CARBON SEQUESTRATION IN FORESTRY

A report for

NUFFIELD IRELAND
Farming Scholarships

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2009 Nuffield Scholar

Sponsored by: Irish Co-Operative Organisation Society

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Executive Summary

Introduction

Widespread concern about global climate change has led to agreements to reduce emissions of carbon dioxide (CO_2) and, under certain circumstances, to count additional carbon absorbed in soils and vegetation as part of the emissions reductions. Forests are a significant part of the global carbon cycle. Plants use sunlight to convert CO_2, water, and nutrients into sugars and carbohydrates, which accumulate in leaves, twigs, stems, and roots. Plants also respire, releasing CO_2. Plants eventually die, releasing their stored carbon to the atmosphere quickly, or to the soil where it decomposes slowly, and increases soil carbon levels. However, little information exists on the processes and diverse rates of soil carbon change.

How to account for changes in forest carbon has been contentious. Land use changes, especially afforestation and deforestation, can have major impacts on carbon storage. Foresters often cut some vegetation to enhance growth of desired trees. Enhanced growth stores more carbon, but the cut vegetation releases CO_2; the net effect depends on many factors, such as prior and subsequent growth rates and the quantity and disposal of cut vegetation. Rising atmospheric CO_2 may stimulate tree growth, but limited availability of other nutrients may constrain that growth.

In this context, timber harvesting is an especially controversial forestry practice. Some argue that the carbon released by cutting exceeds the carbon stored in wood products, and in tree growth by new forests. Others counter that old-growth forests store little or no additional carbon, and that new forest growth and efficient wood use can increase net carbon storage. The impacts probably vary widely, and depend on many factors, including soil impacts, treatment of residual forest biomass, proportion of carbon removed from the site, and duration and disposal of the products. To date, the quantitative relationships between these factors and net carbon storage have not been established.

Some observers are concerned that "leakage" will undermine any efforts to sequester carbon by protecting domestic forests. By leakage, they mean that wood supply might shift to other countries, exacerbating global climate change and causing other environmental problems, or that wood products might be replaced by other products that use more energy to manufacture (thus releasing more CO_2). Others counter that the "leakage" arguments ignore the enormous disparity in ecological systems and product preferences, and discount possible technological solutions.

Several Government and EU programs affect forestry practices and thus carbon sequestration. Activities in forests affect carbon storage and release; timber harvesting is the most controversial of such activity. Forestry programs also provide technical and financial help for managing and protecting private forests, and tax provisions affect private forest management. Theses same programs can also affect the extent of forested area, by supporting development (which may cause deforestation) or encouraging tree planting in open areas, such as pastures.

There are 16,000 Irish Forest Owners in Ireland who are primarily farmers, their understanding of the complex subject, of the carbon debate is lacking and there is a role for a coordinating body in Ireland to educate and inform and thus empower these farmers.

Aims/Objectives

- To enable Irish Forest owners to get an understanding of carbon sequestration and how it relates to their forest holdings.

- To enable Irish Forest owners to take control of the subject from an Irish context, and become informed participants in the decision making process that impacts on them as foresters, farmers and ordinary citizens.

- To make constructive recommendations on domestic and EU policy that should be implemented to assist and stimulate the industry to bring new income streams back into the rural economy.

Methodology

A comprehensive literature review was carried out in advance of compiling this report covering Ireland, United Kingdom, USA, and New Zealand.
EU climate change policy and related documents were also consulted prior to international travel to UK, France, Italy, and United Arab Emirates.

Findings

Apart from the questions of whether climate change is occurring, and whether human activities are the cause, the role of forestry and land use in mitigating climate change has been quite controversial. The disputes are largely the result of the scientific uncertainties in measuring changing carbon levels in forests, changing land uses, and changing demand for products.
Different countries have various views on how to count carbon sequestered or released from forests. In general, countries with extensive and expanding forests (e.g., Russia, Canada, Brazil, and the United States) prefer a full accounting, while countries with less forestland (e.g., many European countries) are concerned about the potential to overstate the carbon benefits of forestry management practices and land use changes that enhance carbon sequestration. Countries with net deforestation rates are also concerned about counting forest sequestration, because it could effectively increase their net emissions, rated under international agreements.
Carbon dioxide sequestration is a valuable resource, and every effort must be made to maximise it's potential, particularly as projected industry figures state that, if the afforestation rate continues below 8,000 hectares per annum, Ireland's forests could become a carbon source by 2037.

A well-designed carbon accounting system should be transparent, consistent, and complete. The system used should be verifiable with efficient recording and reporting of changes in carbon stocks and/or changes in greenhouse gas emissions.

Recommendations

Provided it is practiced in a sustainable way, forestry makes a positive contribution to reducing our carbon emissions. In summary, the amount of CO_2 in the atmosphere can be reduced by:

- Increasing the amount of carbon stored in forests and forest soils
- Increasing the amount of carbon stored in wood products
- Using wood as a fuel, replacing fossil fuels
- Using wood to replace materials with high embodied energy
- Creating new forests on agricultural land

The exclusion of the forestry sector from the EU greenhouse-gas emissions trading regime means, that there is no formal market mechanism to identify the value of trees to sequester carbon. At farm-level, in the event of a greenhouse gas trading scheme for the agriculture sector, consideration could be given to the possibility of allowing farm operators to offset agricultural greenhouse gas emissions with on-farm sequestration, from newly planted forests

Forestry in Ireland provides a range of opportunities to directly offset increases in GHG emissions. It is estimated, that forest sinks alone accounted for a reduction of emissions of 1.36 Mt CO_2e. 80% of forests, planted since 1990 in Ireland, are privately owned, and therefore, account for the majority of these emission reductions. Currently, the value carbon credits from carbon sinks are not realisable by their owners.

It is recommended, that forest sinks be included as part of the measurement of emission reductions in the agriculture sector.
It is imperative, that the EU should agree that forest carbon sinks can be used to offset Ireland's CO_2 emissions. The inclusion of forest sinks is crucial for Ireland.
There is now a much better appreciation, that forest sinks should have a greater contribution, as regards national efforts to reduce greenhouse gas emissions.

As forestry, land use and farming are all part of the same climate change equation, this linkage should be recognised in relation to the EU's Forestry Policy CAP reform post 2013, and, in particular, the EU's climate change strategy.

In my view, the logic is simple, **Cows Emit; Forests Sequester, link the two and we have two productive land uses co-existing.**

The European Union should set out a clear legal and regulatory framework for forest carbon offsets in Member States, such as Ireland, where additional afforestation has the potential to make a significant contribution to reducing emissions.
Such a move would result in a significant up-lift in current afforestation levels (what could be termed a 'Carbon Afforestation Scheme').

In the United Arab Emirates (UAE), carbon offsetting means spending billions of Euro on a carbon neutral Masdar City (www.masdar.ae), which could be described as a "Vanity Project" and not a practical immediate solution to carbon reduction. If only a small percentage of this investment was enticed into the Irish Forestry sector, it could transform the industry.

Background

‘**Properly managed, woodland is an infinitely renewable resource**.’
(Rackham 1990)

I have been farming, in one form or another, since I could think for myself. I come from a dairying background and one of a family of nine, on a farm that would only support one family. Realising that I had only a 9/1 chance of inheriting the family farm, I carved out a career in Civil Engineering, and formed my own rural based and successful Architectural /Engineering practice. The inherent desire to farm, and for farm ownership, is so deeply engrained in my soul, I believe it must be in my genetic makeup.
Acquiring land in Ireland is difficult, as only 3% of the land area in the country changes hands per annum. I was fortunate, that my career choice gave me the income stream to invest in land, and begin my farming career in 1991. You could say, I took the scenic route!!!

When I planted my first forestry back in 1999, I had a wonderful sense of achievement; I had given birth to living woodland that in all probabilities, with good Pro Silva Management, would outlive me. My investment was a passive source of income, and would provide security and a pension for me into my old age and, also provide an asset which could be passed onto the next generation.
Eleven years later, and seven further woodlands planted, my sense of achievement has heightened, given the turmoil of the world economy. Forestry has proven to be extremely resilient to the market meltdown which we are experiencing. Forestry is a tangible asset, unlike the financial instruments that have been traded in one form or another, over the past decade, which has seen a pyramid scheme, on a world scale, collapsing.
Initially, my study subject was to include environmental accreditation and value added timber products. I very quickly established, if I was to do justice to the main topic
“ Carbon Sequestration on Forestry”, I needed to narrow my focus, and consequently, the study as described herein.

I approached the subject from the aspect of the humble farmer/forester, coming to terms with understanding the very complex subject of Carbon Sequestration, where we fit in the National, and European context, and how we can play our part in carbon mitigation, and of course, claim the monetary benefits that may ensue.

Introduction

The Irish forestry sector is a relatively new, but important indigenous industry. The national forest estate has increased from a modest 89,000 hectares in 1928 to 730,000 hectares in 2008. Of this, 46% is privately owned, and the remaining 54% is State owned. The species composition of the national estate is, 25% broadleaf and 75% conifer species.

The private sector forest estate is relatively new, with almost 80% having been planted in the past 20 years. Over 16,000 farmers have planted forests as part of their farming enterprise, with the average size of farm forests being c. 8 hectares.
Crops planted over the past 15-20 years ago, are just beginning to come into the first thinning stage. Consequently, only a small portion of the national timber harvest is derived from privately owned forests.
Ireland's forestry sector is small, by European standards. The percentage of forested land is the second lowest in the European Union, followed only by Malta.

Snapshot of the Irish Forestry Estate

- Only 10% of Ireland is forested compared to the EU average of 36%.
- Forestry in Ireland now employs around 16,000 people. A further 14,000 farmers have also planted land.
- There are 2.4 billion trees growing in the entire forest estate, containing 30 million tonnes of carbon.
- Average carbon storage rates in Irish forest plantations are estimated to be 3.4 tonnes of carbon, per hectare, per annum.
- Over 70 million trees are planted each year in Ireland.

Currently, Ireland produces around 80m tonnes of CO2/year. Agriculture accounts for about 27pc of this. This is due to the fact that we have large dairy and beef industries, and export 75pc of what we produce.

Ireland is producing enough food to feed around 20m people worldwide. (Irish Population in 2006 - 4.25 million)

This translates into our agricultural sector having a large carbon footprint. Around 40pc of the emissions attributed to agriculture originate directly from the natural function of the rumen in cattle and sheep, which produces almost 8m tonnes of CO2 per year. Also 58% of all nitrous oxide emissions in Ireland come from the land-based sector, so it's a really big issue!!.

US:

The American Clean Energy and Security Act will set up a Cap and Trade scheme larger than the EU ETS. (European Union Emissions Trading Scheme)
Unlike the ETS, the Bill offers US operators extensive access to land use offsets, (including forestry) both domestically and internationally, to meet their emission reduction obligations; a massive 2 billion tonnes. These are referred to as tCERS (term offsets), which offer farmers an early income stream from carbon, with no long term commitment to land. If the US position is maintained, future CAP negotiations

may force the EU to change its stance on domestic offset opportunities.
In addition, the voluntary Chicago Climate Exchange (CCX) includes a carbon offset scheme, that allows offset project developers to sell emission reductions to CCX members, who have voluntarily agreed to meet emission targets. The Western Climate Initiative and the Regional Green House Gas (GHG) initiative, both in the US, also include carbon offset schemes.

France:
In March 2007, the Ministry of Finance and the Ministry of Environment, introduced a regulatory framework for a domestic carbon offset programme.

Italy:
In the period 2009-2011, an EU Life Programme funded the setting up of a Local Voluntary Carbon Market for carbon credits (Carbomark).
Carbomark market involves two regions in north-east of Italy – Veneto and Friuli Veneza Giulia.
The market service started in September 2010, when local small and medium enterprises had the opportunity of buying local carbon credits to offset their emissions.

New Zealand:
Government introduced legislation in 2009 to introduce a Carbon Trading Scheme for the Forestry Sector.
Forestry credits are now trading in the domestic New Zealand Emissions Trading Scheme, through a government backed system. These Credits are also tradable on the international markets.

UK:
In an effort to inform and safeguard business and household consumers purchasing carbon offsets, the UK Government introduced a scheme for regulating carbon offset products.
The Department for Environment, Food and Rural Affairs has created the 'Approved Carbon Offsetting' brand, to use as an endorsement on offsets approved by the UK Government. In addition, several companies are now offering forest offset credits which are being purchased by, for example, Marks & Spencer, Stagecoach, and many others.

Australia:
The Australian Government's policy is to work with farmers to encourage sustainable farming practices, that reduce emissions and develop carbon sinks. The Government is consulting, at present, on the regulation of carbon offsets, including setting a standard that will provide guidance on what constitutes a genuine, additional voluntary offset credit, and also to set requirements for the verification and retirement of such credits. Furthermore the Australian Government has been attempting to introduce the 'Carbon Pollution Reduction Scheme' (CPRS) - a wide ranging effort to reduce Australian net carbon emissions that covers, inter alia, the LULUCF sector since 2009.

Chapter 1

Carbon Sequestration in Forests

Global climate change is a widespread and growing concern that has led to extensive international discussions and negotiations. Responses to this concern have focused on reducing emissions of greenhouse gases, especially carbon dioxide, and on measuring carbon absorbed by, and stored in forests, soils, and oceans.
One option for slowing the rise of greenhouse gas concentrations in the atmosphere, and thus possible climate change, is to increase the amount of carbon removed by, and stored in forests. As world countries debate climate change, and options for addressing the issue; ideas for increasing carbon sequestration, in forests, are also been discussed.

This part of the report examines basic questions, concerning carbon sequestration in forests. The first section provides a brief background on general interest in forest carbon sequestration. The second section describes the basic carbon cycle in forests, with an overview of how carbon cycling and storage vary among different types of forests. The third section, addresses how forest carbon is considered in the global climate change debate. The fourth section gives an overview of accounting for forest carbon, then discusses the carbon consequences of forest management practices, the effects of changes in land use, and "leakage." The final section then concludes with a summary of existing programs that could affect forest carbon sequestration.

Background

The widespread and growing concern over global climate change, has led to extensive international negotiations. In 1992, at the Earth Summit in Rio de Janeiro, the United Nations Framework Convention on Climate Change (which included voluntary pledges to reduce greenhouse gas emissions) was opened for signature.
Subsequent negotiations led to the 1997 Kyoto Protocol, under which the developed nations agreed to specified reductions in their emissions of greenhouse gases.

The most voluminous greenhouse gas produced by humans is carbon dioxide (CO_2). In calculating overall carbon emissions, the Protocol allows certain removals of carbon, by a nation's forests and soils "carbon sinks", to be counted and deducted from emissions. Thus, one option for mitigating greenhouse gas emissions, and thus possible climate change, is to increase the amount of carbon stored in forests.

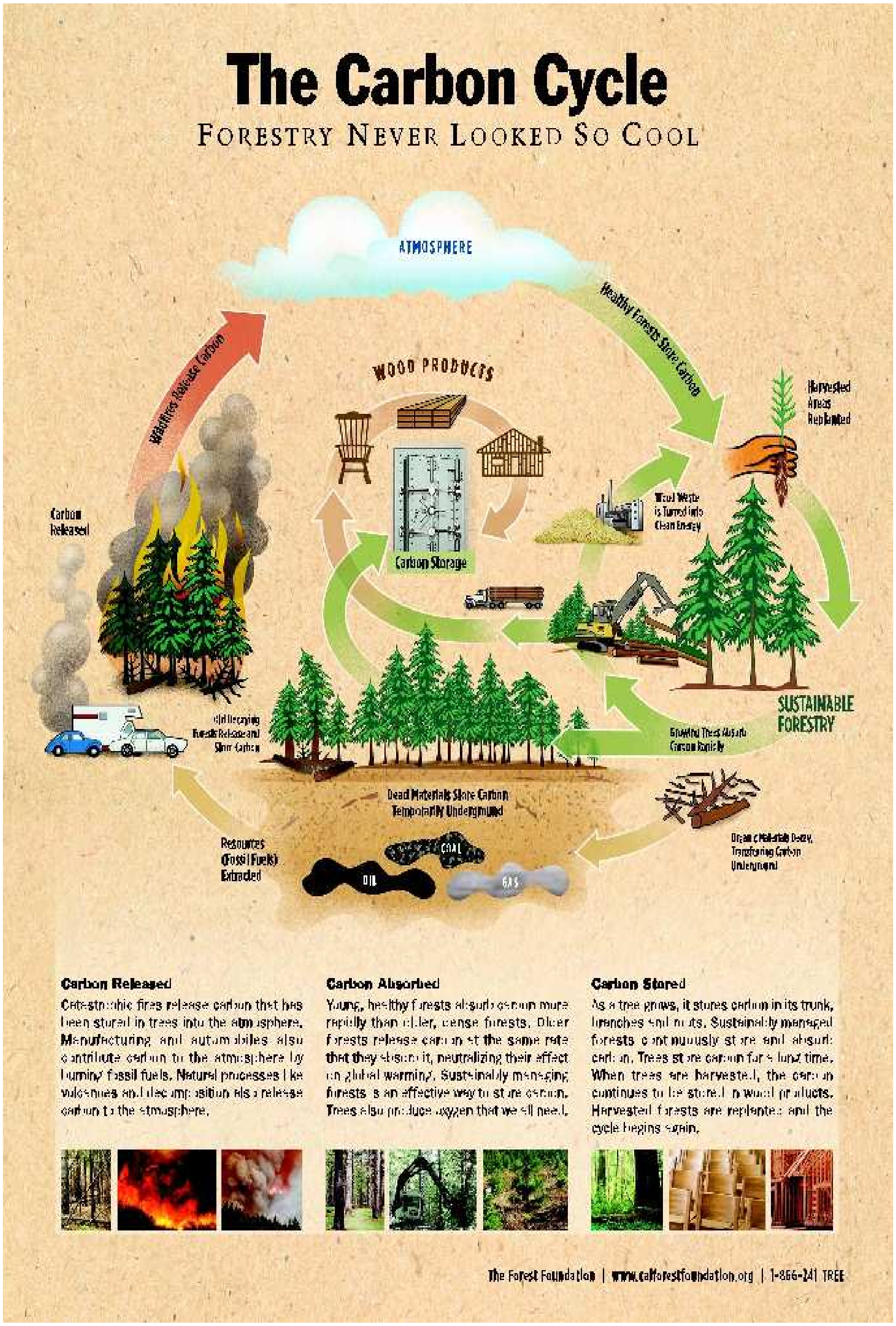
Carbon sequestration, and the extent to which it can be counted as a reduction in a nation's carbon emissions, have been the focus of substantial controversy in international negotiations to finalise the operational rules of the Kyoto Protocol. Countries like the United States, with its extensive forests, argue that the carbon absorbed by them should be allowed to offset emissions, with no quantitative limit to the amounts that can be counted in this way. The European Union argued strongly, in negotiations prior to 2001, that there should be fairly strict limits on how much carbon absorbed by "sinks", such as forests, could be counted against emissions. In final negotiations, during 2001, on rules to implement the Kyoto Protocol, and after the United States had withdrawn from the negotiations, a compromise was reached that allows significant credit for carbon sinks (removals and storage of carbon).

Mitigating climate change, by enhancing forest carbon sequestration, may be a relatively low-cost option, and would likely yield other environmental benefits. However, forest carbon sequestration faces challenges: measuring the *additional* Carbon stored (over and above what would occur naturally); monitoring and verifying the results; and preventing leakage. Numerous issues regarding the carbon cycle in forests, monitoring the levels and changes in forest carbon, and the scientific uncertainties about the relationships among forests, carbon, and climate change are likely to be the subject of ongoing research efforts, with funding from the Department of Agriculture, through organisations like COFORD.

Carbon Cycling in Forests

Photosynthesis is the chemical process by which plants use sunlight to convert nutrients into sugars and carbohydrates. Carbon dioxide (CO_2) is one of the nutrients essential to building the organic chemicals that comprise leaves, roots, and stems. All parts of a plant — the stem, limbs and leaves, and roots — contain carbon, but the proportion in each part varies enormously, depending on the plant species and the individual specimen's age and growth pattern. Nonetheless, as more photosynthesis occurs, more CO_2 is converted into biomass, reducing carbon in the atmosphere and sequestering (storing) it in plant tissue (vegetation) above and below ground. Plants also respire, using oxygen to maintain life, and emitting CO_2 in the process. At times (e.g., at night and during winter seasons in non-tropical climates), living, growing forests are net emitters of CO_2, although they are generally net carbon sinks over the life of the forest. When vegetation dies, carbon is released to the atmosphere. This can occur quickly, as in a fire, or slowly, as fallen trees, leaves, and other detritus decompose. For herbaceous plants, the above-ground biomass dies annually, and begins to decompose right away, but for woody plants, some of the above-ground biomass continues to store carbon until the plant dies and decomposes. This is the essence of the carbon cycle in forests, net carbon accumulation (sequestration) with vegetative growth, and release of carbon when the vegetation dies. Thus, the amount of carbon sequestered in a forest is constantly changing with growth, death, and decomposition of vegetation.

In addition to being sequestered in vegetation, carbon is also sequestered in forest soils. Carbon is the organic content of the soil, generally in the partially decomposed vegetation (humus), both on the surface and in the upper soil layers, in the organisms that decompose vegetation (decomposers), and in the fine roots. The amount of carbon in soils varies widely, depending on the environment, and the history of the site. Soil carbon accumulates, as dead vegetation is added to the surface, and decomposers respond. Carbon is also "injected" into the soil as roots grow (root biomass increases). Soil carbon is also slowly released to the atmosphere as the vegetation decomposes. Scientific understanding of the rates of soil carbon accumulation and decomposition, is currently not sufficient for predicting changes in the amount of carbon sequestered in forest soils.


The Carbon Cycle
FORESTRY NEVER LOOKED SO COOL
ATMOSPHERE
Wildfires Release Carbon
Healthy Forests Store Carbon
WOOD PRODUCTS
Carbon Storage
Harvested Areas Replanted
Wood Waste is Turned into Clean Energy
Carbon Released
SUSTAINABLE FORESTRY
Growing Trees Absorb Carbon Rapidly
Dead Materials Store Carbon Temporarily Underground
Resources (Fossil Fuels) Extracted
COAL
OIL
GAS
Carbon Released
Catastrophic fires release carbon that has been stored in trees into the atmosphere. Manufacturing and automobiles also contribute carbon to the atmosphere by burning fossil fuels. Natural processes like volcanoes and decomposition also release carbon to the atmosphere.
Carbon Absorbed
Young, healthy forests absorb carbon more rapidly than older, dense forests. Older forests release carbon at the same rate that they absorb it, neutralizing their effect on global warming. Sustainably managing forests is an effective way to store carbon. Trees also produce oxygen that we all need.
Carbon Stored
As a tree grows, it stores carbon in its trunk, branches and roots. Sustainably managed forests continuously store and absorb carbon. Trees store carbon for a long time. When trees are harvested, the carbon continues to be stored in wood products. Harvested forests are replanted and the cycle begins again.
The Forest Foundation | www.calforestfoundation.org | 1-866-241 TREE

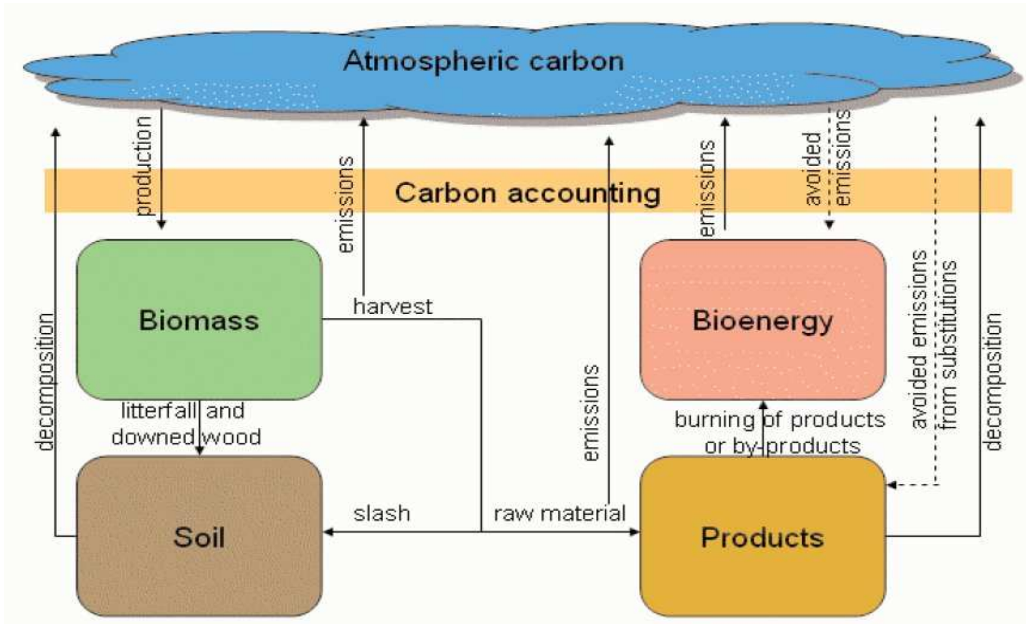


Figure 1: Carbon Cycle [1]

[1] Modelling Framework for Carbon Sequestration in Forest Ecosystems. Alterra-rapport 1068, Wageningen, Netherlands.

Forest Cycle

Forests generally go through cycles of growth and death, sequestering and releasing carbon. Some forests begin on spacious sites, with little or no existing vegetation, which may have been cleared by a natural disaster (most commonly wildfire) or by human activities (e.g., for agriculture). Other forests are relatively continuous, with natural clearings typically limited to the area occupied by one or a few large trees killed by lightning, disease, and such. Regardless of the size, or origin of a clearing, most forests begin from essentially bare land, with some carbon stored in the soil (how much, depends on the environment and history of the site, especially the last clearing process).

As trees and other woody plants become established, carbon stored on the site increases as woody biomass increases and as annual vegetation (e.g., tree leaves and herbaceous plants) typically grows faster than it decomposes. Productivity for commercially usable wood, generally follows an S-shaped curve, with the volume growing at an increasing rate for many years, to a point known to foresters as the culmination of mean annual increment (generally taking 20 to 100 years or more, depending on the fertility of the site and the tree species), and then growing at a decreasing rate for many more years. In theory, forests can eventually become "over-mature," where the loss of commercial volume, through tree mortality, equals or exceeds the additional growth on the remaining trees. However, one study has shown that some old-growth ("over-mature") forests continue to accumulate carbon in their soils.

The relationship between commercially utilizable wood produced and the amount of carbon sequestered varies substantially in three ways. Firstly, the proportion of carbon in a tree's commercial wood (compared to the noncommercial biomass in bark, limbs, roots, and leaves or needles) varies among species; some (e.g., pines and other conifers) have a greater proportion of their total carbon in commercial wood.
Secondly, the proportion of carbon in a tree's commercial wood undoubtedly changes over time; while a temporal graph of carbon storage is probably also S-shaped (as for commercial wood productivity), the changes in timing and rates of increase (that cause the characteristic S shape) certainly differ. Finally, a significant portion of the vegetative carbon sequestered in a forest is in other plants — noncommercial species of trees, shrubs, grasses, and other herbaceous plants. The amount of carbon stored in this other (noncommercial) growth varies widely among forests. Thus, although many research studies assume a fixed relationship between commercial wood inventories, and the amount of carbon stored, the traditional measures of commercial wood production, might not be very accurate for estimating carbon sequestration in forests.

Eventually, trees die. They may be cut down, burned in a wildfire, blown over or snapped off in a wind or ice storm, or killed by insects or diseases. Death can happen to a single tree in a forest, creating a small opening, or to all or most trees in an area. How quickly the carbon is released to the atmosphere, depends on the cause of tree death, on whether it is harvested for use, and on various environmental factors. As noted above, fires quickly break down biomass, and release an enormous amount of CO_2 into the atmosphere. Natural death and decay may require several weeks to several decades to completely decompose the biomass (depending on site conditions), putting some carbon into the soil and some directly into the atmosphere.

Timber harvesting can store some vegetative carbon, for very long periods, in solid wood products with long-term uses (e.g., construction lumber in houses), while tree tops and limbs and noncommercial species are left to decay, or to be burned. These possibilities are discussed in more depth below, under "Forestry Events and Management Activities."

Forest Types

Carbon sequestration and release vary substantially by forest. Nonetheless, some generalisations are possible, because of the relative similarity of forests in specific “biomes", tropical, temperate, and boreal forests. **Table 1** shows average carbon levels sequestered in vegetation and soils for several major biomes, and the weighted average for all biomes.

Table 1. Average Carbon Stocks for Various Biomes[2]

(Global carbon stocks in vegetation and soil carbon pools down to a depth of 1 m.)

Biome(tons/acr)	**Area (10^9 ha)**	**Global Carbon Stocks (Gt C)** Vegetation	Soil	Total
Tropical forests	1.76	212	216	428
Temperate forests	1.04	59	100	159
Boreal forests	1.37	88	471	559
Tropical savannas	2.25	66	264	330
Temperate grasslands	1.25	9	295	304
Deserts and semideserts	4.55	8	191	199
Tundra	0.95	6	121	127
Wetlands	0.35	15	225	240
Croplands	1.60	3	128	131
Total	15.12	466	2011	2477

Note: There is considerable uncertainty in the numbers given, because of ambiguity of definitions of biomes, but the table still provides an overview of the magnitude of carbon stocks in terrestrial systems.

[2] **Source:** Adapted from Intergovernmental Panel on Climate Change, "Table 1: Global carbon stocks in vegetation and carbon pools down to a depth of 1 m [meter]," *Summary for Policymakers: Land Use, Land-Use Change, and Forestry.*

Tropical Forests

Tropical forests are generally defined by their location — between the Tropic of Cancer and the Tropic of Capricorn (23° north and south of the Equator, respectively). Some tropical forests are relatively dry, open woodlands, but many receive heavy rains and are called moist or humid tropical forests; these are the classic rainforests, or "jungles." Tropical forests contain an enormous diversity of "hardwood" tree species, and are difficult to categorise into "forest types," because of this breadth of species diversity.

Moist tropical forests are important for carbon sequestration, because they typically have high carbon contents, averaging nearly 110 tons per acre. **(See Table 1)**
About half of the carbon, in moist tropical forests, is contained in the vegetation, a higher percentage, and a much higher quantity, than in any other biome.
The remaining carbon is in tropical forest soils; tropical forest soils have only modest carbon levels (compared with other biomes), because the dead biomass rapidly decomposes in the warm, humid conditions, and the minerals rapidly leach out of tropical forest soils.

Temperate Forests

Temperate forests typically occur in the mid-latitudes, generally to about 50° north and south of the Equator (a little further north in Europe, because of the continental warming from the Gulf Stream). There are a large variety of temperate forests, including hardwood types (e.g., oak-hickory and maple-beech-birch), softwood types (e.g., southern pine, Douglas-fir, and lodgepole pine), and a few mixed types (e.g., oak-pine). However, within each forest type, and overall, temperate forests have much lower tree species diversity than tropical forests.

Temperate forests generally contain less carbon than tropical forests, averaging nearly 70 tons per acre. More than one-third of the carbon is stored in the vegetation, and nearly two-thirds in the soil. The higher proportion (but lower level) in the temperate forest soils (compared to tropical forest soils) is because of slower decomposition rates. Many of these forests are managed to produce commercial wood products, and the management practices, used in temperate forests, can have a significant impact on carbon sequestration.

Boreal Forests

Boreal forests generally occur north of temperate forests, mostly in Alaska, Canada, Scandinavia, and Russia. (The only boreal forests in the Southern Hemisphere are on mountaintops in New Zealand and high in the Andes Mountains of South America.)
Boreal forests are dominated by conifers, mostly spruce, fir, and larch, with scattered birch, and aspen stands.
Boreal forests generally contain more carbon than temperate or tropical forests, averaging more than 180 tons per acre. Less than one-sixth of boreal forest carbon is in vegetation. The rest, 84%, is in boreal forest soils, about three times the amount in temperate and tropical forests, and far higher than any other biome, except wetlands.

Carbon accumulates to high levels in boreal forest soils, because of the very slow decomposition rates, owing to short summers, and the high acidity of conifer forest soils, both of which inhibit decomposition. The high boreal forest soil carbon level is important for carbon cycling, because many believe that management activities, that disturb boreal forest soils, can increase their release of carbon.

Chapter 2

Measuring and Altering Forest Carbon Levels

Aside from the questions of whether climate change is occurring, and whether human activities are the cause, the role of forestry and land use in mitigating climate change has been quite controversial. The disputes are largely the result of the scientific uncertainties in measuring changing carbon levels in forests, changing land uses, and changing demand for products. This section summaries forest carbon accounting concerns, possible consequences of changes in land use, forest management events and practices, "leakage," and existing EU programs related to these concerns.

Carbon Trading Explained [3]

Carbon Trading

Emissions Trading or 'Cap-and-Trade'

Pollution permits to large industrial emitters [e.g. emission allowances under the EU Emissions Trading Scheme [ETS];

Trading that involves the selling and buying of such allowances / permits is often referred to as 'cap-and-trade' because the volume of permits limits / caps the amount of emissions, which can then be traded among companies.

If such permits were auctioned, and the focus were on the companies upstream in the fossil fuel economy [refineries, energy utilities e.g.] such cap-and auction would not be that different from a carbon tax but would likely be less effective and involve much more price volatility than a tax.

In all of the existing cap-and-trade schemes, the permits are by-and large handed out for free, resulting as in the ETS in huge windfall profits for e.g. the energy utilities who passed on the extra cost – and more- to the energy consumer.

Also, the ETS is not really a cap-and-trade' scheme because the cap has a hole: **The EU Linking Directive**.

This Directive allows companies covered by the ETS to release more greenhouse gases than they have allowances for as long as they buy a necessary volume of carbon credits from offset projects approved by the Kyoto Protocol's Clean Development Mechanism (CDM; project in the South) or Joint Implementation (JI, offset project in another country with a Kyoto emission target, mostly Eastern European countries).

Offset Schemes or Project-based credits

Carbon credits from offset projects: Projects claim that their emissions are lower than the emissions that 'would have happened otherwise'. The difference between the projects actual emissions and the hypothetical emissions 'that would have happened without the project' is the volume of carbon credits the project can sell to 'offset' / 'neutralise' someone else's emissions elsewhere. The reasoning is that these 'additional' emission reductions would not have happened without the extra carbon money and that therefore the climate impact of extra emissions elsewhere is 'offset'.

Because the calculations involve quantifying a hypothetical scenario of 'how many emissions would have been released without the project', none of these offset projects can ultimately verify their claim of x additional tonnes of emissions having been reduced by their project.

"Offset credits are an imaginary commodity created by deducting what you hope happens ***from what you guess would have happened***."
Dan Welsh

Kyoto Offset Market

Offset credits from projects related to the Kyoto Protocol: (1) Clean Development Mechanism (CDM) projects which are approved by the CDM Executive Board and which sell 'certified emission reductions' CERs

(2) Joint Implementation projects

Project list: http://cdm.unfccc.int/index.html

Voluntary Offset Market

Projects that sell carbon credits to individuals and companies without any legal emission limits, often carmakers, airlines, oil companies. Compared to the Kyoto offset market, the voluntary offset market is characterised by a lack of transparency and projects do not require any form of third-party verification or approval against an agreed standard. Some such standards exist and some projects are assessed by third parties but criticism abounds about the quality of both the verification processes and the projects. More than 40 companies sell such voluntary 'offset' credits.

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[3] Source Coford

Forest Carbon Accounting

Different countries have various views on how to count carbon sequestered or released from forests. In general, countries with extensive and expanding forests, (e.g., Russia, Canada, Brazil, and the United States) prefer a full accounting, while countries with less forestland (e.g., many European countries), are concerned about the potential to overstate the carbon benefits of forestry management practices, and land use changes, that enhance carbon sequestration. Countries with net deforestation rates, are also concerned about counting forest sequestration, because it could effectively increase their net emission, rated under international agreements.

Article 3.3 of the Kyoto Protocol, allows counting the carbon effects (both sequestration and release) of afforestation, reforestation, deforestation, and other forestry and land use changes, that have occurred since 1990, if the change in carbon stock is verified. Verification requires a system for estimating the carbon effects, because a census of carbon changes on every forested acre is unfeasible,for reporting the carbon effects.

For countries with carbon commitments (rather than for projects), the surest, easiest system for verifying the change in carbon levels is to measure the change in the levels from the beginning to the end of the relevant time period — 1990 (the baseline) and 2008-2012 (the Kyoto Protocol commitment period); however, this is a very slow and expensive approach. A variety of models can be used for estimating carbon level changes. The two basic approaches are:

1. A "land-based" approach, which begins by identifying the acceptable activities for sequestering carbon, and estimating the carbon consequences of those activities, and then monitoring the lands to determine the extent to which those activities occur,
2. A "activity-based" approach, which also begins by identifying the acceptable activities for sequestering carbon, estimating the carbon consequences of those activities, and then monitoring the activities to determine the extent to which those activities occur.

The approach taken, affects the intensity and spatial scale of the monitoring required, and different models impose different requirements for data, boundary conditions, carbon stocks, and more. However, the Intergovernmental Panel on Climate Change contends that, regardless of the approach and model.

A well-designed carbon accounting system would provide transparent, consistent, comparable, complete, verifiable, and efficient recording and reporting of changes in carbon stocks and/or changes in greenhouse gas emissions by sources and removals by sinks from applicable land use, land- use change, and forestry activities and projects under relevant Articles of the Kyoto Protocol.
There are significant difficulties in achieving such a "well-designed carbon accounting system." Some observers have noted that the "language, terminology, and accounting methods contained in the (Kyoto Protocol) are somewhat vague and can be interpreted in different ways." In addition, there are scientific uncertainties in measuring the 1990 baseline carbon stocks, the lands treated, the carbon impacts of various treatments, and the issue of ‘leakage’ as discussed in the following sections.

Land Use Changes

Over time, forests can grow on lands that were in other uses (e.g., croplands), and vice versa. Deforestation is the conversion of forests to pasture, cropland, urban areas, or other landscapes that have few or no trees. Afforestation is planting trees on lands that have not grown trees in recent years, such as abandoned cropland.

The conversion of forestland to other uses is dominated by development. The rate of development reflects economic growth, interest rates, development incentives, stronger growth, lower interest rates, and greater incentives stimulate more development (and more conversion of forestland), while slower growth or recession, higher interest rates, or weaker incentives, may retard development. While individual countries monetary, fiscal and tax policies clearly affect development rates, their impact on forest land conversion is less of a consideration, than the goal of trying to provide stable economic growth for their respective economies. Although conversion of pasture and cropland to forests is also affected by the general economy, it is also likely to be directly affected by individual country programs, such as the forestry programme in Ireland.

Forestry Events and Management Activities

As discussed above, forests cycle carbon, accumulating carbon from the atmosphere during some periods in the forest cycle and releasing carbon to the atmosphere at other times. When forest practices alter the vegetation on a site, they alter this ebb and flow of carbon storage and release by changing biomass levels, vegetative growth patterns, soil structure and composition. This section examines the implications of various forestry practices and events for carbon sequestration. Firstly, however, it examines generic considerations of what happens to the carbon in cut vegetation and in soils from forestry practices.

Vegetation and Soil Carbon

A wide array of practices is used in managing forests. Most involve altering the vegetation, and thus the carbon cycle, on the site. Before discussing specific practices, it is important to examine what happens to vegetation that is cut but not removed from the forest, and what happens to the soil carbon. These factors apply to most, if not all, forest management practices.

What Happens to the Cut Vegetation?

Most forest practices involve cutting some of the existing vegetation on a site to harvest commercial wood, to focus growth on fewer trees, to reduce competition among plants, etc. What happens to the cut vegetation is critical for assessing carbon sequestration. When commercial harvests are involved, some of the biomass is removed from the site and turned into products. (The carbon consequences of removed vegetation are discussed below.)

The amount of biomass (and carbon) removed has not been broadly quantified, various studies report that 50% to 80% of tree carbon (excluding forest soil carbon) is removed in commercial timber harvest operations. Others have stated that "wood products formed only a modest fraction of the total" carbon stored by a forest. This is consistent with a newer report showing wood products (and landfills) accounting for a little more than 6% of forest-related carbon stocks. The proportion of carbon and biomass removed from any particular site varies widely, and depends on the species involved, the density of the stand (which affects both tree form and undergrowth vegetation), the diversity of tree species and tree sizes in the stand, and various environmental factors (e.g., the site's climate and soil fertility).

Much biomass (and carbon) remains on the site; for some forest practices, such as pre-commercial thinning (described below), all the cut biomass remains on the site. The remaining biomass, coarse roots, limbs, leaves or needles, and other unusable woody material, often called "Brash" in timber harvesting — begin to deteriorate, and to release carbon. How fast the carbon is released, depends on whether and how the biomass is treated. Brash treatments include rolling, chopping, and crushing, all of which are designed to compact the biomass and accelerate its deterioration, which typically takes several weeks to several years, depending primarily on the climate. Burning is also common, and leads to deterioration (and release of some of the carbon to the atmosphere) in minutes or hours, rather than weeks, months, or years.

Many research studies presume that the carbon from brash is released within a year of the harvest, others presume that it is quickly absorbed by new growth resulting from the treatment. Data on the extent of various brash treatments and on the carbon impacts of the various treatments are sparse.

What Happens to Forest Soil Carbon?

There is relatively little literature, on forests and carbon, address the mechanisms by which carbon is accumulated in and released by forest soils. There is large uncertainty in estimates of change in soil carbon. Decomposers, primarily invertebrate animals and fungi, break down dead vegetation. Decomposition releases carbon to the atmosphere and incorporates carbon as organic matter (humus) in the soil. The dead carbon in the soil (i.e., not the decomposers or fine plant roots, which comprise the living carbon in the soil) slowly continues to decompose, changing from organic to inorganic forms; the inorganic forms eventually

(1) dissolve in percolating rainwater and leach through the soil into groundwater and surface waters;
(2) oxidize and get released directly to the atmosphere; or
(3) are absorbed by new vegetation.

The rates at which carbon, from dead vegetation, returns to the atmosphere depend on a variety of factors, such as the nature of the vegetation, the composition of the soil, and the humidity levels, all of which affect the type and quantity of decomposers on a site.

Activities that disturb soils, almost certainly decrease soil carbon levels. Some studies presume a loss of soil carbon, following a soil-disturbing activity, such as timber harvesting. Others note the loss without quantifying it. In general, disturbing soils accelerates decomposition rates, by increasing exposure of soil carbon to air, thus accelerating oxidation. Activities that disturb soils, also kill living soil carbon, invertebrate animals, fungi, and fine roots, which then begin to decompose. Thus, forestry activities that disturb soils, particularly activities to remove the cut vegetation (such as commercial timber harvesting), will also likely reduce soil carbon levels. Forestry activities that do not disturb soils, such as fertilisation and prescribed burning, probably have much less effect on soil carbon, although they affect the forest carbon balance in other ways (as discussed below).

Forest Events — Fire

Fires in forests and grasslands are common events that significantly affect the carbon cycle. As noted above fire is a self- sustaining chemical process that quickly mineralizes organic matter, in minutes. Fires convert organic matter into its components, minerals, water vapor, and CO_2. Fires are a very significant source of atmospheric CO_2, and the need to control fires, to reduce CO_2 emissions, as well as for safety reasons, needs to be discussed.
Furthermore, the likelihood, extent, and/or frequency of fires may be exacerbated by expected climate change. Fire is a natural phenomenon, although efforts are made to manage fires.

Forestry Practices

In general, forestry practices are used for four basic goals or purposes: to establish trees on a site; to reduce vegetative competition; to improve tree growth in other ways; and to harvest the commercially usable wood. In the climate change negotiations, credit for carbon, sequestered by forests, was considered allowed, only for additional carbon sequestered because of changes in forestry practices.

Stand Establishment

One basic objective of forestry is getting trees to start growing. On sites that have recently had trees on them, but are now cleared (because of timber harvesting or natural disaster), the practice is called reforestation. Tree planting on sites that have not recently had trees on them, such as pastures, is called *afforestation*. In addition, *interplanting* (planting additional trees) is used on sites that have fewer trees than are considered desirable.

Reforestation can use natural or artificial methods. Natural regeneration relies on tree seeds, from surrounding forest stands. Artificial regeneration includes planting seeds, or more commonly seedlings from nurseries, on the site. Advantages of natural regeneration include, lower cost and greater stand diversity (both of tree species and of the genetic diversity of the dominant tree species), which generally increases forest resilience and resistance to pests and pathogens. Advantages of artificial regeneration include, greater dominance of commercially desirable tree species, greater control over the number of trees established, and more rapid establishment of trees, all of which increase growth of the desired trees. Artificial regeneration may be necessary for afforestation, since surrounding tree seed sources might be inadequate or nonexistent. Artificial regeneration probably provides more commercial wood growth faster, and may sequester more carbon faster, than natural regeneration.

Establishing stands of trees will generally sequester more carbon than leaving the sites without forest cover. Savannas, and other non-forest biomes, store much less carbon in their vegetation, and *may* reach a plateau, or stable carbon stock, in their soils, in only a few years. In contrast, forests continue to sequester additional carbon in vegetation and roots as it grows for many years — usually at least decades, and even centuries in some ecosystems. (Note, however, from **Table 1 Page 18**, that temperate grasslands have greater average carbon stocks than temperate forests, generally because perennial grasses increase soil carbon more than forests.) Thus, reforestation, especially afforestation, whether by natural or artificial regeneration, generally provides continuing additional carbon sequestration for an extended period.

Reducing Competition

Thinning is the forestry practice of removing some of the desired tree species (as well as the undesired tree species) when the competition for space, light, and nutrients reduces the growth rate of the commercial timber volume. Precommercial thinning occurs, when the trees are too small to have any commercial value (generally less than 150mm in diameter), while commercial thinning is the practice of selling the trees to be removed. Thinning and release are often proposed as forest management practices, to increase forest carbon sequestration. Some models estimate total carbon on a site, as a fixed relationship to commercial wood volume on a site. Since thinning and release increase commercial timber growth, these models would similarly project thinning and release to increase carbon sequestration.
Others, however, observe that the purpose of thinning and release is often to concentrate the same amount of growth on fewer stems. It should also be noted that thinning may increase the loss of soil carbon, by reducing canopy cover and disturbing the surface, thus accelerating decomposition rates. In contrast, release in a southern pine ecosystem was found to increase total carbon storage over the life of the stand, and to promote soil carbon storage. Thus, forestry practices that reduce vegetative competition will increase carbon sequestration in some circumstances, but not in others, limiting generalisations about the potential for increasing co2 sequestration.

Other Growth Improvement

Other forestry practices are also intended to increase tree growth rates. Pruning removes the lowest branches of a commercial tree, which may stimulate some upward growth, but generally emphasises wood value (growing clear wood, without knots) rather than growth. It is not used much, because it has been found to be unprofitable, in most situations.

Fertilising forest stands is another practice to increase tree growth. Applying fertilisers to forests can significantly increase growth rates, if the nutrient being applied (nitrogen, potassium, phosphorus, etc.) is in short supply in the forest soil. Furthermore, fertilisation is likely to stimulate all vegetative growth, not just tree growth. This is borne out in research on the impact of forestry practices on carbon sequestration. An important question, to which an is not apparent from the research, is whether the accelerated growth rate from fertilisation persists for a long time (i.e., whether the growth rate remains higher for an extended period), whether it produces a short-term increase for which the pre-fertilizer rate is sustained for a long time (i.e., whether the pre-fertilization growth rate is maintained after the short- term increase); or whether other factors limit long-term growth rates (i.e., whether growth rates after the short-term increase are less than the pre-fertilization growth rates, because other nutrients are overdrawn by the fertilizer-stimulated growth).

Some have suggested that greater atmospheric CO2 levels could fertilise forests, stimulating tree growth. A number of studies artificially increased CO2 levels in tree plantations, and found that growth rates did increase. Others, however, question whether the increased growth rate can be sustained. On the broader scale, in at least some areas, other nutrients (especially nitrogen) are likely to limit the ability of forests to expand growth with more CO2 available.

Another forestry practice, which is becoming more widely used, is prescribed burning, that is intentionally setting fires in certain forest areas under specified weather and fuel conditions. Prescribed burning typically produces many forest benefits, including less competing vegetation (akin to release or thinning), lower fuel loads that may contribute to catastrophic wildfires, and a flush of nutrients (since fire reduces biomass to its mineral components). However, prescribed fires also present a risk, as they occasionally escape from the prescribed areas, and can cause damage. They also generate substantial amounts of carbon dioxide (one of the mineral components of biomass) and other air pollution. In the short term, prescribed fires clearly increase atmospheric carbon levels. Prescribed burning reduces catastrophic wildfires, but this practice may be shifting one source of carbon emissions (wildfire) to another (prescribed fire); however, to date, no quantitative relationship has been established between prescribed burning and the extent and severity of wildfires. With regards to dead biomass on a site, prescribed burning merely concentrates into a few minutes or hours the carbon release that occurs years in other forms of biomass decomposition.

Thus, it is not clear how much of the carbon release from prescribed burning is in addition to the carbon release that might otherwise occur from forests.

Timber Harvesting

For wood that has been removed from the forest, the rate of carbon release depends on what is done with the wood. For Sawlog (logs of at least 300mm in diameter), about half is converted into solid wood products (primarily sawlog and plywood); another 10% is bark, and the remaining 40% is sawdust and wood scrap. Lumber and plywood have differing usable lives, depending on the use of the wood, and ranging from less than 10 years for pallet wood, to 100 years or more for residential construction. Clearly, some wood from broken pallets, furniture, concrete forms, etc, is disposed in landfills (and probably sequesters carbon there) and some is burned, but the majority of carbon in solid wood products remains sequestered in those products for decades. Most (more than 95%) of the bark and sawdust are either used as pulp to make paper, or burned to produce energy (thus substituting for timber used in papermaking or for fossil fuels); less than 5% of waste wood from sawmills ends up in landfills.

For Pulpwood (logs less than 300m in diameter and usually less than 2.40M in length) and waste from sawlog timber processing, virtually all the wood fiber (the cellulose and hemi-cellulose) is used in paper products. The spent pulping liquors (the chemicals that dissolve the lignin, the "glue" which holds cellulose in a rigid structure) are generally used to produce energy. Any waste paper in the production facility is generally recycled into pulp. Other than in energy production (which substitutes for fossil fuels), there is little paper waste that returns carbon directly to the atmosphere.

In contrast to solid wood products, which may sequester carbon for decades, most paper products have relatively brief duration, releasing their carbon to the atmosphere relatively quickly — in less than a year for many paper products, and in less than 10 years for most paper products. However, paper can also be recycled, dissolved, cleaned, and made into new paper products.

Increasing the recycling of post consumer paper (the paper disposed by consumers and most likely to end up in landfills) can reduce the carbon released by paper production and use.

The carbon impacts of commercial timber harvesting have been debated extensively, but with little resolution. Some have calculated that harvesting timber from an "over-mature" forest can sequester substantial additional carbon, because

(a) The forest is currently sequestering little additional carbon (the amount stored is large, but annual addition from tree growth is small or even negative),

(b) The timber can continue to store carbon for decades, in long-term solid wood products, and

(c) The newly established stand can sequester large amounts of carbon through its vigorous growth. Others have calculated that the carbon released by harvesting operations substantially exceeds the additional carbon sequestered by new forest stands. One source has stated that timber harvesting (in a heavy thinning or selection harvest) reduces carbon storage, "because the growth of residual trees is less rapid than the decomposition of the detritus and harvested wood products."

Another study has shown, that some old-growth forests continue to accumulate carbon in their soils. All of these conclusions may be valid in certain circumstances; the consequences depend on a variety of factors, such as which products are manufactured, how those products are used, how much carbon is left on the site, and what happens to it.

Wood Energy

Using wood residues for energy production has occurred for many years at wood production facilities. The old "teepee" burners, for disposing of wood waste, are all defunct, and as noted above, the wood waste not used for paper production is already being used to produce energy to operate lumber and plywood mills. Even 30 years ago, less than 4% of the woody biomass, removed from forests, ended up as unused wood residues.

Wood can be used to produce energy, either by burning it directly, modifying it to produce more consistent burning characteristics (e.g., by pulverising it and compressing it into pellets), or by digesting it to produce liquid fuel (methanol or ethanol). The biomass remaining from ethanol production is also burnable, and can be used to power the ethanol production, instead of using fossil fuels. Many have noted that abnormally high biomass levels are exacerbating risks of forest fires, and have proposed removing much of that biomass to protect forests and communities located near forests. Such woody forest residues could be used to produce energy.

Using wood for energy has some significant drawbacks. Although wood could replace some fossil fuels, it still produces CO_2 (and water vapor and some other by-products) when burned. Wood residues in the forest from timber harvesting, thinning, or other forestry practices are widely dispersed; haul distances (and thus costs) may limit the scale of wood energy production facilities. More important, perhaps, is that wood residues are highly variable in size, ranging from tree tops (100mm or more in diameter) to twigs. Thus, collecting residues is a very labour-intensive activity. The cost to collect and transport forest residues, to a wood energy facility, can be a major hindrance to using woody forest residues for energy production.

Chapter 3

Leakage

Changes in land use practices to sequester carbon in the EU can also have more subtle impacts on carbon storage globally. Domestic practices to store carbon by reducing the amount of timber harvested can have an effect commonly called Leakage, by shifting land uses geographically (e.g., more tropical forest harvests to offset less temperate forest harvests) or by shifting demand to other products that require more carbon to produce (e.g., steel or aluminum studs to replace wood studs in homebuilding).

Land Use Leakage

The primary concern, expressed by numerous experts, is that forest protection and felling restrictions within the EU will lead to more timber harvesting and associated environmental damage elsewhere, such as tropical forests, to satisfy EU demand for wood products. This leakage is undesirable, it is argued, because EU forest management protects the environment, more than comparable activities in other countries. It is easy to assert that EU environmental laws are stricter, and more rigorously enforced, than other nations' environmental laws for protecting air and water quality, maintaining animal habitats, and preserving rare plants and animals. The result is less forest destruction and greater soil protection, both of which would lead to less carbon release following timber harvesting. In addition, most EU countries require reforestation following timber harvests (by Law)

Other reasons are also given for why leakage is undesirable. One is that harvesting, in tropical forests, typically results in more waste. Tropical forest harvests typically focus on the most valuable species, leaving most of the trees, many of which are damaged. Temperate forests have less diversity of plant species, which can lead to greater efficiency in biomass utilisation, and thus less biomass waste to return carbon to the atmosphere. Also, temperate forests have less carbon per acre, on average, to release when timber is harvested than do tropical forests.
It is also worth noting that timber extraction is often the first step towards opening up the tropical forest and clearing the land for agricultural production. What is more, in many developing countries, property law establishes deforestation as a prerequisite of formal claim over the land for those settling in forested areas." Tropical timber harvests can thus lead to permanent deforestation.

Product Demand Leakage

Another concern, often noted, is that domestic Forest protection to sequester carbon could shift demand to substitute products whose production requires more energy, and thus releases more carbon. Most sawlog and plywood are used in construction — new residences, home remodeling, and non- residential buildings. Substitute products include steel and aluminum for studs, joists, and concrete for walls and flooring.

Its worth noting, that wood production requires only about a quarter of the energy needed for concrete production, and less than 5% of the energy needed for steel or aluminum produced for residential construction.

Other economists point out that supply substitution is not the only feasible response to changing domestic timber supplies. That demand could be influenced through price changes, through development of less energy-intensive/carbon-producing non-wood substitutes, and through government policy (e.g., by altering established building regulations).

Chapter 4

Individual Government Programs

Various Government programs could be used to encourage forestry practices to increase carbon sequestration. One approach is to implement more carbon-sequestering forestry practices on state lands. Another is to provide technical and financial assistance for forest management practices to private landowners. Introducing tax incentives would also encourage carbon-sequestering forestry practices by private landowners.

State Forests

In Ireland the state owns about 445,000 hectares of forestry lands which equates to 7% of the land cover of Ireland .
Forestry practices to sequester additional carbon (e.g., planting trees) can occur on sites that would not generally be considered "working" forests (e.g., Public and National parks)

Government Assistance for Private Forestry

Ireland has numerous programs, that provide technical and financial assistance, for forest establishment and management of private forest lands.
Such programs provide assistance for forestry practices, especially planting trees and improving tree growth.
Some (e.g., the Forest Stewardship Program) provide technical assistance. Others (e.g., the Forest Premium scheme) provide financial assistance to compensate loss of income on the lands during the first 20 years. All are coordinated and funded through the Forest Service.

Government Tax Incentives

"Tax incentives" are specific tax incentives established to encourage or allow certain activities. Three tax incentives apply to forestry practices in Ireland.

One is the payment of a Forestry Premium tax fees for the first 20 years of the establishment of a new plantation

The second is a provision, whereby all proceeds, from the sale of the timber from the forestry, is tax free.

The third is 100% grant aid to enable the establishment of the forestry plantation

These three tax incentives affect carbon-sequestering forestry practices in several ways. The establishment grant and premium grant effectively reduces the landowners costs of forestry establishment and income forgone, while establishment is taking place. These schemes may add to carbon sequestration, because forestry establishment would not take place without such incentives. However, tax exemptions at harvesting, encourages timber extraction, but as discussed above, the carbon consequences of timber harvesting are disputed.

Chapter 5

Conclusions

Forests store substantial amounts of carbon. The amount stored, however, changes over time as forests grow and die. Land use changes, and forestry practices, alter the level and rates of carbon storage, while "leakage" (shifting production) may offset some of the increases in forest carbon sequestration. N0o matter how one accounts for this carbon sequestration in policies and programs to mitigate climate change has been controversial. Under the 1997 Kyoto Protocol of the 1992 United Nations Framework Convention on Climate Change (UNFCCC), developed nations agreed to specified reductions in their emissions of greenhouse gases, especially carbon dioxide. The Protocol allows some carbon sequestration as a way of meeting the specified reductions. Some countries, notably the USA, rejected the Protocol and withdrew from the continuing activities under the Protocol. Nonetheless, accounting for the carbon absorbed by forests and soils (and how much credit is due) continues to be discussed internationally.

The role of forestry and land use in mitigating climate change has been controversial. Forests are enormously variable, with a broad array of plant species (both trees and under-story vegetation) and substantial differences in the diversity of plant (and animal) species they contain. The myriad permutations of forest plants and soils present formidable obstacles for estimating existing carbon stocks and the carbon sequestration and release that result from forestry activities. The carbon consequences of timber harvesting have been particularly controversial.

Because of the scientific uncertainties, as well as differences in the types and extent of forests among nations, reaching agreement on ways to account for carbon sequestration in forests has been difficult. Some argue for a broadly inclusive accounting, others for a more conservative approach. "Land-based" or "activity-based" models are generally proposed for estimating changes in carbon storage. However, the ambiguous language and terminology, used by proponents, contribute to the inherent difficulties of measuring baseline carbon stocks, land uses, the carbon impacts of various activities, and "leakage" (shifting land or product uses). Furthermore, the enormous diversity of forest types, and widespread disputes over the carbon consequences of various practices (which result at least partly from the diversity of forests) make it difficult to generalize about the opportunities to mitigate global climate change through forest carbon sequestration. It is likely, that research to reduce some of these ambiguities and uncertainties will be an ongoing element in the efforts of nations to deal with carbon sequestration — and with concerns about climate change.

The forestry and grassland sector in Ireland provides a range of opportunities to directly offset increases in GHG emissions. Forests, hedgerows and grassland all act as a carbon sink, contributing to the removal of greenhouse gases from the atmosphere. In 2007, it is estimated that forest sinks alone accounted for a reduction of emissions of 1.36 Mt CO2e.

80% of forests planted, since 1990, in Ireland are privately owned, and therefore, account for the majority of these emission reductions.

Currently carbon credits from carbon sinks are not attributed to agriculture. Ireland has the highest level of carbon sequestering permanent pastures in Europe, which when combined with the opportunity to expand the forestry cover, can promote a substantial national carbon sink.

Ireland has only 10% forest cover, compared with a European average of 30%. If farmers are to be responsible for the sector reaching a critical mass, and maximising its potential for carbon sequestration, forest sinks must be included as part of the measurement of emission reductions in the agriculture sector. In addition, the inclusion of forest sinks will contribute indirectly to emission reductions in the energy sector, through the production of wood biomass.

Observations:

- Forestry Owners would be willing participants in all things Carbon if there was clear guidance and rules surrounding sequestration, offsetting, and trading.
- Potential conflict between Government and Forest Owners as to the legal ownership of forestry generated Carbon Credits.
- Proper regulation is needed for the sector with regard to all forms of Carbon Trading

Chapter 6

Recommendations

Natural carbon sinks, such as forests, grassland and Bog Land, should be used for CO_2 emission reductions. They should be included in the overall measurement of the contribution of the agriculture and forestry sector to emission reductions.

Re - establish an annual afforestation programme of 15,000 hectares, and remove the replanting obligation (with safeguards), which currently acts as a deterrent to farmers considering forestry.

Promote excellence in forestry management practices to increase carbon sequestration in working forests, for example, modification of forest management practices to emphasise carbon storage, lengthening forest rotation and entry cycles, and adoption of agro-forestry practices.

Mechanism should be found to ensure that some benefits of the carbon storage of forests gets back to the landowner.

A revaluation, within the Department of Agriculture Food and Forestry (DAFF) of the importance and real value of forestry, as a replacement or an additional farmer enterprise, with the appropriate allocation of resources must be considered. This might continue on the work of Kearney and others since the '90s.This would entail an analysis of the value of other agriculture based schemes, with a view to prioritising forestry.

The 1946 Act should be amended to make it more relevant to present day forestry requirements.

Provided it is practiced in a sustainable way, forestry makes a positive contribution to reducing our carbon emissions. In summary, the amount of CO_2 in the atmosphere can be reduced, by increasing the amount of carbon stored in forests and forest soils & wood products, using wood as a fuel, replacing fossil fuels and by replacing materials with high embodied energy, and creating new forests on agricultural land.

The exclusion of the forestry sector from the EU greenhouse-gas emissions trading regime means, that there is no formal market mechanism to identify the value of trees to sequester carbon. At farm-level, in the event of a greenhouse gas trading scheme for the agriculture sector, consideration could be given to the possibility of allowing farm operators to offset agricultural greenhouse gas emissions with on-farm sequestration from newly planted forests.

Currently, the value carbon credits from carbon sinks are not realisable by their owners.
It is recommended, that forest sinks be included as part of the measurement of emission reductions in the agriculture sector.

It is imperative, that the EU should agree that forest carbon sinks can be used to offset Ireland's CO_2 emissions. The inclusion of forest sinks is crucial for Ireland.
There is now a much better appreciation that forest sinks should have a greater contribution, as regards national efforts, to reduce greenhouse gas emissions.

As forestry, land use and farming are all part of the same climate change equation. This linkage should be recognised in relation to the EU's Forestry Policy CAP reform post 2013, and, in particular, the EU's climate change strategy.
The European Union should set out a clear legal and regulatory framework for forest carbon offsets in those Member States, such as Ireland, where additional afforestation has the potential to make a significant contribution to reducing emissions.
Such a move would result in a significant up-lift in current afforestation levels (what could be termed a 'Carbon Afforestation Scheme').

Acknowledgements

I consider myself privileged to have been accepted into the scholastic organisation of Nuffield, and I am particularly proud in having the Irish Co-Operative Society as my sponsor. My belief and conviction in the Co-Operative movement knows no bounds, and I believe, and predict, that a return to co-operative endeavours will redefine the agricultural industry in the next couple of decades. By my actions and work for the common good, I undertake to give a return on the investment that Nuffield Ireland and ICOS have made in me.

I am forever indebted to all the people I have met in various parts of the world who were generous with their time and hospitality, and for the many lifelong friends that I have made.

I sincerely thank my colleagues in Nuffield Ireland for their support, encouragement and friendship since my scholarship award.

To my wife Yvonne and our three children, Emma, Calum and Alanna, I am grateful for the space, the support and the backup which enabled me to embark on the Nuffield Journey.

Appendix I. Glossary

[These definitions are provided solely for the purposes of this Report.]

Additionality - A measure of carbon sequestered or precluded from release by a project that exceeds the baseline characterization.

Afforestation - The establishment of a forest or stand in an area where the preceding vegetation or land use was not forest.

Baseline
A reference scenario against which a change in greenhouse gas emissions or removals is measured.

Biosphere
That component of the Earth system that contains life in its various forms, which includes its living organisms and derived organic matter (e.g., litter, detritus, soil).

Carbon Credit
A financial instrument equivalent to either (a) the right to emit 1 metric ton of co2 or an equivalent GHG (i.e. an allowance) or (b) the reduction or sequestration of 1 metric ton of the same (i.e. an offset).

Carbon Flux
Transfer of carbon from one carbon pool to another in units of measurement of mass per unit area and time.

Carbon Offset
A type of carbon credit representing the reduction or sequestration of 1 metric ton (tonne) of CO2 or an equivalent amount of another GHG. Offsetting involves reducing one's net emissions by buying the rights to emissions reductions generated by projects that reduce GHG's. Offsets are project-based emissions reductions and may be used in the voluntary or regulated markets.

Carbon Pool
A reservoir. A system which has the capacity to accumulate or release carbon. Examples of carbon pools are forest biomass, wood products, soils, and atmosphere. The units are mass (e.g., t C).

Carbon sink - Natural reservoirs or processes that take in and store more carbon than they release.

Carbon sequestration - The uptake and storage of carbon.

Carbon Stock
The absolute quantity of carbon held within a pool at a specified time.

Deforestation - The removal of a forest stand where the land is converted to a non-forest use

Double Counting
When two entities claim ownership or rights t the benefits of the same emissions reduction.

Emissions Trading
A market based GHG emissions reduction toolthat allows entities to buy and sell permits representing the right to emit (Allowances) or credits for emissions reductions (offsets). It is one of the three 'flexibility mechanisms' of the Kyoto Protocol.

Flux
See "Carbon Flux."

Forest Estate
A forested landscape consisting of multiple stands of trees.

Forest Stand
A community of trees, including aboveground and below-ground biomass and soils, sufficiently uniform in species composition, age, arrangement, and condition to be managed as a unit.

Greenhouse gas (GHG) - A gas that contributes to the warming effect exerted by the atmosphere upon the earth because the atmosphere radiant energy from the earth and re-emits infrared radiation or heat. 69 The Kyoto Protocol includes six GHGs produced by human activities: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.

Kyoto Protocol
An international agreement on climate change that sets a target for signatory countries collective emissions reductions and a mechanism for doing so (cap-and-trade). The agreement was reached in 1997 in Kyoto, Japan and came into effect in February 2005. Limits were placed on countries GHG emissions relative to levels emitted in 1990.

Land Cover
The observed physical and biological cover of the Earth's land as vegetation or man-made features.

Land Use
The total of arrangements, activities, and inputs undertaken in a certain land cover type (a set of human actions). The social and economic purposes for which land is managed (e.g., grazing, timber extraction, conservation).

Leakage - The extent to which events occurring outside the project boundary tend to reduce a project's carbon sequestration benefit

Offsets - The results of a specific project of action implemented to avoid, sequester, or displace green house gas emissions

Permanence
The longevity of a carbon pool and the stability of its stocks, given the management and disturbance environment in which it occurs.

Pool
See "Carbon Pool."

Practice
An action or set of actions that affect the land, the stocks of pools associated with it or otherwise affect the exchange of greenhouse gases with the atmosphere.

Regeneration
The renewal of a stand of trees through either natural means (seeded on-site or adjacent stands or deposited by wind, birds, or animals) or artificial means (by planting seedlings or direct seeding).

Reservoir
A pool.

Respiration
The release of carbon dioxide from decomposition of organic matter.

Sequestration
The process of increasing the carbon content of a carbon pool other than the atmosphere.

Shifting Agriculture
A form of forest use common in tropic forests where an area of forest is cleared, or partially cleared, and used for cropping for a few years until the forest regenerates. Also known as "slash and burn agriculture," "moving agriculture," or "swidden agriculture."

Sink
Any process or mechanism which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere. A given pool (reservoir) can be a sink for atmospheric carbon if, during a given time interval, more carbon is flowing into it than is flowing out.

Source
Opposite of sink. A carbon pool (reservoir) can be a source of carbon to the atmosphere if less carbon is flowing into it than is flowing out of it.

Stand
See "Forest Stand."

Stock
See "Carbon Stock."

Soil Carbon Pool
Used here to refer to the relevant carbon in the soil. It includes various forms of soil organic carbon (humus) and inorganic soil carbon and charcoal. It excludes soil biomass (e.g., roots, bulbs, etc.) as well as the soil fauna (animals).

Thinning - Reducing the stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality (trees dying from natural causes).

Uptake
The addition of carbon to a pool. A similar term is "sequestration."

Verification - A method (in most cases conducted by an objective third party) that validates and confirms the accuracy of the monitoring process and sequestration data.[152]

Wood Products
Products derived from the harvested wood from a forest, including fuelwood and logs and the products derived from them such as sawn timber, plywood, wood pulp, paper, etc.

Working forest - A forest that provides goods, such as timber, and employment.