IMPLICATIONS FOR CARBON POLICY

Lichen: Lamington National Park, Queensland. Photo: Michael Hodda.

E. obliqua, Mt. Wellington, Tasmania. Photo: Rob Blakers.

THE IMPORTANCE OF CARBON CARRYING CAPACITY

We noted in the introduction that the Intergovernmental Panel on Climate Change (IPCC) has identified the need for forest-based mitigation analyses that account for natural variability in forest conditions, use primary forest structure and composition data and provide reliable baseline carbon accounts (Nabuurs et al. 2007). The approach we document in this study provides the means to generate such reliable baseline green carbon accounts for natural forests.

Once estimates of the carbon carrying capacity for a landscape have been derived, it is possible to calculate a forest's future carbon sequestration potential. This is the difference between a landscape's current carbon stock (under current land management) and the carbon carrying capacity (the maximum carbon stock when undisturbed by humans).

The current carbon stocks reflect the impact of human land-use activities in removing woody biomass from the forest, in some cases degrading soil carbon, and reducing residence time of organic carbon pools in the ecosystem. Some human activities also lead to an increase in fire, which again reduces current stocks, especially if there is post-fire salvage logging (Mackey et al. 2002).

The carbon sequestration potential is the amount of green carbon that potentially can be sequestered and stored in a landscape, if no further carbon-degrading land-use activity occurs and prevailing natural disturbance regimes persist. If a natural forest has not been subjected to intensive human land-use activity, the current carbon stock should be equal to the estimated carbon carrying capacity. When the carbon carrying capacity is known, the limiting factor in calculating the carbon sequestration potential of a landscape is the availability of data needed to calculate current carbon stocks, especially data about: 1) land-use history, and 2) the carbon stocks in dead and living woody biomass and soil. All of these data are needed on a landscape-wide basis.

The correct baseline to use when undertaking green carbon accounting is the carbon carrying capacity, against which the significance of changes in carbon stocks can be gauged. The calculation of most practical significance is the carbon sequestration potential. The approach developed by Roxburgh et al. (2006) includes a simulation model that, once calibrated properly, can estimate the carbon sequestration potential of natural forests. Such analyses are part of our continuing research activities.

Given the extensive impact of human land-use activities, particularly land clearing and all forms of commercial logging, carbon carrying capacity has to be estimated carefully in many landscapes from the best available data. If the carbon carrying capacity is not considered explicitly, the current carbon stock will be taken as representing the baseline against which future changes are gauged. Assuming there is a history of intensive

land use, the result will be an underestimate of the green carbon account. The landscape's potential for carbon storage will have been undervalued.

DEFORESTATION AND FOREST DEGRADATION

After the 2007 Bali Climate Change Conference, the international community formally recognized the need to reduce emissions from deforestation and forest degradation as part of a comprehensive approach to solving the climate change problem. Deforestation is the result of a complex process reflecting the interaction of many factors such as national development priorities, local community needs and aspirations, the concerns of civil society organisations and commercial interests. Land and its resources are factors in production, and usually end up being allocated to the highest market-based economic value, unless governments intervene to protect non-market values through special conservation policies and legislation.

Clearing natural forests for bio-fuel plantations currently gives the highest economic return in many situations. Unfortunately, international rules defining forests and government carbon trading do not prevent natural forests in developing countries from being cleared for bio-fuel plantations. For example, in Indonesia, natural forests are being cleared for monoculture plantations of oil palms (Fargione et al. 2008). The international rules also do not prevent natural forests in developed countries being cleared for monoculture plantations (see Milne 2007).

Clearing natural forests to establish plantations does not reflect a scientific understanding of the difference between natural and industrialized forests. In terms of greenhouse gas emissions, the international rules that govern carbon trading and national-level policies do not distinguish between what we call in this report grey, brown and green carbon. Ignoring the difference between these forms of carbon can create ecologically perverse incentives for changing the land use and land cover.

It has now been shown that converting natural ecosystems to produce food-based bio-fuels creates a 'bio-fuel carbon debt' by releasing 17 to 420 times more carbon dioxide than the annual greenhouse gas reductions these bio-fuels provide by displacing fossil fuels (Fargione et al. 2008). The larger the natural carbon carrying capacity of a forest ecosystem (and the more intact the forest's carbon stocks), the greater will be the carbon debt from clearing to grow plantations. For eucalypt forests, recovery of the carbon debt from clearing intact natural forest through afforestation or reforestation takes more than 100 years (Roxburgh et al. 2006).

Forests are defined under the United Nations Framework Convention on Climate Change (UNFCCC) as woody vegetation of at least 2 m in height and 10 per cent canopy cover. It is therefore

a simple structural definition based on the height and density of woody plants in an area (UNFCCC 2002)[13]. One reason for the perverse outcomes we are now witnessing in forests is the limitation of this definition and associated rules that do not reflect: 1) an understanding of green carbon accounting as presented here; and 2) an ecological and evolutionary scientific understanding about how a natural forest differs from an industrialized forest. To appreciate this difference, we need to consider the web of ecological and evolutionary processes that sustain the system within which the green carbon is stored.

In addition to the dominant tree canopy layer, natural forests contain a vast array of other plant species that support, through the biomass they produce from photosynthesis, an extraordinary diversity of animal species (mammals, birds, reptiles, invertebrates), fungi and a multitude of microbial organisms. A natural forest contains genetic information that is being copied continually (through reproduction), corrected (through the failure to survive of organisms with faulty copies), replaced (by the survivors) and revised (through proliferation of organisms possessing favourable modifications to the genome). Most importantly, this revision of the genome allows populations to adapt to environmental changes, including the climate change that we are currently experiencing.

Maintenance of the genetic diversity of natural forests, and therefore the capacity of the organisms contained therein to continue to adapt to environmental change, requires a self-perpetuating system. When land is deforested, this store of genetic information is reduced and the capacity of the remaining population of the species to adapt to environmental change is compromised. Clearing of natural forest reduces the population viability of the biota in the remaining unmodified forest (Lindenmayer and Fischer 2006). The living information in the genetic material of the forest biota regulates the bio-geochemical and ecosystem processes (Gorshkov et al. 2000). As natural forest is self-sustaining, it is able to persist without the need for management inputs from humans. Consequently, carbon accounting in natural forests need consider only the carbon gains and losses associated with biological processes; photosynthesis, respiration and oxidative combustion by wildfire and the production of charcoal.

In contrast with natural forests, industrialized forests comprise a very small number of species. Plantations are not self-sustaining systems; they consist of copies of genetic information and require a succession of energy inputs (mostly sourced from fossil fuels) during their lifetime, from seedling propagation to harvest. These include: site preparation (removal of existing vegetation), seed collection, growth trials to test the potential survival of species, seedling nursery inputs to grow seedlings for planting, planting of seedling

13 In addition to tree crown cover (>10-30%) and height (2-5 m) at maturity, the IPCC definition of forest includes consideration of the minimum area (0.05-1.0 ha) and width of land.

trees, application of herbicides to suppress competition from weed species, measures to prevent animal species (vertebrates and invertebrates) from browsing on the seedlings, fertilizer application (most soils in Australia are nutrient impoverished) and continuing maintenance to suppress plant and animal pest species and fire.

As plantations are not self-sustaining systems, when the trees are harvested or die, energy inputs (again, sourced mostly from fossil fuels) are required to establish a new crop of trees. All of these fossil-fuel inputs, including those required for the manufacture of consumables such as fertilizer and pesticides, need to be taken into account, along with the biological processes, when assessing the carbon sequestration potential of tree plantations (and other agricultural crops). As plantations are eventually harvested, the fossil-fuel inputs, such as those required for road-making and upgrading, transport of the saw-logs for processing, the energy needs (and carbon dioxide emissions) for processing of timber or woodchips, and other industrial processes, should also be deducted from the gross pre-harvest carbon stock.

Despite the progress we are now seeing in the development of international policy responses to the problem of deforestation, there remains a lack of clarity about the kinds of human activities that contribute to forest degradation. From a climate change perspective, forest degradation needs to be defined to include the impact of all human land-use activity that reduces the current carbon stock in a natural forest compared with its natural carbon carrying capacity. The impact of commercial logging on natural forests must therefore also be considered when accounting for forest degradation. As discussed earlier, commercially logged forests have substantially lower carbon stocks and reduced biodiversity than intact natural forests, and studies have shown carbon stocks to be 40 to 60 per cent lower depending on the intensity of logging (Brown et al. 1997; Dean et al. 2003; Roxburgh et al. 2006). In Brazilian Amazon, the area of natural forest that is logged commercially resulting in degraded carbon stocks is equivalent to that subject to deforestation and represents approximately 0.1 Gt of green carbon emissions to the atmosphere (Asner et al. 2005).

While clearing for agriculture (either intensive or subsistence) can be a major cause of deforestation and forest degradation (especially in tropical forests), commercial logging can also be the initial causal factor. Depending on the prevailing regulatory framework, a succession of planned and unplanned, legal and illegal land-use activities can be introduced into a landscape facilitated by the logging infrastructure—in particular, the road network. The end point of this process can be broad-scale degradation and deforestation, with associated increased carbon dioxide emissions.

GREEN CARBON AND MITIGATION

Given the scale and urgency of the climate change problem, we need to take a fresh look at the contribution natural forests can

make to mitigating rising levels of atmospheric carbon dioxide. We can illustrate the implications of taking a fresh approach by considering again the carbon carrying capacity we have calculated for the eucalypt forests in south-eastern Australia (Figure 7). Our comments here, however, can be of a preliminary nature only as we have not yet calculated the carbon sequestration potential of these forests—a task that remains part of our continuing research.

About 30 per cent of Australia's forests have been cleared and the land converted to agricultural or other land uses. Of the 14.5 million ha of eucalypt forest shown in Figure 7 (which is about half of Australia's remaining eucalypt forests), about 4.9 million ha are in some kind of protected area, while 9.6 million ha are on either public or private land. Of the unprotected natural forest, about 8.1 million ha (about 56 per cent) have been logged commercially.

Protecting natural forests can be part of a comprehensive mitigation strategy in two ways:

1. keeping the carbon in the forest ecosystem—that is, in the biomass and bound to soil particles
2. allowing the forests that have been logged previously to re-grow and reach their carbon sequestration potential.

The carbon carrying capacity of the 14.5 million ha of eucalypt forest in our study area is about 9 Gt C (equivalent to 33 Gt CO_2). About 44 per cent of the area has not been logged and can be considered at carbon carrying capacity, which represents about 4 Gt C (equivalent to 14.5 Gt CO_2). About 56 per cent of the area has been logged, which means these forests are substantially below their carbon carrying capacity of 5 Gt C. If it is assumed that logged forest is, on average, 40 per cent below carbon carrying capacity (Roxburgh et al. 2006), the current carbon stock is 3 Gt C (equivalent to 11 Gt CO_2). The total current carbon stock of the 14.5 million ha is 7 Gt C (equivalent to 25.5 Gt CO_2). If logging in native eucalypt forests was halted, the carbon stored in the intact forests would be

E. regnans in Mt. Baw Baw, Victoria. Photo: Chris Taylor.

protected and the degraded forests would be able to regrow their carbon stocks to their natural carbon carrying capacity. Based on the assumptions above, the carbon sequestration potential of the logged forest area is 2 Gt C (equivalent to 7.5 Gt CO_2).

Costa and Wilson (2000) have derived an equivalence factor to relate the stock of carbon in the biosphere to the effect of the emitted carbon dioxide in the atmosphere, stated as "the effect of keeping 1 t CO_2 out of the atmosphere for 1 year". This is based on the inference that "removing 1 t CO_2 from the atmosphere and storing it for 55 years counteracts the radiative forcing effect, integrated over a 100 year time horizon, of a 1 t CO_2 emission pulse". Applying this equivalence factor, every 1 t CO_2 sequestered as a biosphere stock for 55 years is equal, in a radiative forcing context, to 0.0182 t CO_2 yr^{-1} (for 100 years) of avoided emissions, and every 1 Gt CO_2 stored is equivalent to 18.2 Mt CO_2 yr^{-1} (for 100 years) of avoided emissions. The effect of retaining the current carbon stock of 25.5 Gt CO_2 in our study area is therefore equivalent to avoided emissions of 460 Mt CO_2 yr^{-1} for the next 100 years. Allowing logged forests to realize their sequestration potential to store 7.5 Gt CO_2 is equivalent to avoiding emissions of 136 Mt CO_2 yr^{-1} for the next 100 years. This amount of emissions is equal to 24 per cent of the 2005 Australian net greenhouse gas emissions across all sectors (559 Mt CO_2 yr^{-1}) (Australian Greenhouse Office 2007b). This approach is assuming a 100 year lifetime for most of the carbon dioxide in the atmosphere. However, Archer (2005) considers a better approximation of the lifetime of fossil fuel carbon dioxide might be "300 years plus 25% that lasts forever".

Another way of appreciating the relative importance of the carbon stock in forests is to compare it with the stock in the atmosphere. If the entire carbon stock was released from the forests in our study area into the atmosphere, it would raise the global concentration of carbon dioxide by 3.3 ppmv[(14)]. This is a globally significant amount of carbon dioxide; since 1750 AD, the concentration of carbon dioxide in the atmosphere has increased by some 97 ppmv.

It is possible to achieve protection of the carbon stocks in natural forests by switching to timber sourced from existing plantations and, if necessary, from new plantations on previously cleared land. In this way, the commercial demand for wood fibre can be met and the contribution of natural forests to greenhouse gas mitigation can be maximized. Currently, about 68 per cent of wood fibre is sourced from the plantation estate, but current plantation stocks are sufficient to meet nearly all the national demand for wood and paper products (Ajani 2007).

14 1 ppmv CO_2 in the atmosphere is equivalent to 2.13 Gt C (Carbon Dioxide Information Analysis Center).