(52), Fall Meet. Suppl.,

² Costa M.H. and Foley J (2000). Combined effects of deforestation and doubled atmosphere CO₂ concentrations on the climate of Amazonia. Journal of Climatology. 13 18 – 24.

It is widely acknowledged that such models are highly dependent upon accurate biophysical measurements of forest and land cover qualities such as albedo, leaf area index, water balances affecting evapotranspiration rates³. Global models apply generalised mean parameters for land cover types and use coarse resolution land-cover spatial data. The Australian vegetation is very different compared to the vegetation of North America or Europe where most climate models have been developed and parameters tailored towards⁴. Given this Northern Hemisphere-developed global models, such as the study discussed above, can not be considered reliable in the prediction of Australian forest-carbon-climate relationships.

Albedo has been measured for very few Australian vegetation types. However it is known that many species of eucalypts have glaucous (waxy) leaves to reflect incoming radiation and reduce water loss through evapotranspiration. For example *Eucalyptus unigera* reduces the absorption of incident energy by up to 30% by increasing the density of wax on its leaf surface. Given this, and that only a small area of Australian forests receive snow fall, it is reasonable to conclude that it is highly unlikely that the differences in albedo between Australian forest canopies and cleared/agricultural landscapes are so great as to offset the climate benefits of CO₂ sequestration. This is supported by a PhD climate modelling study that found that summer temperatures were warmer when there was less vegetation. This was likely to be due to a decline in transpiration with less vegetation therefore a reduction in the cooling effect of that process⁵.

The issue is the topic of further research and discussion. A workshop is being convened by the Global

Carbon Project (http://www.globalcarbonproject.org/about_gcp.htm) at the Earth Observation Centre, CSIRO

Marine and Atmospheric Research on the topic. Carbon Planet is closely following findings of this ongoing research.

³ Myhre G and Myhre A (2003) Uncertainties in radiative forcing due to surface albedo changes caused by land-use changes. *Journal of Climate* 16 1511 - 1524

⁴ Peel D. R, Pitman, A. J. Hughes, L.A. Narisma, G.T. Pielke R.A. 2005 The impact of realistic biophysical parameters for eucalypts on the simulation of the January climate of Australia. *Environmental Modelling and Software* 20 595-612.

⁵ Berry, S. (2002) A study of the relationships between climate, carbon dioxide and the vegetation over the Australian continent at the present and the last glacial maximum (PhD Thesis Australian National University)

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