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Tree plantations still valid as carbon sinks

Commentary by Phil Polglase, Keryn Paul and Trevor Booth

Summary

In a recent article in the international science journal, Nature, Keppler and colleagues from the Max Planck Institute in Germany reported for the first time that plants can directly emit methane. This finding is highly significant as methane is an important greenhouse gas and was thought to come only from anaerobic (oxygen limited) conditions such as from bogs, wetlands, landfills, rice paddies, and from livestock, termites, and from vegetation fires.

http://www.nature.com/nature/journal/v439/n7073/abs/nature04420.html

Subsequent speculative media reports have been fuelled by an opinion piece by Lowe in the same issue of Nature that states 'we now have the spectre that new forests might increase greenhouse warming through methane emissions rather than decrease it by sequestering CO_2'.

http://news.bbc.co.uk/2/hi/science/nature/4604332.stm
http://www.abc.net.au/news/newsitems/200601/s1545977.htm
http://www.terradaily.com/news/Could_Forests_Worsen_Global_Warming.html
http://www6.lexisnexis.com/publisher/EndUser?Action=UserDisplayFullDocument&orgId=1925&topicId=100002042&docId=l:344764705&start=12

We tested this assumption using the methodology provided in Keppler's article to compare estimates of methane emissions for seven different regional case studies of afforestation in Australia with the amounts of carbon stored to determine the overall effect. We calculated that the average amount of methane emitted would off-set less than 5% of the amount of carbon dioxide stored in terms of its effect in contributing to global warming.

However, under afforestation the key question is actually 'what is the amount of change when planting new forests on agricultural land'? Several issues need to be addressed, for example soils take up and oxidise methane. Also, Keppler suggests that all plants emit methane, so it may even be possible for some agricultural land practices to emit more methane than forests for any given land area.

Based on all the available evidence so far, the use of new forests as carbon sinks remains valid. Methane emissions by trees might have a small negating impact, but the effect could be much less or even positive, depending on the net emissions of methane from trees and soil relative to the preceding agricultural land.

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The article by Keppler has created enormous interest internationally and is sure to lead to much more work in this area. It has important implications for understanding the role of terrestrial vegetation in contributing to the global methane budget.

Overview of the paper

- Up until now it had been considered that major sources of methane emissions came only from anaerobic (no oxygen) conditions during the decomposition of organic matter in bogs, wetlands, landfills, rice paddies, and from livestock, termites, and from vegetation fires.
- The authors had been running a research program for some years measuring the release of volatile organic compounds from vegetation. During some experiments they apparently detected some traces of methane in an incubator that had held some leaves but concentrations were low compared with concentrations in the ambient air and thus hard to detect. They then conducted some controlled experiments including incubating leaves and whole plants in air purged free of methane and use of isotopic signatures.
- Methane was found to be emitted from a variety but limited cross section of plants. Rates were higher in sunlit than dark conditions.
- The authors used an average rate of emission from their whole plant and leaf experiments to estimate global emissions of methane from plants – this turns out to be up to one-third of the entire annual emission of methane from all global sources. The results also help explain other data, such as the observations from remote sensing of large plumes of methane above tropical forests. These were thought to have come from wetlands below the forests, but now may have come from the forest themselves.
- The authors suggest that the role of terrestrial vegetation may have to be reconsidered in calculating the global methane budget and implications for climate change.
- They do not make any comment on the usefulness of plantations as carbon sinks – others have made that extrapolation.

Are new tree plantings net sinks of greenhouse gases?

To answer the question of whether methane emissions from tree plantations outweigh the benefits from carbon uptake, the most obvious calculation is to compare methane emissions with carbon dioxide storage. We used Keppler's methodology, which assumes an average emission rate of methane under sunlit and non-sunlit conditions and which is multiplied by annual net primary production (NPP), taking into account season and day length.

1. Calculate the daily rate of methane emissions.

$ER_{day} = (ER_{sun} \times h_{sun}) + (ER_{nosun} \times h_{nosun})$ Equation (1)

where,

ER_{day} is the daily rate of methane emissions (ng/ g dry wt/ hr)
ER_{sun} is the emission rate in sunlight (authors' calculate to be =374 ng/ g dry wt/ hr)
h_{sun} is the number of sunlit hours in the day
ER_{nosun} is the emission rate in dark (authors' calculate to be =119 ng/ g dry wt/ hr)
h_{nosun} is the number of dark hours in the day.

2. Calculate annual production of methane.

$P(CH_4)annual = NPP \times SL \times ER_{day} /\ 1{,}000{,}000{,}000$ Equation (2) where,

$P(CH_4)$annual is the annual production of methane (g/ ha/ yr)
NPP is net primary productivity (g dry wt/ yr)
SL is the season length (days)

Methane has 23 times the global warming potential of carbon dioxide so when comparing greenhouse gases it is usual to refer to CO_2-equivalents (CO2-e). Also, carbon storage is usually expressed in tonnes, so to convert the units of equation (2):

$P(CH_4)CO_2$-e = $P(CH_4)$annual x 23/ 1000000, where Equation (3).

$P(CH_4)CO_2$-e is the annual emission of methane in CO_2 equivalents (t CO_2-e/ ha/year).

Note the authors did this on a global biome basis. We have done the calculations on a per hectare basis for seven different regional case studies of afforestation in Australia. Data collated from numerous field studies of above-ground growth, litterfall, accumulation of litter and, in some cases root biomass, were used to calibrate a carbon accounting model as described by Paul and co-workers in the following publications. Using these model outputs, calculations are provided using average mass of foliage (Table 2) as well NPP (Table 1) as used by Keppler et al. This was because NPP represents productivity due to both growth and turnover, and yet methane is presumably emitted mostly from intact foliage.

http://www.greenhouse.gov.au/ncas/reports/pubs/tr29final.pdf

http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6T6X-46YXKSG-1-R&_cdi=5042&_user=2322062&_orig=browse&_coverDate=04%2F07%2F2003&_sk=998229998&view=c&wchp=dGLbVtz-zSkzS&md5=7a6611d23135cac073450a7c46bafd79&ie=/sdarticle.pdf

Case studies were:

(i) LRWA: 10 year *Eucalyptus globulus* plantation growing in the low rainfall zone (590-950 mm) of south-west Western Australia (Collie, Vasse, Donnybrook, Darkan);
(ii) HRWA: 10 year *E. globulus* plantation growing in the high rainfall zone (1,023-1,450 mm) of south-west Western Australia (Manjimup, Northcliffe),
(iii) SA: 35 year *Pinus radiata* plantation (with three thinnings) growing in the Green triangle of South Australia and Victoria (Mount Gambier region),
(iv) QLD: 13 year *E. grandis* plantation growing in south-eastern Queensland and north-eastern New South Wales (Atherton, Gympie, Coffs Harbor),
(v) NSW: 35 year *P. radiata* plantation (with three thinnings) growing in the Australian Capital Territory and south-east New South Wales (Pierces Creek, Tumut),
(vi) VIC: 18 year *E. globulus* plantation growing in south-east Gippsland, Victoria (e.g. Moondarra), and
(vii) TAS: 15 year *E. nitens* plantation growing in Tasmania (e.g. Florentine Valley).

For all case studies, the SL was assumed to be 365 days and h_{sun} and h_{nosun} were both assumed to be 12 hours. Therefore, ER_{day} was calculated as 5917 ng g^{-1} d^{-1} on average, but with a minimum and maximum of 2745 and 9661 ng g^{-1} d^{-1}, respectively. Estimates of average annual NPP (Table 1), foliage mass (Table 2) and carbon sequestered in biomass during the first rotation were obtained from work by Paul and co-workers as described above. It should be noted that these carbon sequestration estimates are for average carbon sequestered in biomass during the first rotation. It does not include carbon sequestered in litter, soil or biomass removed from the site following stand thinning operations.

Our calculations show that the negative impact of methane emissions is small - less than 5% of the benefit derived from carbon sequestration (Tables 1 and 2, and Figure 1). Thus there is no basis for the statement that new forests might contribute to global warming rather than decreasing it.

Table 1. Calculated amounts of carbon sequestered and methane emitted when a new plantation is established in temperate Australia, calculated as a proportion of NPP following the methodology of Keppler.

Plantation	C sequestered ($t\ ha^{-1}\ yr^{-1}$)		Production/foliage mass and methane emitted ($t\ ha^{-1}\ yr^{-1}$)		Reduction in potential sequestration due to CH_4 emissions (%)
	C	CO_2-e	DM	CO_2-e	
HRWA	17.1	63.9	45.2	-2.2	3.5
VIC	15.1	55.4	44.3	-2.2	4.0
QLD	11.9	43.5	35.9	-1.8	4.1
TAS	10.4	38.0	29.4	-1.5	3.8
LRWA	8.8	32.3	25.7	-1.3	3.9
SA	6.9	25.1	24.6	-1.2	4.9
NSW	5.5	20.2	19.7	-1.0	4.8

Table 2. Calculated amounts of carbon sequestered and methane emitted when a new plantation is established in temperate Australia, assuming methane is emitted from intact foliage.

Plantation	C sequestered ($t\ ha^{-1}\ yr^{-1}$)		Production/foliage mass and methane emitted ($t\ ha^{-1}\ yr^{-1}$)		Reduction in potential sequestration due to CH_4 emissions (%)
	C	CO_2-e	DM	CO_2-e	
HRWA	17.1	63.9	5.7	-0.3	0.44
VIC	15.1	55.4	4.0	-0.2	0.36
QLD	11.9	43.5	6.9	-0.3	0.79
TAS	10.4	38.0	5.5	-0.3	0.72
LRWA	8.8	32.3	3.3	-0.2	0.50
SA	6.9	25.1	3.6	-0.2	0.71
NSW	5.5	20.2	4.4	-0.2	1.08

Other comments

- The average values for emissions of methane calculated by Keppler were derived from a limited number of intact plants, only one of which was a tree species (Norway spruce), the rest being grasses and crop species. There is enormous variation between species in emission rates of methane
- The studies were mostly based in the laboratory and more species need to be tested and including in the field and under a range of environmental conditions.
- The authors also included ‘detached leaves’ (which they termed leaf litter) in their calculations as a source of emissions, but these were relatively low compared to intact plants. We have not included these in our calculations because of the low emission rates and because real leaf litter might be expected to be inoculated with methane-oxidising bacteria that remove methane from the atmosphere. Thus the litter would be a sink and not a source.

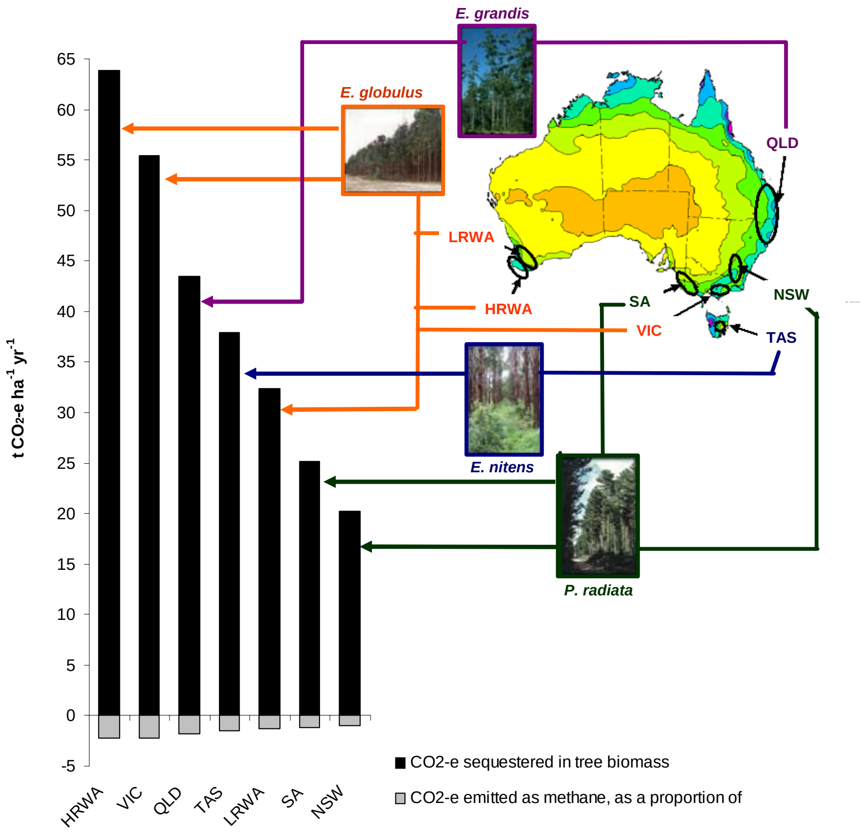

Figure 1. Calculated amounts of CO_2-e sequestered in tree biomass and emitted as methane (calculated by multiplying emission rates per year by average annual NPP) when a new plantation is established in temperate Australia.

- Our calculations above do not factor in the contribution by soil, which takes up methane. Again it will be the change in emissions going from pasture to plantation that will be important. Methane may be emitted from forest soils following clear felling with rates of emission likely to vary with forest type as well as soil properties such as clay content.
- Some of the focus of subsequent comments on the paper has been on tropical forests. It is important to distinguish between these and new plantations in terms of their contribution to greenhouse gas emissions. Tropical forests are mostly in a mature state, they have more or less stopped storing any more carbon, they do however contain a lot of carbon by virtue of storage in previous decades. Recent research also published in Nature has shown that tropical forests can be a source or a sink for carbon depending on the climate in any given year. Hot, dry years lead to tropical forests being a source of carbon and in cool, wet years they are a sink. The same may well be true for methane emissions. Thus tropical forests seem to be finely balanced, acting as a bit of a see saw, tipping from source to sink depending upon the year. In contrast, new forests are aggrading – that is they start from seedling and progressively store more carbon. Providing they survive, over the long term they will always be a carbon sink although rates might vary from year to year. Thus we should not generalise from research on tropical forests to new forests in terms of their contribution to greenhouse gas emissions.

Useful links

http://www.newstech.co.nz/story.aspx?storyid=297924

http://www.stuff.co.nz/stuff/0,2106,3538259a7693,00.html