Carbon lockdown

Could burying trees and plants help save us from the worst of global warming, asks Richard Lovett

A FEW years ago, Ning Zeng began to wonder about the hidden potential of landfill sites. He had been discussing a mystery with his students: for some reason, North America's carbon dioxide emissions are not quite as high as they "should" be. Perhaps, one student suggested, America's huge landfill sites were acting as carbon sinks. After all, a lot of what is thrown away does not decompose: even 50-year-old newspapers can be perfectly legible.

Zeng, an atmospheric scientist at the University of Maryland in College Park, later calculated that the amount of carbon sequestered in this way is actually tiny, but it gave him an idea. What if we could sequester the carbon locked up in trees in such a way that it doesn't get released back into the atmosphere? Could we store enough of it to offset a meaningful amount of emissions?

It sounds like a long shot, but Zeng is convinced it could work. In a recent paper in the journal *Carbon Balance and Management* (vol 3, p 1), he calculated that if we buried half of the wood that grows each year, in such a way that it didn't decay, enough CO_2 would be removed from the atmosphere to offset all of our fossil-fuel emissions. It wouldn't be easy, but Zeng believes it could be done.

Zeng's is not the only proposal of its kind. Other researchers are totting up the amount of carbon that could be sequestered in various kinds of biomass and are finding that it is a surprisingly large amount. Not enough to halt climate change on its own, perhaps, but enough to make a sizeable dent in atmospheric carbon and to buy us the time we need to sort out the mess we've made.

The idea of burying carbon in biomass makes sense: plants remove CO_2 from the air to produce carbohydrates by photosynthesis. The carbon is returned to the atmosphere when the plant dies and decays. Planting trees to sequester carbon is approved under the Kyoto protocol, but critics of this approach point out that the carbon locked up in forests is only kept out of the atmosphere for as long as the tree is alive, and that older trees start emitting more carbon than they take up as they reach old age. Recent studies have also suggested that warmer temperatures and higher atmospheric CO_2 may eventually kill trees, casting doubt on the use of forests as long term carbon sinks (*New Scientist*, 27 October, 2007, p 42).

There is a lot of interest in the possibility of sequestering CO_2 in disused gas and oil wells or porous rocks, or even in ocean beds. Trouble is, finding viable sites for this kind of project is tricky and the technology needed is far from ready. Burying biomass, say enthusiasts, has none of these problems.

Wood burial is perhaps the simplest of the ideas. Zeng's proposal is to thin forests regularly, and to bury excess wood, forestry waste and even trees that have been grown specifically to be buried in trenches between the remaining trees. To prevent the wood decomposing and the carbon being released, it would need to be buried deep enough to avoid being broken down by soil fauna and fungi, or stored above ground in watertight shelters. Zeng gives an example of a plot of 1 square kilometre (100 hectares), with the excess wood from 1 hectare of woodland buried deeper than 5 metres and down to 20 metres. He calculates that this could sequester 1 tonne of carbon per hectare – using that land to grow trees would sequester 1 to 5 tonnes, depending on the age of the forest and the type of tree. Burying wood sounds like a lot of trouble for a small gain, but Zeng insists that, unlike simple growing, this is a long-lasting and perhaps permanent carbon sink. He estimates that offsetting all of the world's current emissions would be achievable with a workforce of one million people – substantially fewer than those already employed in the forestry industry in the US alone. Even so, to offset all our emissions, most of the world's forests would have to run a wood burial scheme.

Zeng's idea may be the new kid on the block, but another approach to carbon burial has a much longer history. More than 500 years ago Amazonian people were creating almost pure carbon by smouldering their domestic waste and letting it work its way int the soil. This earth, known as terra preta

SHONAGH RAE

'black earth") remains to this day, in some reas half a metre deep.

Such charred organic matter, or "biochar", an be made when organic matter is heated in he absence of air to around 350 °C – the kinds of temperatures reached in the Amazonians' mouldering waste piles. "The lack of air neans the organic matter does not combust, out most constituents other than carbon are driven off as gases or liquids," says Malcolm Fowles at the Open University in Milton Keynes, UK, who studies the process. The leftovers are charcoal-like chunks of nearly pure carbon. Ancient farmers had no idea that they were sequestering carbon, of course, but they did know that adding biochar to the soil hugely increased its quality.

The Amazonian method can reduce pretty much any organic material to char, given enough time, but it works best with dry materials like dead wood. A modern alternative is called hydrothermal carbonisation – which steams organic material under pressure until it is reduced to char. This process also works with wet material like green wood and household waste. Until recently, hydrothermal carbonisation was a slow process, taking days to complete. But Markus Antonietti of the Max Planck Institute of Colloids and Interfaces in Potsdam, Germany, has found a way to speed it up to between 5 and 12 hours. His technique uses citric acid as a catalyst at a relatively low temperature of 180 °C. It's a very simple process, "really nothing more than a pressure cooker", says Fowles. ▶

Once the reaction has got going both these processes readily produce heat, which could be used to generate electricity or heat water. But there is a trade-off: the more heat the process produces, the more CO_2 it gives off and the less carbon you have left at the end. Perhaps unsurprisingly, low-temperature hydrothermal carbonisation produces less energy than high-temperature pyrolysis, but it still gives off a worthwhile amount. "It readily gives off heat," Fowles says. "[Antonietti's group] has had some rather entertaining laboratory explosions." Once the process is explosion-proofed, Fowles says, it might be possible to sell household water-heating units that need only trash, food scraps and garden debris for fuel. Such units would make a small quantity of biochar on the side. "You'd be looking at it as a way in which people who are suffering angst over global warming could make a contribution," he says.

Jim Amonette, a soil geochemist at the US Department of Energy's Pacific Northwest National Laboratory in Richland, Washington, sees biochar working as an industrial-scale technology too, with economic benefits as well as environmental ones. "My vision is that every municipal landfill is going to have a pyrolysis unit," he says. Logging companies may start using it as a way to obtain carbon credits for disposing of the debris left over from logging. "There's a company in Washington state that is starting to head that way," he says.

Re-filling the sinks

Another idea to sequester carbon as biomass is to let nature bury its own by restoring natural carbon sinks. One such project is already under way on Twitchell Island, on the delta of the San Joaquin and Sacramento rivers, east of San Francisco. Researchers are replanting marsh grasses and bulrushes (cattails) in the hope that when they die they will accumulate beneath the surface and gradually transform into peat. It's the same process that created the marshes after the last ice age, but this huge carbon sink, covering nearly 1300 square kilometres, was drained for farming more than a century ago, leaving the peat to dry out and rot away at a rate of about 2.5 centimetres per year. Since draining, the land has dropped by up to 6 metres.

Eight years ago, Roger Fujii of the US Geological Survey undertook a study to see how quickly it might be possible to rebuild the peat. The answer appears to be even faster than it was lost: up to 10 centimetres per year once a marsh has had a few years to mature. That offers the prospect of a substantial amount of carbon sequestration. Fujii and Bergamaschi calculate that reflooding the whole delta and converting it back to tules – a form of bulrush – would be equivalent to swapping all of California's SUVs for high-efficiency hybrids.

Part of the benefit of reverting to peat marshes comes from shutting down ongoing peat oxidation which, according to Fujii's colleague Brian Bergamaschi, causes emissions of about 17 tonnes of carbon per hectare per year. On a delta of over 130,000 hectares, that really adds up. Since building up new peat takes about 60 tonnes of carbon per hectare per year out of the atmosphere, the net benefit is something like 77 tonnes per hectare, Bergamaschi says. That is substantially more carbon sequestration than you would get from planting forests (see Diagram). Even so, all of these approaches bump into the question of how far they can be scaled up to sequester meaningful quantities of carbon. Tules may be highly efficient carbon accumulators, but there are only so many areas that can be converted to marshland. Based on Bergamaschi's preliminary estimates from Twitchell Island, it would take a tule marsh more than double the size of California to offset most of our current carbon emissions.

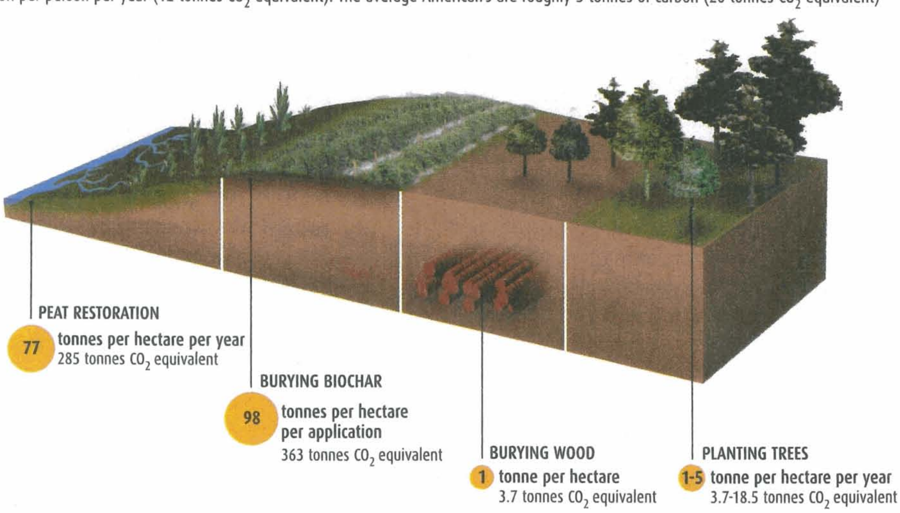
The production of biochar could also be used on a massive scale, in theory. In a paper presented at the American Geophysical Union last December, Amonette estimated that biochar production could halt the rise in atmospheric CO_2, but we would have to pyrolyse and bury at least 8 per cent of the Earth's annual biomass production to do it. Conservationists might have a thing or two to say about that.

None of these approaches need stand alone, of course. Zeng does not envision a globally or even nationally coordinated wood burial scheme – he sees small-scale activities by individual owners of wooded land, paid in carbon credits. This is the key to many of these schemes: to get off the ground they will ultimately need to be approved for inclusion in carbon trading schemes – and the price of carbon will have to be right.

Bergamaschi is confident that investing in tule marsh would be an attractive prospect. With carbon priced at €23 ($36) per tonne on the European market right now, he adds, it is beginning to look like farmers could earn

HOW TO GET THE BEST BANG FOR YOUR BIOMASS

Estimated carbon sequestered in tonnes per hectare. For comparison, the average European's emissions are in the region of 3 tonnes of carbon per person per year (12 tonnes CO_2 equivalent). The average American's are roughly 5 tonnes of carbon (20 tonnes CO_2 equivalent)



SOURCE: MINGXIN GUO, DELAWARE STATE UNIVERSITY/YADVINDER MALHI, UNIVERSITY OF OXFORD/NING ZENG, UNIVERSITY OF MARYLAND/BRIAN BERGAMASCHI, US GEOLOGICAL SURVEY


SHONAGH RAE

"Once the process is explosion-proofed, people could make carbon and bury it at home"

about €1400 to €1700 per hectare. At that level, "I think you're going to see widespread interest." Amonette estimates that biochar processes could also become a highly sought-after investment – as long as the price of carbon credits is in the region of $20 per tonne or more. Zeng sees wood burial becoming viable at around $50 per tonne.

There are a few hurdles to get over before any of these projects will be ready for launch onto a global carbon market, if and when such a thing gets going. One key issue is how long the carbon will stay sequestered. Ideally, the carbon would stay captured indefinitely or at the very least for thousands of years. Some Amazonian terra preta has already persisted for more than 2500 years, Amonette notes. Elsewhere, a carbon-14 study by Amonette's colleague, Johannes Lehmann of Cornell University, has found that charcoal residue near abandoned kilns in America's Appalachian mountains indicates that charcoal has persisted for a century or more. Restored peat marshes will continue to gather carbon for as long as the marsh is maintained, or until it is completely submerged in rising waters. Zeng says that carbon buried in wood could only stay sequestered permanently if it could be buried under perfect, unchanging conditions so the wood would never rot. Zeng isn't clear exactly what those conditions would be, and offers perhaps a more realistic estimate of 100 to 1000 years.

None of these solutions offer sequestration on the timescale promised by geological solutions such as injecting CO_2 into abandoned gas fields, but even the lower end of the range is long enough, Amonette reckons, to buy time for a smoother transition to energy sources with lower greenhouse gas emissions.

Another big problem for all biomass sequestration schemes is methane, because it tends to be generated when biomass is broken down by methane-producing bacteria in the soil. As a greenhouse gas, methane is about 20 times as potent as CO_2. Its saving grace, to the extent it has one, is that it is short-lived in the atmosphere. It persists for about 10 years, so transient burps, as one area of buried biomass breaks down, for example, will not warm the planet for long. Despite that, it would not take much methane to wreck a carbon-sequestration scheme. Fujii's team is looking into methane generation in their tule marsh, and their preliminary results look promising. Methane doesn't look to be a showstopper, Bergamaschi says.

Burying wood in the wrong types of soils might also generate methane. "It would depend crucially on where and how you bury it," Zeng says. Termites, in the regions where they live, would be another problem. They could eat the buried wood, converting its sequestered carbon back into CO_2 through respiration. Zeng also admits that removing dead wood on a large scale could destroy the habitats of woodland species that specialise in breaking down wood, and have the knock-on effect of depriving plants of the nutrients that these species release.

Despite its long history, much about biochar remains unknown too. The Amazonian's terra preta, Fowles says, was made by a quite different process from that being considered today. They smouldered organic waste directly on the land and covered the char with more waste in an ongoing cycle. "The mulch protects the char, and animals churn up the soil, taking the carbon down with it," Fowles says. "The assumption that you can just plough it in [and have it stay there] is completely untested."

So can we be sure that sequestering carbon in biomass will truly help to stave off global warming? It's a pressing question because, as Amonette points out, scientists keep finding that climate change is occurring more and more rapidly than anyone previously anticipated. "We don't have much time," he says. "We have to implement something fairly quickly. It may not be the perfect solution, but it's better than the disaster of waiting 40 or 50 years for the perfect solution to be found." ●

Richard Lovett is a freelance science writer based in Portland, Oregon

www.newscientist.com/channel/climate-change