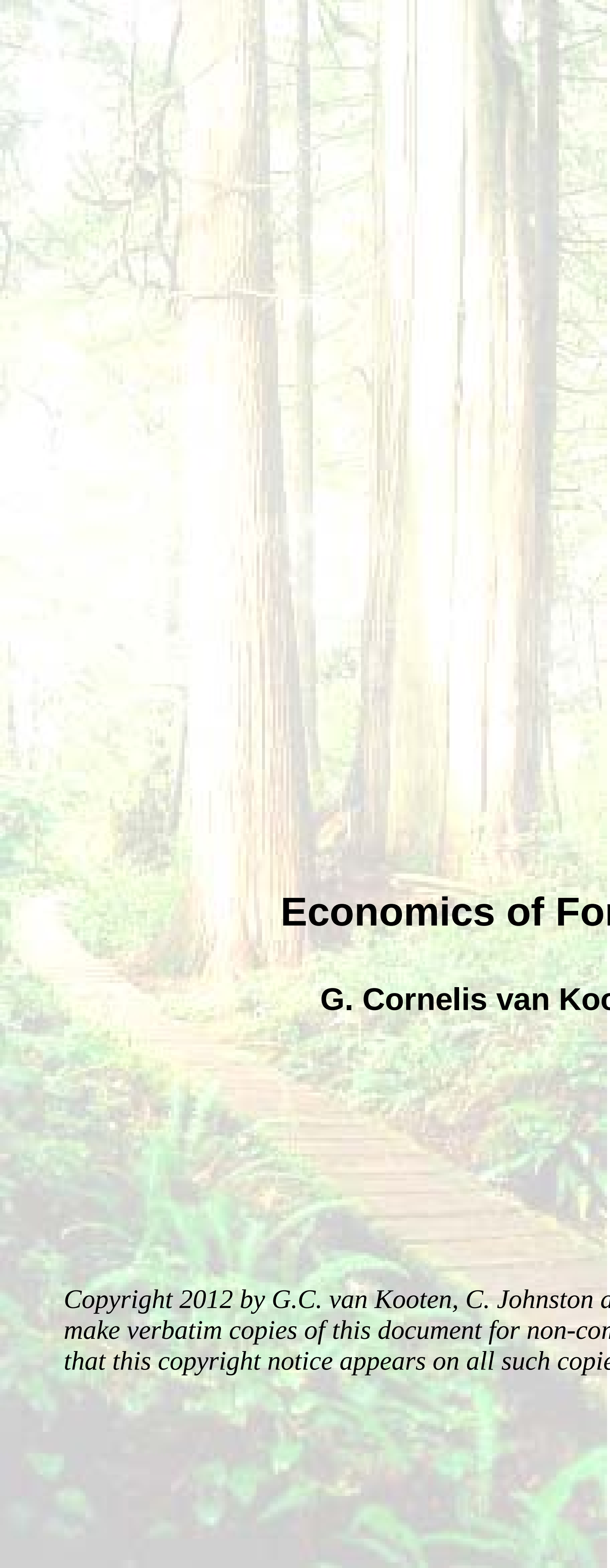

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Economics of Forest Carbon Sequestration

G. Cornelis van Kooten, Craig Johnston and Zhen Xu

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Economics of Forest Carbon Sequestration

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1. Introduction

In order to mitigate projected climate change, leaders of the G8 countries meeting in L'Aquila, Italy, agreed on July 8, 2009 to limit the increase in global average temperature to no more than 2°C above pre-industrial levels. To do this, the leaders set an ambitious target – to reduce global greenhouse gas (GHG) emissions by 50% from 1990 levels by 2050, with rich countries to reduce their aggregate emissions by 80% or more. The European Union's target is to reduce GHG emissions by 20% from the 1990 level by 2020, while the United Kingdom's Climate Change Act (2008) is even more ambitious, requiring GHG emissions to be cut by 34% from 1990 levels by 2018-2022, and by 80% by 2050 (see Lea 2012). Given the draconian and unrealistic nature of the emission reduction targets, countries need to find ways around these targets. This has been done by permitting emission offsets, or simply carbon offsets. These are defined as reductions in GHG emissions (principally carbon dioxide or equivalent emissions), or an equivalent removal of CO_2 from the atmosphere, that are realized outside a compliance market and can be used in lieu of emissions reductions required under an official target (van Kooten and de Vries 2012).[1] Thus, reductions in $CO_{2\text{-e}}$ emissions in other countries and activities in other sectors that reduce concentrations of $CO_{2\text{-e}}$ in the atmosphere can substitute for domestic reductions in $CO_{2\text{-e}}$ emissions, thereby providing countries with escape valves that protect their industries and economy.

The motivation for the current paper is the 1997 Kyoto process that permitted developed

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[1] CO_2 is the most important greenhouse gas, with other GHGs equated to CO_2 using an index of global warming potential (see http://unfccc.int/ghg_data/items/3825.php).

countries to meet a portion of their $CO_{2\text{-}e}$ emission-reduction targets through the purchase of carbon offsets in developing countries. In essence, rich countries could pay poor countries to reduce their emissions by investing in processes that improve energy efficiency in the developing country (e.g., upgrading power plants, investments in wind turbines or solar panels). Alternatively, rich countries could sponsor activities in developing countries that remove carbon dioxide from the atmosphere and store it in terrestrial ecosystems (e.g., afforestation, conversion of cropland to pasture). Projects that create offsets in developing countries are certified under the United Nations' Clean Development Mechanism (CDM). These are referred to as certified emission reductions (CERs), whether they come from actual emissions reduction or from activities that destroy triflurومethane (HFC-23) or increase sequestration of carbon in forest ecosystems (Wara 2007).[2] Developed countries, on the other hand, would be responsible for certifying emission reductions or offset schemes in their own countries, including certifying activities that sequester carbon in forest ecosystems.

The focus of the current study is on carbon dioxide emissions and, in particular, the potential for forestry activities to contribute to major reductions in atmospheric CO_2. Under Kyoto's rules, activities that affect land use, land-use change and forestry (LULUCF) can generate carbon offset credits, both in developed and developing nations. The only difference relates to certification: LULUCF projects in developing countries are certified under the CDM, while those in developed countries are certified by the relevant national government. Along with limits on the overall use of LULUCF generated carbon offsets, the certification requirement presumes that the problems associated with such offsets, including additionality, leakages and governance (which are discussed below), are thereby minimized.

The overarching question that we address in this chapter is whether it is worthwhile including

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[2] Wara (2007) found that 28% of 1534 CER projects involved destroying HFC-23, primarily in China, because HFC-23 has a global warming potential 9100 times greater than that of CO_2.

forestry-generated carbon offset credits in a cap-and-trade scheme that sets a target on CO_2 emissions. Do carbon offsets enable a country to attain its emission reduction targets more efficiently than in the absence of terrestrial sequestration? What are the costs and benefits? What are the challenges and limits to forestry activities?

We proceed in the next section by demonstrating that carbon offsets reduce the costs to large emitters (countries) of meeting emission reduction targets. Because carbon offsets are meant to substitute for emission reductions and be traded in markets, in section 3, we consider carbon markets in more detail, with particular focus on the Europe's Emissions Trading System because it is the only such market in existence. Then, in section 4, we focus specifically on carbon sequestration in forest ecosystems, examining in particular issues related to the additionality of forestry projects, potential for leakages, duration, transaction costs and governance. Along with biological uncertainty, these problems make it extremely difficult to determine the actual carbon flux associated with forestry activities and especially so if avoided deforestation and forest degradation are taken into account. Finally, in section 5, we illustrate what happens to the overall net carbon flux associated with forestry activities when wood product carbon sinks and the substitution of wood products for steel and/or concrete in construction are included. As indicated in the conclusions (section 6), the task of creating valid forest carbon offsets may well exceed our capacity to do so.

2. Forest Carbon Sequestration: Theory

Carbon sequestration in forest ecosystems must yield economic benefits or there would be no sense pursuing this option in lieu of CO_2 emissions reduction. In a perfect world with no transaction costs, leakages, governance, duration or other issues, it is straightforward to demonstrate the benefits of carbon sequestration. Consider Figure 1. The emissions reduction and carbon sequestration sectors are shown as back-to-back panels. In the left panel, there is a cap on emissions given by *0E*. In the absence of carbon offsets, the costs of reducing emissions through a combination of emissions trading and abatement of emissions by industrial emitters are given by the area under the marginal cost function, or area *0aE*. At the level of the cap, the marginal cost of abatement is *P*, which is also the price of purchasing an emission allowance.

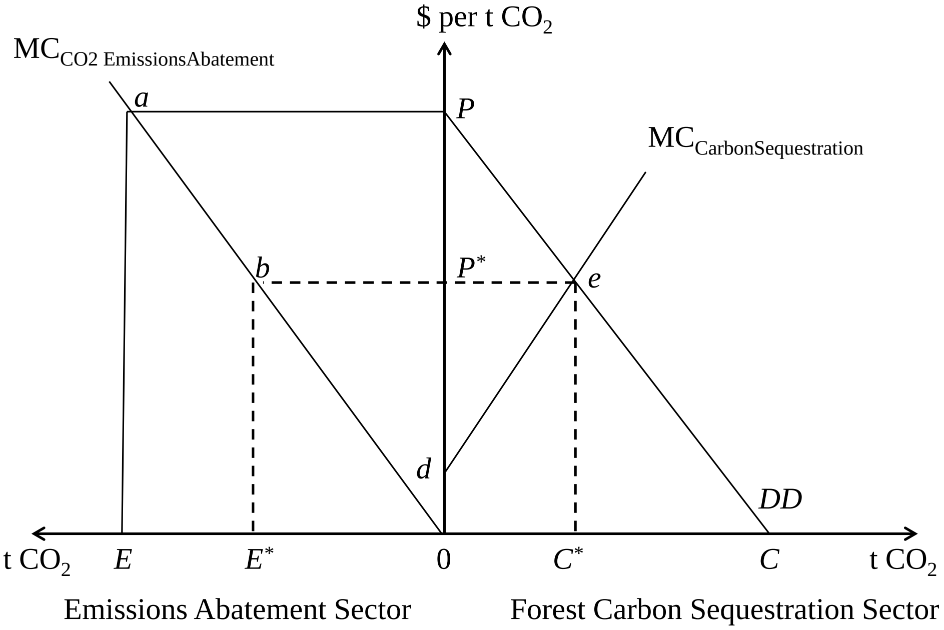

Figure 1: The Benefits of Carbon Sequestration

Assuming no other means of purchasing offsets, the derived demand for carbon offsets in the forest sector is denoted by *DD*. Such a carbon offset is referred to as a ‘removal unit’ (RMU), which is defined under Kyoto rules as an emission reduction unit generated by removing a tonne of CO_2 (tCO_2) from the atmosphere by sequestration. If the price a country or large emitter is required to pay for an RMU is *P*, there is no benefit to purchasing carbon offsets in the forest carbon sequestration sector because firms will abate or buy allowances from firms that exceed their abatement targets (known under Kyoto as Assigned Amount Units or AAUs). If, on the other hand, RMUs are costless, emitters will obtain their entire targeted reduction *0E* in the forest sequestration sector; hence, *0E* = *0C*. At other prices for carbon offsets, the derived demand is determined in a similar way, so that the line *CP* is parallel *0a*.

Now introduce a marginal cost of carbon sequestration as shown in the right panel. The forestry sector would provide $0C^*$ carbon offsets at price P^*. This would then be the marginal cost of abatement, so that $0E^*$ emissions are abated, with $0E^* + 0C^* = 0E$. That is, carbon offsets of amount $0C^*$ would be substituted for E^*E of emissions abatement.

Given the relationship between the derived demand function *DD* and the marginal cost of abatement, the area under *DD* provides an indication of the net benefit of carbon sequestration in forest ecosystems. Without carbon offsets, the cost of achieving the targeted emission reductions *OE* is given by area *0aE*. When carbon offsets are permitted, the cost of attaining the target is given by area $0bE^* + 0deC^*$. The cost saving is given by $EE^*ba - 0deC^* > 0$; because *CP* is parallel *0a* the cost saving is identical to area *deP* under the derived demand function.

Clearly, if activities to create carbon offsets in forest ecosystems are too costly (see van Kooten et al. 2004, 2009), then the MC in the right panel might well intersect the vertical axis at or above *P* ($d \geq P$), in which case there is no benefit for a country or large emitter to purchase RMUs in the forest carbon sequestration market. What factors affect the marginal costs of creating carbon offsets?

3. Carbon Markets

Economists prefer economic incentives over regulation because they incentivize firms to adopt technical changes that lower the costs of reducing CO_2 emissions. In the case of a cap-and-trade scheme, firms can sell permits or avoid buying them; in the case of carbon taxes, they seek ways to avoid paying the tax. Further, market instruments provide incentives to change products, processes and so on, as marginal costs and benefits change over time. Because firms are always trying to avoid the tax, or avoid paying for emission rights, they tend to respond quickly to technological change.

In the context of climate change, most economists generally favor carbon taxes over cap and trade because the marginal damage (marginal benefit of mitigation) function is likely flatter than the marginal cost of mitigation. In an uncertain world, a tax is a more flexible instrument than an emissions cap. While an emissions cap guarantees that a target is met (assuming the cap is enforceable), if the cap is set too low, the costs of attaining that emissions level could be unbearably high. With a tax the marginal cost of abatement is known when the tax rate is revealed as firms set the marginal abatement cost equal to the tax. The tax could be increased over time if insufficient abatement occurs and more becomes known about potential damages from climate change. Of course, one could similarly adjust the cap over time in like fashion to avoid unpalatable costs.

There are other drawbacks to emissions trading, of which two are particularly troublesome. First, politicians and extant firms prefer to grandfather rights to emit CO_2. Firms are given permits to emit an amount of CO_2 that is below their current level depending on the domestic or global target. Firms can present permits to enable them to release CO_2 into the atmosphere, or they can reduce their own emissions (e.g., through improvements in energy efficiency, switching to non-fossil fuels, or going out of business) and sell permits in carbon markets. Whatever the case, the price that permits fetch in the carbon market is considered a cost of production by all firms that are affected by the trading scheme. To avoid the adverse impacts on the economy (e.g., firms going out of business, permit prices rising too high), carbon offsets are allowed, which effectively negates a true cap-and-trade scheme.

To date few jurisdictions have imposed carbon taxes (one exception is British Columbia) and there have been few carbon markets. The voluntary Chicago Climate Exchange disappeared at the end of 2010 leaving the European Union’s Emissions Trading System (ETS) as the only carbon market in operation. ETS is a mandatory market for large industrial emitters in

Europe; these firms have been allocated allowances (EUAs) and they must present one EUA for every tCO_2 that they emit. If they emit more CO_2 than their allocated permits allow, they must purchase EUAs on the ETS. However, they could also purchase carbon offsets that are sold on the ETS. Two carbon offsets are available: Emission Reduction Units (ERUs) that are created in countries of the former Soviet Union through Kyoto's Joint Implementation program and Certified Emission Reductions (CERs) that are created in developing countries through Kyoto's Clean Development Mechanism (CDM).

CERs are certified strictly under the United Nations' Framework Convention on Climate Change (UNFCCC) process, while ERUs are certified by developed countries that invest in the creation of carbon offsets in ex-Soviet states, sharing these offset credits with the host country, which is also has an emissions-reduction target under Kyoto. Likewise, EUAs are certified by the EU, although it has delegated this to the individual countries. This, in turn, led to the collapse of the first stage of the ETS as countries permitted their large industrial emitters to overstate their emissions and the number of permits for which they were eligible.

Finally, there has been remarkable growth in voluntary carbon markets, with a number of private companies emerging as certifiers of voluntary emission reductions (VERs). In this market, forestry activities and especially forest conservation play a large role, accounting for more than 40% of VERs sold globally in 2010 (Peters-Stanley et al. 2011). Certification standards include the 'Gold Standard' (GS), the Climate, Community and Biodiversity Alliance's CCB certification, and the Verified Carbon Standard (VCS). Various (mainly European) sponsors grant the certifying agencies their legitimacy. For example, core sponsors of the Gold Standard include the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, WWF International (headquartered in The Netherlands), the European Climate Foundation, and Merrill Lynch Commodities (Europe) Limited; the GS standard is endorsed by Renewable Energy and Energy Efficiency Partnership (Austria), MyClimate (Switzerland), and 'astmosfair' (Germany), among others. The market for VERs amounted to $424 million in 2010, with trades averaging $3.24 per tCO_2 in 2010, down from a high of $5.81/tCO_2$ in 2008; but the VER market is small compared to global trade in emissions worth $142 billion in 2010 (van Kooten 2012). However, there is concern that VERs are being sold not only in the voluntary market but are also entering the ETS as carbon offsets (see van Kooten et al. 2012). If that is truly the case, then the existence of a legal carbon offset market facilitates the laundering of VER credits, aided and abetted by environmental NGOs, governments and financial intermediaries.

Increasing reliance on carbon offsets, including illegitimate ones, might help explain the drop in prices on the ETS, as indicated in Figure 2. This issue is discussed further in the section on 'governance.' At this stage, we only point out that forestry activities that create carbon offset credits, whether these are legitimate or not, play an important role in the marketplace.

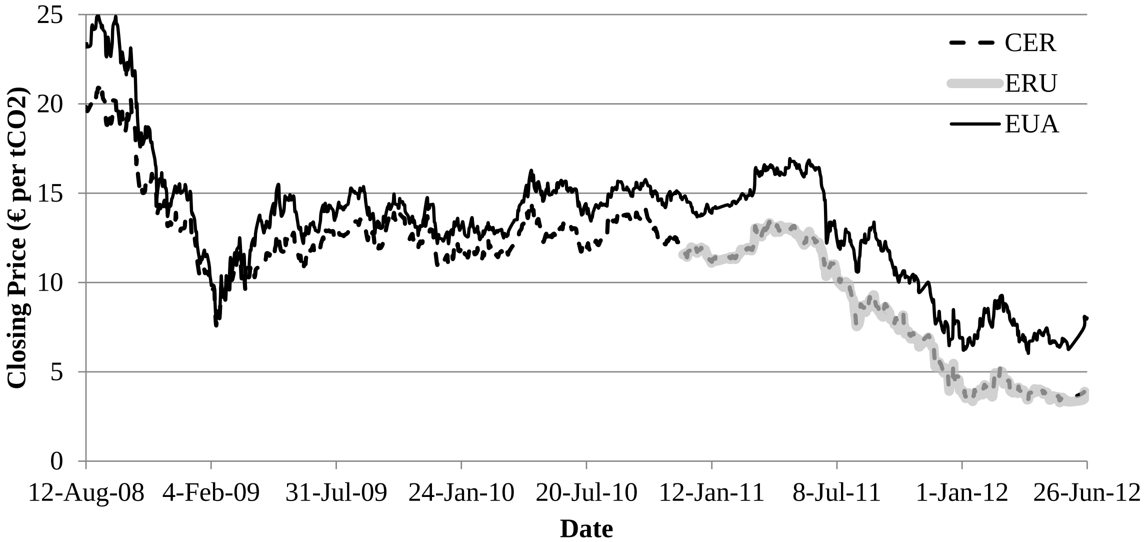

Figure 2: Prices of Emission Allowances (EUAs) and Carbon Offsets (CERs and ERUs), European Trading System, 2008 to mid-2012

4. Forest Carbon Sequestration: Real World Challenges

Society wishes to mitigate climate change at the lowest possible cost, but any activities to achieve emission reduction targets must also be effective in reducing atmospheric concentrations of carbon dioxide and equivalent greenhouse gases. When it comes to carbon sequestration in forest ecosystems, the greatest challenges pertain to the compatibility of carbon offsets (RMUs) and CO_2 emission reductions (AAUs). Issues relate to the additionality of forestry projects, leakages, duration, transaction costs and governance. Although these issues are inter-related, we address each in turn.

Additionality

In principle, carbon offset credits should be earned only for carbon sequestration above and beyond what occurs in the absence of carbon-uptake incentives, a condition known as additionality. Thus, carbon sequestered as a result of incremental forest management activities (e.g., juvenile spacing, commercial thinning, fire control, fertilization) would be eligible for carbon credits only if the activities would not otherwise have been undertaken because it is profitable to do so. Similarly, afforestation projects are additional if they provide environmental benefits (e.g., regulation of water flow and quality, wildlife habitat) not captured by the landowner and would not be undertaken in the absence of economic incentives, such as subsidy payments or the ability to sell carbon credits. Further, if it is demonstrated that a forest would be harvested and converted to another use in the absence of a specific policy (say, subsidies) to prevent this from happening, the additionality condition is met. Demonstrating that the additionality criterion is met is not easy; the problem is that the process is not readily transparent and open to political manipulation and, thus, corruption.

Consider for example the case of zero tillage. Schmitz et al. (2010, pp.18-19) argue that, as a result of reduced tillage and conversion of cropland to perennial grasses, Saskatchewan farmers sequester annually some 20 million tonnes of carbon, or more than 70 Mt CO_2. However, as Nagy and Gray (2012) point out, “the development and adoption of zero tillage cropping systems is perhaps the most important agricultural innovation of the past fifty years," with farmers gaining some $1.7 billion in terms of reduced fuel, labour, machinery and other input costs. Although farmers often argue that they should be compensated for the carbon uptake benefits associated with the adoption of such practices (e.g., Paustian et al. 1997), clearly compensation is unwarranted because zero tillage has been adopted (by over 90% of farmers in Saskatchewan) in the absence of carbon payments. Carbon sequestered as a result of zero tillage clearly fails the additionality test even though policy makers clamour for the acceptance of carbon offsets related to the adoption of zero tillage.

Leakages

Another difficulty is that of assessing leakages – the extent to which carbon sequestration in one place increases harvests and release of stored carbon as CO_2 in another. Estimates indicate that, for forestry activities meant to sequester carbon, leakages range from 5% to 93%, depending on the type of project and its location (Murray et al. 2004; Sohngen and Brown 2006; Wear and Murray 2004). The effect on the marginal cost function in the right-hand panel of Figure 1 could be large, with Boyland (2006) finding that a failure to include a 25% leakage factor will underestimate costs by one-third.

Based on the result of a meta-regression analysis by van Kooten et al. (2009), and adding 25% to costs to account for leakage which none of the reported studies took into account, the only forestry activities that might be able to provide carbon offsets at prices below what emissions reduction allowances (EUAs) trade for on the European emissions trading system (Figure 2) are tree planting projects in the tropics. In essence, if the marginal cost function found by the meta-regression analysis were adjusted upwards to account for leakages, it would likely intersect the vertical axis in Figure 1 above point *P*. This would especially be true if duration was also properly taken into account. The 68 studies considered by van

Kooten et al. (2009) ignored the problem of duration – the fundamental incompatibility between emissions reduction and terrestrial carbon sequestration credits because of the differing lengths of time that CO_2 is prevented from residing in the atmosphere.

Duration

If carbon offsets can be created via forest carbon sequestration, one must deal with the problem of duration (van Kooten 2009). Duration refers to the fact that carbon offsets created by sequestering carbon in terrestrial sinks remove CO_2 from the atmosphere over some time period, but eventually release it back to the atmosphere. Since the timing of removal and release are not known with certainty, and varies across projects, it is impossible to determine how many RMUs any project creates. If one assumes that an emissions reduction is permanent – one tCO_2 not released to the atmosphere as a result of taking the bus instead of driving one's car is permanent – but the CO_2 sequestered in a forest ecosystem is temporary, then there needs to be some means to compare the permanent and temporary credits. There needs to be a mechanism for equating an assigned amount unit (AAU) and a removal unit (RMU) – there must be some way to compare a permanent emissions reduction with a temporary carbon offset.

It is no wonder that, while LULUCF activities are eligible as CERs under the CDM, strict conditions apply to have RMUs certified. For one thing, only carbon offsets earned through afforestation or reforestation projects are considered eligible as certified emission reductions. Afforestation refers to tree planting on sites that had not previously been forested, while reforestation refers to tree planting on sites that are considered forestland but where no trees are currently growing, perhaps because land has recently been converted to another use.

The certification process dealt with the duration issue by creating a temporary certified emission reduction (tCER) and long-term certified emission reduction (lCER). The tCER operates like an annual rental of a permanent CER, while the lCER is something between an annual rental and a permanent reduction. Both instruments are a response to the duration problem, but are also designed to reduce transaction costs. For example, a tCER facilitates the sale of carbon offsets from forestry activities, because it allows a firm to purchase tCERs to cover emissions while it makes the necessary investments to reduce emissions permanently.

To understand how tCERs and lCERs have been implemented, consider Figure 3, where a landowner plants trees to create carbon offset credits.[3] The landowner chooses the initial time to enrol tCERs for sale, say time T_1. At that time, the number of eligible tCERs for sale is given by $tCER_1$, which is equal to the total carbon sequestered from time 0 to T_1 as a result of tree planting. The owner can sell an amount $tCER_1$ each year for five years, despite the fact that the site will continue sequestering carbon beyond T_1. After five years, the carbon available on the site is re-evaluated, with the landowner now eligible to sell whatever carbon is available on the site at time $T_2 = T_1+5$; the eligible amount is now $tCER_2 > tCER_1$, which can then be sold for the next five-year period. Ten years after the initial sale of carbon offset credits, at $T_3 = T_1+10$, the tCERs available for sale has fallen dramatically to $tCER_3$ as a result of an intervening harvest. The sequestered carbon subsequently lost to the atmosphere as a result of harvests is completely ignored.

The landowner could also sell more permanent lCERs, which equal the change in carbon over the project life. In the context of Figure 3, for example, an lCER might equal $tCER_2 – tCER_1$. The purchaser would be able to claim the CO_2 equivalent of the carbon that is sequestered against any emissions, but would then be responsible for buying further carbon offset credits after T_2, or purchase permanent emissions reduction credits (AAUs) to cover the lCERs.

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[3] This example is adapted from van Kooten (2012, Chapter 9).

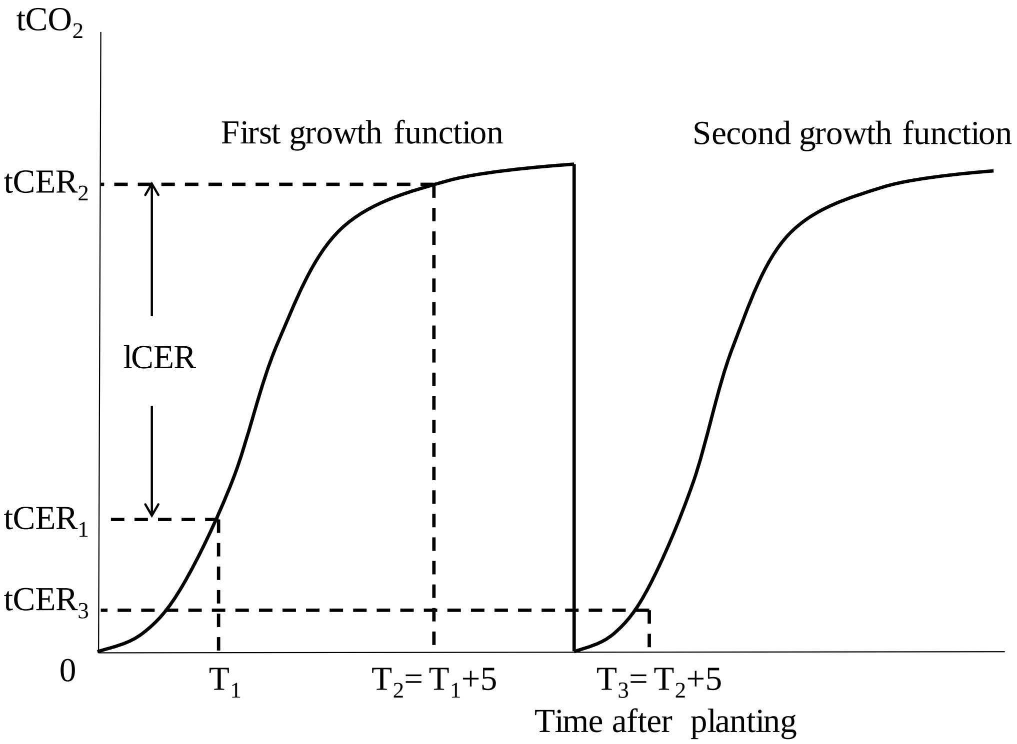

Figure 3: Defining tCERs and lCERs from Forestry Activities

If the landowner wants to participate in LULUCF activities that are eligible for CER offsets, she can choose to sell either tCERs or lCERs to address the impermanence problem. From the point of view of the purchaser, a tCER can be applied against emissions each year for a five-year period, while an lCER enables the buyer to apply a much larger amount against emissions but only in a given year (or presumably the lCER can be spread across years). The lCER is paid for only once, while a rental payment for a tCER is required each year; however, the price of the former will be greater than that of the latter and an emitter can buy several lCERs. Once an approach is chosen, however, it has to remain fixed for the entire crediting period (UNFCCC 2006), although it still needs to can be replaced by permanent credits at a future time.

How does one choose between tCERs and lCERs at the beginning of a project? Unlike permanent CERs, there is no universally applicable pricing mechanism for both kinds of expiring CERs (Singh 2009). Dutschke et al. (2006) and Bird et al. (2005) argue that the value of tCERs and lCERs greatly depends on buyers' expectations about a future market or, more specifically, the prices in the subsequent commitment period. Based on that, Lecocq and Couture (2008) indicate the feasible range of prices of tCERs and lCERs in the current commitment period should be less than or equal to the difference between the price of permanent credits in the current period and its discounted expected value in the next period. Whether expiring CERs are preferable, in that case, depends on the expected change in the future discount rate and the expected price of permanent credits. The choice of tCERs or lCERs then becomes speculative due to risk preferences toward unexpected expiry of a project and financial needs of landowners.

A landowner who sells lCERs should be held responsible for the potential loss of carbon that might occur as a result of a planned harvest or a natural disturbance. Suppose a landowner sells lCERs for the period T_2 to T_3. If the drop in sequestered carbon just prior to T_3 in Figure 3 is due to a planned harvest, the landowner is acting dishonestly by selling credits. This is a governance problem that is discussed in more detail below, although it is worth mentioning here that carbon sequestration in forest ecosystems is susceptible possible bogus carbon uptake claims.

The problem with forest carbon offsets is that, while facilitating trade and enabling large emitters to keep costs down, they are not truly equal to emissions reduction credits. Both are clearly artificial constructs that have little to do with real emissions reduction. In the case of tCERs, harvests are clearly ignored; with lCERs, the time path of carbon uptake is ignored.

Governance

Another major problem with forest carbon sequestration is governance. Measurement, monitoring and enforcement of forest carbon projects are especially problematic, mainly because tree growth is variable and ecosystem carbon fluxes are difficult (and expensive) to measure. Transaction costs are high and there is opportunity to misrepresent the size of the carbon offsets that are generated – projects are particularly vulnerable to corruption (Helm 2010; van Kooten and de Vries 2012). The link between an LULUCF project and the creation of carbon offset credits is not always clear. Those who certify CDM forestry projects must rely on computer models and analyses by forest management specialists to forecast future carbon uptake and release, and to identify the counterfactual (business-as-usual alternative). Significant leeway remains for speculation, error and corruption. Further, developing countries may well sell carbon offset credits to developed countries, but, since they are not bound by international targets, still credit the activities to their own emissions reduction, resulting in 'double-dipping' (Woodward 2011).

The principles involved in creating CERs from carbon offsets through LULUCF activities also apply to industrial countries, except certification falls to the government of the rich country. Further, as noted earlier, voluntary markets have circumvented government enabling forest landowners to earn (voluntary) carbon offsets for potential sale. There already exists a market for voluntary emissions reductions in developed countries (Peters-Stanley et al. 2011), with some voluntary forest carbon offsets potentially even making their way onto legitimate markets, perhaps because the project certifiers take charge of some of the carbon offsets. This appears to have been the case for a forest conservation project in south-eastern British Columbia (van Kooten et al. 2012), even though forest conservation is not a permitted activity for generating carbon offsets under Kyoto (see below). The interaction between the voluntary market and the compliance market, which currently exists only as the EU's ETS (Figure 2), is troublesome. The problem is that there is too much room for rent seeking (Helm 2010).

Governance may become an even bigger problem as a result of other recent initiatives.

Although forest conservation activities are currently not eligible as carbon offsets, concerns about tropical deforestation and related CO_2 emissions (which account for perhaps some 20% of total annual GHG emissions) have led many commentators to commend the use of forest conservation in developing countries as a tool for addressing global warming. In international negotiations, activities that Reduce Emissions from Deforestation and forest Degradation (REDD) are touted as an alternative means for earning certified emission reduction credits. Indeed, as a result of negotiations at Cancun in December 2010, the narrow role of REDD has been expanded to include sustainable management of forests, forest conservation and the enhancement of forest carbon stocks, collectively known as REDD+. In this way, it is possible to link the UNFCCC and the Convention on Biological Diversity (CBD) – the other agreement signed at the 1992 Earth Summit in Rio de Janeiro. Increasingly, therefore, climate negotiators appear willing to accept REDD+ activities as potential carbon offsets to the extent that these activities also enhance biodiversity. Since deforestation and biodiversity are a greater problem in developing countries and because industrial nations are also interested in providing indirect development aid through the CDM, only REDD+ projects in developing countries merit attention, although these still need to be approved under the CDM.

It is this complexity that fundamentally impacts the carbon price mechanism. That is, by supplying the market with REDD+ carbon offsets, the price mechanism that ensures demand for credits equals supply becomes distorted because sales of credits from other than emissions reduction take place. Instead of dealing only with the sale and purchase of permits to emit CO_2, the market mechanism has to deal with emission reduction credits from sources that have nothing to do with CO_2 emissions from fossil fuel burning. REDD+ credits derive from protection of biodiversity on private forestland and do not contribute explicitly to reductions in CO_2 emissions. By allowing these offsets into the carbon market, the corresponding carbon price does not reflect its true value, i.e., it is distorted, with the price of carbon below what it would otherwise be. This results in inefficiency and reduces the incentive to invest in R&D that conserves energy, results in greater efficiency in the use of fossil fuels or spurs alternative energy sources. Thus, credits created by activities that enhance preservation of biodiversity enter the global carbon market without actually contributing to a net carbon reduction.

While carbon sequestration in terrestrial ecosystems was only meant to be a bridge to provide time for an economy or firm to develop and invest in emission-reducing technologies, the sale of such credits has turned out to be an impediment to the implementation of new technology (as carbon prices are lower than necessary), while creating a larger gap between actual emissions and emission targets in the future (van Kooten 2009) and doing little if anything to mitigate climate change. One can only conclude that any carbon offset program is a second-best solution that induces rent-seeking.

5. Carbon Sequestration: Forest Products

Currently, the Framework Convention on Climate Change and Kyoto Protocol do not include carbon stored in Harvested Wood Products (HWPs) in their carbon accounting guidelines. The current protocol assumption is that additions to the forest product carbon pool are equal to emissions from decomposition.[4]

There are many reasons why we may want to include HWPs in forest carbon accounting. The amount of carbon stored in forest products may remain sequestered for a considerable time. In addition, carbon comprises about one half the mass of dry wood in structures, furniture and other finished wood products (Sjostrom 1993). Carbon that is transferred from the living timber into wood products can be considered an addition to the carbon that is stored as a result of forestry activities. The carbon stored in wood products increases with each harvest.

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[4] This is equivalent to assuming that such carbon is discounted at zero percent – that the timing or duration of uptake and release of CO_2 does not matter.

Carbon in wood products decreases when the product reaches the end of its life, although it might be recycled (prolonging the carbon storage), used for energy (displacing emissions from fossil fuel energy production), or left to decompose in a landfill (resulting in slow release of CO_2 over time). Thus, accounting for the forest product pool may result in better management of the forest and the various carbon pools, encouraging recycling and energy production through incineration. Accounting for HWPs could assist timber producing countries such as Canada meet carbon emission targets, particularly if the carbon sink benefits of forest products can be enhanced by including the abatement of CO_2 emissions resulting from the substitution of lumber for steel and/or concrete in construction (Hennigar et al. 2008).

There are reasons for discouraging the consideration of forest products, however, because doing so would increase carbon accounting complexity and introduce greater uncertainty into estimates of carbon flux. There are also concerns that it may incentivize enhanced forest management and harvests, while eroding concerns for forest conservation and protection (e.g., see van Kooten et al. 2012). It might also result in trade disputes related to the responsibility for carbon stored in HWPs. Forest product exporting countries would like to claim the carbon contained in products but consumer countries, such as the U.S., China and some EU countries, would not be willing to accept responsibility for CO_2 emissions from imported wood products as these decompose.

The impact of including wood products in forest sector carbon budgets can be analyzed by expanding forest management models to include products. Indeed, forest management models have been used to demonstrate how the inclusion of HWPs and CO_2 emission reductions caused by substituting wood products for steel and/or concrete can affect optimal forest management strategies and how these can significantly increase the forest sector's contributions towards reducing atmospheric carbon dioxide (Hennigar et al. 2008; van Kooten et al. 2012).

In Figure 4, we compare levels of carbon abatement when HWPs substitute for more fossil-fuel demanding products in construction. The results provide an indication of the impact on optimal harvest volumes when carbon storage in forest and product pools is considered in conjunction with different levels to which HWPs substitute for steel and concrete. Harvest levels are presented for a carbon price of $5/tCO$_2$ and a 200-year time horizon. As the substitution value rises, the optimal forest management strategy is to harvest trees as quickly as possible subject to sustainability and growth constraints; an increase in the 'pickling factor' (proportion of carbon in harvested biomass that remains sequestered in wood products for a long period) has a similar impact. Conversely, a scenario with a low substitution benefit encourages a more even pattern of harvests over the time horizon so that more harvesting occurs later in the horizon and less early on. Overall, the substitution benefit of removing 1 tC/m^3 (3.67 tCO$_2$/m^3) from the atmosphere results in an overall increased harvest of approximately 4.8 million m^3 over the 200-year time horizon as compared to the scenario with a substitution benefit of 0 tC.

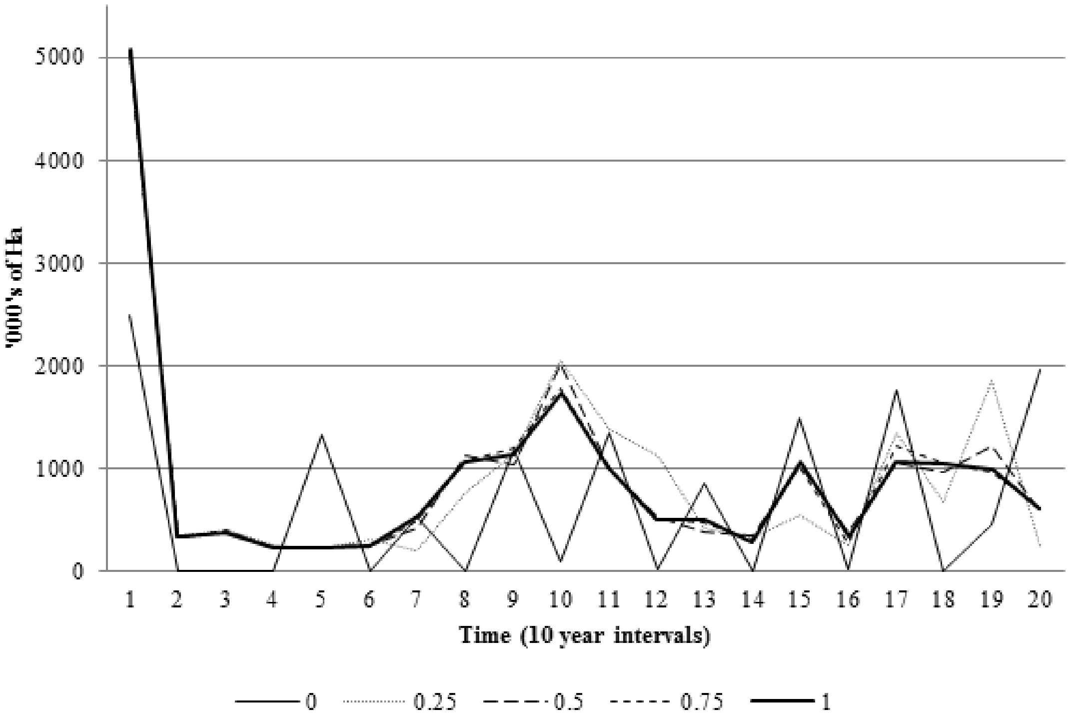
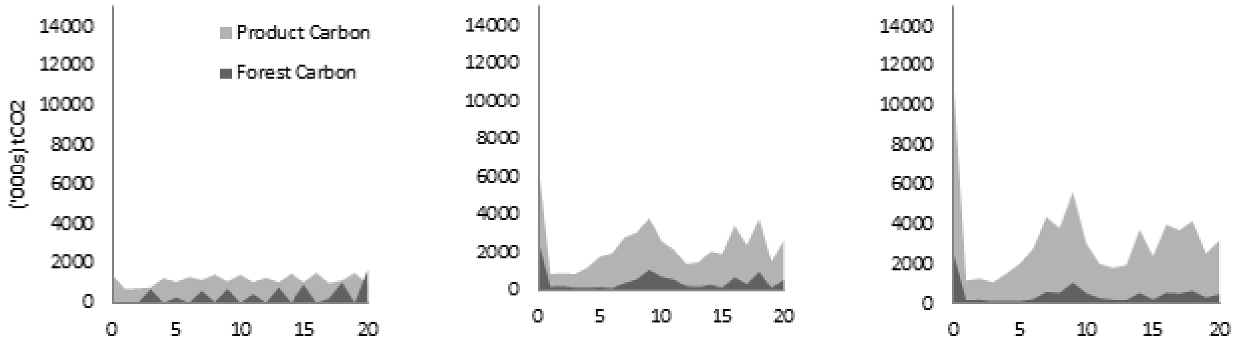


Figure 4: Volume harvested over 200 years for five lumber substitution benefit levels ranging from 0 to 1 t C abated from the atmosphere per m^3 *of lumber used relative to more fossil-fuel demanding products such as steel or concrete.*

By recognizing carbon stored in wood products, optimal forest management strategies change considerably for positive carbon prices. Not only do harvest patterns change with the degree of benefit of substitution, but also the magnitude of the overall harvest. With positive (non-zero) carbon prices, higher substitution benefits make it more profitable to harvest a greater amount of timber to be used in the production of wood products, particularly lumber. The next logical question is to ask: Does this increase or decrease the amount of carbon sequestered?

In Figure 5, we present the amounts of carbon stored in the forest and wood product pools over the 200-year time horizon; the product pool includes CO_2 savings from reduced fossil fuel emissions associated with the substitution of wood for steel and/or concrete. Different degrees of product substitution are assumed in the figure. Similar to the harvest volumes indicated in Figure 4, when account is not taken of the reduced fossil fuel emissions by substituting wood for other material in construction, the optimal forest management scheme leads to a small albeit consistent level of carbon storage in the forest and wood products over time (Figure 5(a)). As the degree of substitution increases, forest management strategies change (Figure 4) so that greater amounts of carbon are sequestered in both the forest ecosystem and product pools, although the latter simply swamps the former. This is clear from panels (b) through (e) in Figure 5.


(a) Sub. saving = 0 tC/m^3 (b) Sub. saving = ¼ tC/m^3 (c) Sub. saving = ½ tC/m^3

(d) Sub. saving = 3/4 tC/m^3 (e) Sub. saving = 1.0 tC/m^3

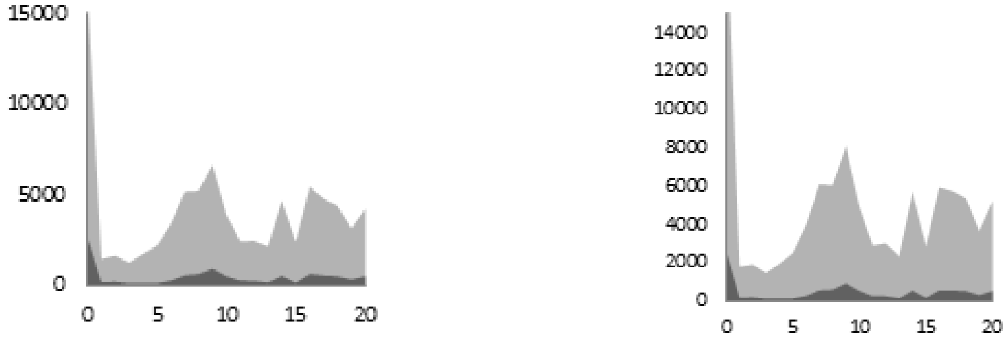


Figure 5: Carbon stored in forest and product pools over 200 years, five levels of substitution of lumber for steel and/or concrete, measured as per m^3 of commercial timber harvest.

If the issue of including the carbon stored in HWP were only technical, then it would likely have been included in the global protocols for carbon accounting long ago. In fact, there are limited technical questions left unanswered. International political obstacles to their acceptance remain because different issues need to be resolved. What nation should get credit for carbon stored in internationally traded wood products? Will acknowledging carbon storage in wood lead to more forest harvesting? Will recognizing the longevity of stored carbon in discarded products within landfills encourage waste and discourage durability and recycling? These are a few of the political questions which keep HWPs out of the global protocols.

6. Conclusions

There is no denying that forestry activities impact the Earth's carbon balance, with harvest activities contributing to human emissions of CO_2 and activities such as reforestation, afforestation and silvicultural activities that enhance tree growth removing CO_2 from the atmosphere and storing it in wood biomass. By taking into account the carbon that gets stored in wood product pools and potential substitution of wood for steel and/or concrete in construction, even harvest activities could enhance carbon uptake and storage. Further, forest activities that reduce CO_2 emissions, primarily conservation activities that prevent deforestation, benefit biodiversity and other services provided by forests. None of this can be denied. Nonetheless, none of this is sufficient to make the case that forest activities should be allowed to generate carbon offsets that can be sold in lieu of CO_2 emission reductions. As demonstrated in this chapter, the problems associated with the creation of carbon offsets through forestry activities are simply too complicated.

As one simple example, consider the issue of forest conservation and the creation of REDD or REDD+ credits. The idea is interesting, but, if harvested timber is used to produce wood products that then substitute for concrete in construction, say, the carbon offset benefits would swamp the carbon sink benefits of leaving the forest in its undisturbed state (Figure 5). There are other problems. Uncertainty and duration (impermanence) alone prevent the comparison of one forestry activity to sequester carbon with another, and neither can be compared with an emissions reduction. Transaction costs related to the striking of contracts, monitoring, verification and enforcement (how are those who act dishonestly in promoting projects to be punished?), and issues of governance, additionality and leakage simply militate against carbon offsets. Further, while we could demonstrate that carbon offsets lower the costs of meeting emission reduction targets, they also reduce incentives for investing in conservation, R&D and substation of renewable energy source for fossil fuels.

The road that enabled the inclusion of carbon offsets from forestry activities in nations' carbon mitigation arsenal has been a rocky one, and for good reason. Along with the biophysical uncertainty associated with the carbon fluxes associated with forestry activities (e.g., uncertain growth, natural disturbance), measurement, governance and transaction costs make it difficult to achieve any sort of policy consensus (e.g., agreement on REDD+, agreeing on which country to credit carbon offsets stored in traded wood products). Finally, even if nations managed to achieve consensus about how forest carbon offsets are to be treated, there remains uncertainty regarding whether a forestry project actually reduces the amount of carbon dioxide in the atmosphere. It is simply not possible to take into account all of the economic and biological factors that enable one to make an affirmative statement one way or another.

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