Can trees help curb the greenhouse effect?

The chief cause of the greenhouse effect is the increasing quantity of the gas carbon dioxide in our atmosphere. But CO_2 is also essential for plant growth, being one of the raw materials of photosynthesis.

Although it is present in such a small concentration (just 0·035%), plant leaves take it from the air and use it to build sugar and starch and, ultimately, all plant matter.

So, would a possible solution to the greenhouse effect be simply to plant trees (the biggest plants of all), hoping that they would suck up sufficient quantities of CO_2 to compensate for the release of this gas through our burning of coal, oil, and gas?

Dr Roger Gifford of the CSIRO Division of Plant Industry has looked into this question, in collaboration with Dr Michele Barson of the Bureau of Rural Resources. Assessment of how planting millions of trees affects the atmosphere does not lend itself easily to direct experimentation. But, by collating facts and figures from a range of relevant research areas and running simple computer models, the scientists have come up with some interesting conclusions.

They started by looking at the broad picture — how carbon is distributed around the Earth. All the world's vegetation contains 700–800 billion tonnes of carbon, about the same as the atmosphere does in the form of CO_2. Every year, plants take up nearly 10% of the atmosphere's total CO_2 content, converting it into more plant matter. But at the same time other plants decompose, releasing an almost identical quantity of CO_2 — either when animals eat them and then exhale CO_2, or through microbial breakdown in the soil or burning in fires. This balanced cycling of carbon between the biosphere (which includes plant life in the oceans) and atmosphere was disturbed when humans started to burn large quantities of fossil fuels.

Although derived from plants aeons ago, oil and coal were in effect removed from the system, having been 'sealed off' underground, until we extracted them and put their carbon into the atmosphere in the form of CO_2.

About 80–85% of the additional CO_2 now going into the air comes from the fossil fuels we burn. The rest gets there because we chop down trees, but the simple idea that felling trees means taking away natural CO_2-removers is not the whole story. The notion that the mighty tropical rainforests are the 'lungs of the Earth' sounds good but, in fact, mature forest does not lower CO_2 levels in the air. (Of course, plenty of other benefits accrue through maintaining forest ecosystems.)

Once a forest matures, no further net growth occurs. Any growth is balanced by the death and decay of old trees, branches, or leaves. Hence, such forests do not take up any more CO_2 than they release through plant respiration and decomposition, and are therefore not net CO_2 'sinks'.

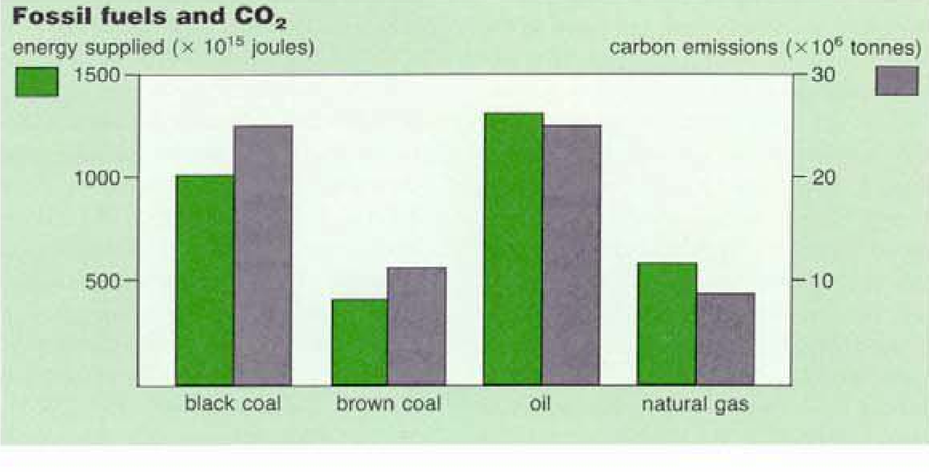
So why does felling them contribute to the greenhouse effect? First, the wood they contained is eventually oxidised to carbon dioxide, through either burning or decomposition of the wood or its products — paper, for example. (If disposed of in land-fills, these products may also produce some methane — an even more effective greenhouse gas.) What remains in the cleared area rots on the ground, or is deliberately burnt. Either way, CO_2 from the organic matter returns to the atmosphere. Second, the removal of the vegetation cover, and the concomitant ripping of the ground, exposes the soil's own organic matter to increased oxidation, which means that CO_2 is released and the concentration of organic matter decreases.

An established mature forest, therefore, acts as a kind of carbon store — chop it down and you release that carbon to the atmosphere — but it is not a net CO_2-absorber. If you clear it and plant crops in its stead, they too will take up CO_2 during their brief growing season. But they neither grow as large as trees, nor for as long. And, of course, within a year or so either we or our animals eat them, and oxidise them back to CO_2. Alternatively, their remains will decompose, being oxidised by small invertebrates and microbes. So, cropping systems return the CO_2 to the atmosphere very soon after its removal, and do not therefore constitute a long-term CO_2-removal mechanism.

Plant trees!

Young growing trees, like growing crops, consume CO_2; but unlike crops, trees keep growing — and taking up CO_2 — for decades. Eventually, however, they mature and reach a steady state, or die and release CO_2. So new forests only give us a short-term 'buffer' against increasing atmospheric CO_2 — reforestation cannot provide a permanent solution. There is a limit to how much carbon the biosphere can hold; the total quantity of the element locked up as fossil fuels still in the ground (and, presumably, likely to be used) is ten times more than was present in the biosphere before humans started clearing forests.

To continue soaking up CO_2, we would need to continually plant new areas with forest, and we'd soon run out of suitable land. The alternative, as Dr Gifford has pointed out, would be to remove a forest that has reached maturity, and somehow keep its stored carbon (the wood) and prevent any of it from decomposing and so



Energy output and carbon emissions (as CO_2) from fossil fuels in Australia in 1987/88. Coal combustion produces substantially more CO_2 per unit energy output than natural gas.

releasing CO_2 into the atmosphere. Then, we'd need to plant a new forest of trees on the old site. As soon as those trees reached a steady state, with no net carbon uptake, they too would be felled and somehow stored.

Of course, this is unrealistic. Where could vast quantities of timber be stored in a manner that would prevent any decomposition? They would occupy several times the volume of the coal that produced the CO_2 in the first place. And if the timber is available, it seems silly not to use it in a worth-while way.

In Australia, there has been much talk of tree-planting recently. Apart from the other benefits of such a program, could it help offset our CO_2 emissions — at least for a while? Dr Gifford and Dr Barson have examined the situation carefully. The burning of fossil fuels within Australia gives off some 70 million tonnes of carbon per year; our exported fuels release a further 80 million. Although we contribute only 1·2% of the world's total, per person we release 4 tonnes of carbon per year, which makes us, on our domestic consumption alone, the world's fifth-largest emitter of CO_2 per head of population.

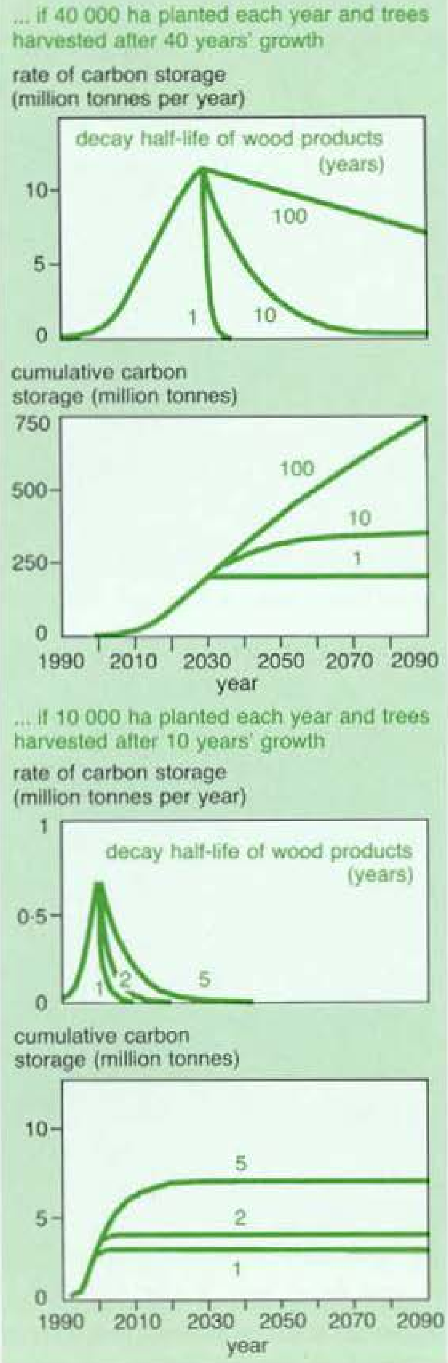
Although we can't do much to soak up the whole world's CO_2 (5600 million tonnes of extra carbon goes into the atmosphere each year from human activity), can we at least do something about our own contribution?

Modelling...

Knowing that a cubic metre of timber contains between 220 kg of carbon (for softwoods) and 320 kg (for hardwoods), we can calculate how much carbon a given area of forest with a known tree density can sequester during its growth. The speed of carbon uptake and the total stored both depend on the productivity of the forest and this can vary considerably, being influenced by the species of tree, soil fertility, and climate. With a range of figures already known for productivities of native and plantation forests in different parts of Australia, Dr Gifford and Dr Barson were able to devise a mathematical means of describing the uptake of carbon into organic matter as time progresses.

Their model also considered the speed of decay, which depends on the ultimate use of the timber. Obviously the carbon in newspaper or disposable tissues will, on average, find its way back into the air far more quickly than that in the treated timbers used to build a house. The paper we throw out, unless it is recycled, can decompose quickly in a garbage tip.

Impact of plantations...



Both scenarios assume plantation areas are replanted after harvesting. While the first alternative would capture much more carbon than the second, neither would have a large impact on CO_2 levels in the atmosphere.

The scientists took into account estimated half-lives (the time that half a sample takes to decay) for different wood products. Paper has a half-life of about 1–5 years; for wood products like pallets and posts the figure rises to 5–10 years; and for treated timber and wood used in structures and furniture with their slower rate of decay it may be 10–100 years or more.

Using their mathematical model Dr Gifford and Dr Barson examined the effectiveness of three possible scenarios of deliberate tree-planting — which they presumed would start in 1990 — over and above any existing forestry activities.

The first involved planting 40 000 hectares a year for 40 years, harvesting each 40 000-ha block when the trees reached 40 years of age, and replanting on the same area. (How many times the land would yield a worth-while tree crop is not certain.) In total, 1·6 million ha would be covered, this figure being reached by 2030.

Assuming a wood growth rate of 10 tonnes of dry matter per ha per year (a typical value on good sites), this gave annual figures of 20 cubic metres of wood per ha for pine trees and 15 cu. m for eucalypts. Final calculations, after accounting for carbon in the leaves and roots, gave a rate of carbon storage of 7·5 tonnes per ha regardless of tree genus.

The total quantity of carbon removed from the cycle, however, depends on the rate of decay as well as on the rate of storage. At first the planting of new seedlings on an area just felled more than compensates for the oxidation back to CO_2 of the newly harvested wood products. But after many years, so much previously harvested material is decomposing that even the new growth does not result in further net carbon storage — rather, there is a net carbon emission.

Taking a half-life of 10 years for decay, the annual rate of net carbon storage peaks in 2030 at 11 million tonnes. It falls thereafter, first sharply and then more gradually until by about 2090 no further net uptake occurs (see the adjoining graph). The total amount of carbon removed by this 100-year experiment would be 350 million tonnes, which only matches our total carbon emission from fossil fuel use for the 5 years 1985–90.

If the wood is used for more ephemeral products (for example, newsprint) with a half-life of just 1 year, then the planting scheme would remove a net total of only about 200 million tonnes of carbon. At the other extreme, a half-life of 100 years means the continually replanted forest area would continue to sequester carbon at the rate of about 8–10 million tonnes annually for many decades after 2030, and the total net removal to the year 2090 would be 750 million. But the scientists consider that such a half-life for all the wood is unrealistic.

...with differing results

The second scenario gives a more optimistic result than the first, and assumes that the planting of new lots of 40 000 ha continues for 100 years, by which time 4 million ha

These jarrah logs are likely to be used for functions with relatively long half-lives.

Actively growing forest, such as the regenerating area shown here, is a net CO_2 sink.

would be involved in the scheme. With a 10-year half-life for the wood, such a scheme soaks up carbon at a high rate for many decades. The total net removal by 2090 would be about 650 million tonnes (equivalent to 9 years' CO_2 emissions at our present rate), but the carbon would continue to be absorbed beyond this date. Of course, the problem here would be finding 4 million ha of suitable land for high-productivity forestry in a country with a rapidly increasing population and demands on its good land.

The third scenario envisages what foresters call a short rotation time — that is, harvesting after only 10 years. The small logs would be used for paper-pulp production. In this case, 10 000 ha of a fast-growing species such as *Eucalyptus globulus* would be planted each year for 10 years. (Again, the scientists assumed that we start in 1990.) Each 10 000-ha lot would be felled after 10 years and replanted.

This turns out to be much less useful. Although on average such a scheme sequesters 7·1 tonnes of carbon per ha annually, because of the short half-life of the wood products the rate of re-emission of CO_2 would be greater than the rate at which the new growth in the next planting incorporates it. After 10 years, therefore, the effective rate of carbon uptake falls to nothing. The model showed that the total carbon accumulated over the years in this system would only be 3·2, 4·2, or 7·2 million tonnes, depending on decay half-lives of the wood of 1, 2, and 5 years respectively.

All in all, the scientists conclude, the most reasonable of the three scenarios is the first — planting 40 000 ha per year for 40 years, producing wood that can be used for products with longer half-lives than paper pulp.

However, this would require 1·6 million ha, which raises the next question — the availability of suitable land. Various estimates of cleared agricultural land technically suitable for hardwood plantations range from 830 000 ha to 9·7 million ha. The researchers produced their own estimate, calculating the area of pasture south of latitude 20°S receiving an annual rainfall of more than 800 mm that had originally supported forest or woodland. The total came to 3·6 million ha. Being able to use 1·6 million ha, or 45%, of this would seem most unlikely. Of course, some agricultural land receiving annual rainfalls between 600 and 800 mm could also be used for growing certain species, although at lower productivities.

Economic and social factors must also be considered in these greenhouse-reducing schemes. The wood produced would far exceed projected demand. Some of it could then, perhaps, be used as fuelwood, reducing the consumption of fossil fuels, and essentially establishing a renewable fuel system. But, of course, wood-burning is inefficient and brings its own local air pollution problems.

Persuading private land-owners to plant large quantities of trees on productive land for which they would receive no return for 40 years may prove difficult too. However, this tree-planting does have some advantages, such as soil conservation, stock shelter, and the provision of an alternative, albeit long-term, source of income.

Thus, extensive tree-planting, although it may give a modest mopping-up of some of our carbon emissions (in the region of 7–12 million tonnes of the 70 million we currently put into the atmosphere annually), does not offer a means of substantially reducing Australia's contribution to the greenhouse effect.

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More about the topic

Carbon dioxide sinks: the potential role of tree-planting in Australia. M. M. Barson and R. M. Gifford. *Proceedings, Greenhouse and Energy Conference, Sydney, Dec 4–8, 1989.*

Trees in the global greenhouse. R.M. Gifford. *Trees and Natural Resources*, 1989, **31**, 9–11.

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