



what
Trees

can do to

reduce

atmospheric

CO₂





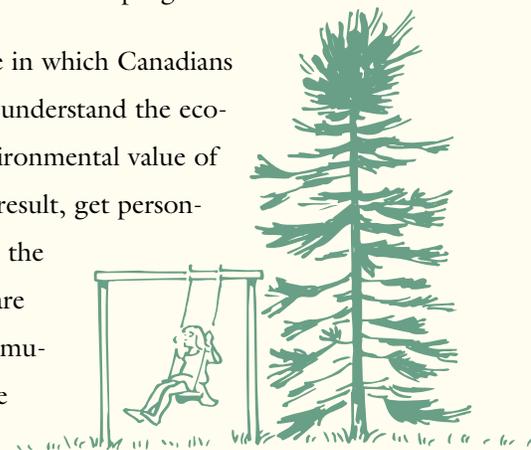
What We Do

The Tree Canada Foundation is a not-for-profit, charitable organization established to encourage Canadians to plant and care for trees in urban and rural environments. One of the goals is to help reduce the harmful effects of carbon dioxide emissions in support of climate change.

The Foundation provides educational, technical and financial support through partnerships with the private and public sectors in order to:

- facilitate the planting and care of trees throughout urban and rural Canada;
- educate Canadians about the environmental benefits of planting and caring for trees;
- assist interested parties in implementing a wide range of self-sustaining tree planting and educational initiatives;
- encourage corporations, communities and individuals to participate in the program.

We see a future in which Canadians appreciate and understand the economic and environmental value of trees and, as a result, get personally involved in the planting and care of trees in communities across the country.



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The Climate System and Greenhouse Gases

Well documented increases in atmospheric carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) have occurred over the last 200 years. Collectively, these gases are referred to as ‘greenhouse gases’ (GHG), because they absorb longwave radiation emitted from the Earth and this leads to the heating of the atmosphere. From gases trapped in bubbles in ice cores, it is known that the concentration of these gases vary naturally over long time scales (thousands of years), but current concentrations and rates of increase are unprecedented over the last 200,000 years. In 1995, the Intergovernmental Panel on Climate Change (IPCC), a group of over 2,000 scientists dealing with all aspects of climate change and variability, assembled under the auspices of the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP), concluded that “the 20th century global mean temperature is at least as warm as any other century since at least 1400 AD” (IPCC 1995: 43) and “that the observed warming trend is unlikely to be entirely natural in origin” (IPCC 1995: 43). Further, based on recent studies of patterns in climate, the observations are consistent with what “one would expect as an anthropogenic signal increases in strength” and “the probability is very low that these correspondences could occur by chance as a result of natural internal variability only” (IPCC 1995: 44). There is reasonable evidence that human-caused climate change is occurring.

In December 1997, in Kyoto, Japan, 160 countries reached an agreement that industrialised countries would, by 2008 to 2012, collectively reduce GHG emissions by 5.2% relative to their 1990 emissions.¹ The methods of how this could be obtained and the mechanisms for accounting for reductions in GHG

emissions were discussed at a meeting of the parties in Buenos Aires in November, 1998. Canada has agreed to a 6% reduction in GHG emissions by 2012 relative to 1990 levels. The government of Canada has stated that it does not wish to achieve these reductions via legislation, but would rather see this target attained through voluntary initiatives in the public and private sectors. The Kyoto agreement has left a range of flexibility for countries to develop their own strategies for obtaining reductions. Overall, long-term reductions in greenhouse gases will largely be reached through a combination of increased energy efficiency, implementation of alternative technologies, and reduction in energy demand. Short-term reductions, however, can also be attained through conservation measures and the development of carbon sinks, such as the sequestration of carbon dioxide by growing trees. There is considerable discussion over what forest practices would constitute a legitimate carbon sink. Discussion based on the Kyoto agreement focuses on the concept of reforestation, afforestation, and deforestation (RAD). While it can be argued that reforestation is part of good forest management and therefore might not be directly accounted for, there is little question that afforestation of previously non-forested land or as the result of land-use change (e.g. trees in urban areas, abandoned agricultural lands, etc.) is a carbon sink.

¹ For details on the United Nations Framework for Convention on Climate Change see the Official Web Site of the Climate Change Secretariat (www.unfccc.de). This site contains details of the Conference of Parties (COP3 Kyoto, December 1997; and COP4 Buenos Aires, November, 1998).





Atmospheric CO₂, the Global Carbon Budget and the Influence of the Terrestrial Biosphere

The global carbon budget comprises a series of reservoirs that store carbon, and a number of pathways that exchange carbon among reservoirs, mostly in the form of CO₂ (Figure 1). Scientists have been able to delineate the reservoirs reasonably well, but have greater uncertainty in the rates of exchange (Schimel, 1995). The surface ocean and the terrestrial biosphere (plants and soils) are the two reservoirs that most strongly influence the mass of CO₂ in the atmosphere over the time scale of decades to centuries. The exchanges between the atmosphere and these two reservoirs are large, but annually the reservoir inputs and outputs are almost equal, so the net exchange with the atmosphere is almost zero (Figure 1). In comparison, the net input of CO₂ to the atmosphere by human combustion of fossil-fuels and changes in

land-use is large. Unlike the biospheric influences, there are no human activities that provide an uptake equivalent to the anthropogenic emissions.

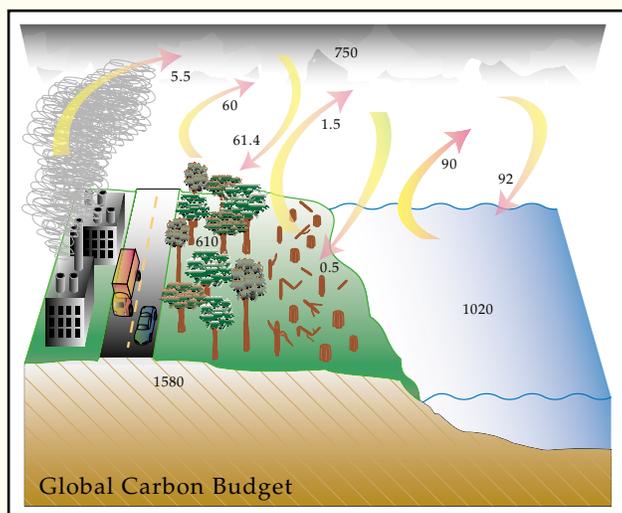
The terrestrial biosphere is a large store of carbon. About one-third of the carbon is stored in living plant biomass (trees, shrubs, etc.) and the remaining two-thirds is in soil as the residuals of plant decomposition and minerals. Small changes in the biosphere reservoir can have a tremendous effect on the concentration of CO₂ in the atmosphere. The sources and sinks of CO₂ in the biosphere are very difficult to quantify, but it is estimated that CO₂ emissions resulting from the conversion of forest to grassland and agricultural systems accounts for almost half of the total anthropogenic emissions of CO₂ over the past century (Houghten *et al.*, 1987). At present, however, about 20% of the anthropogenic CO₂ emissions to the atmosphere comes from deforestation and other land-use changes (Table 1).

Conversion of land from unproductive uses back to forests (this is known as afforestation) can provide an important sink in the contemporary carbon budget. In much of Europe and North America, abandoned farmland has been converted back to forests and this has resulted in a large, net sink of CO₂ (Table 1). Measurements of the CO₂ exchange over secondary-growth forests in eastern North America and Europe reveal that they are able to take up and store between 1 and 3 t C ha⁻¹ yr⁻¹ (Wofsy *et al.*, 1993; Greco & Baldocchi, 1996)

Table 1. Annual average carbon budget for the period 1980 to 1989 based on Schimel *et al.* (1995)

CO ₂ Sources	Gt C yr ⁻¹
Emissions from fossil-fuels and cement production	5.5 ± 0.5
Net emissions from land-use change	1.6 ± 1.0
Total anthropogenic emissions	7.1 ± 1.1
Partitioning CO ₂ amongst the reservoirs	Gt C yr ⁻¹
Storage in the atmosphere	3.3 ± 0.2
Oceanic uptake	2.0 ± 0.8
Uptake by forest regrowth in the Northern Hemisphere	0.5 ± 0.5
Inferred sink in northern forests	1.3 ± 1.5

Figure 1. The global carbon budget influences the mass, and therefore the concentration of CO₂ in the atmosphere. The stores of carbon in the terrestrial and oceanic biospheres and the atmosphere are in Gt C (GT-gigatonne; 1 Gt = 1 Pg = 10¹⁵ g), and the exchanges between the terrestrial and oceanic biosphere and the atmosphere are expressed in Gt C yr⁻¹. The values used in this diagram are taken from Schimel *et al.* (1995). To convert the stores and exchange from Gt carbon to Gt of CO₂ multiply the values in the diagram by 3.67.





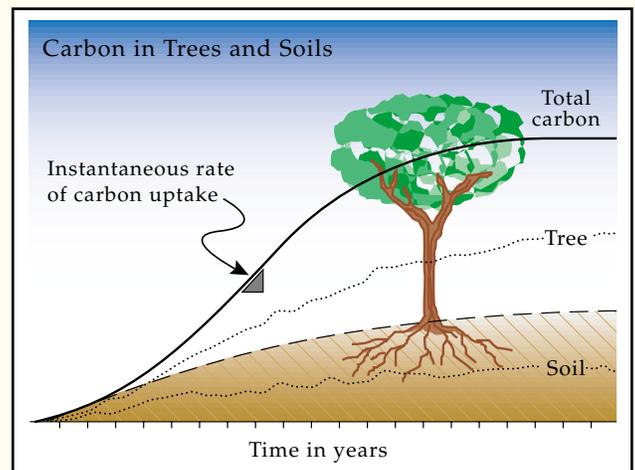
Trees and the Uptake of Atmospheric CO₂

Forested ecosystems sequester carbon through the annual increment in growth in their woody biomass, plus the proportion of litter fall that becomes incorporated into the soil carbon pool. When trees are first planted, a large proportion of the annual exchange of CO₂ goes into growing plant biomass. Also, early in the growth of the tree planted on an agricultural or urban land, the amount of carbon in the soil is small, and consequently soil respiration is not large. This results in a high rate of carbon sequestration in the first several decades of growth of a tree (*Figure 2*). As a forest ecosystem matures, the organic content of the soil also increases, and the total ecosystem respiration rises. When the ecosystem is mature, the total ecosystem respiration is approximately equal to gross production, and the ecosystem will no longer be a net sink of CO₂. The total amount of CO₂ removed from the atmosphere is then equal to the carbon stored in the living biomass of the trees and soil. The age at which trees reach maturity differs greatly among species and climatic regions, but the largest component of carbon sequestration occurs during the first 60 to 100 years.

If the trees are harvested and used in a way that returns the carbon to the atmosphere as CO₂, (e.g. if used as firewood, or allowed to decompose), then the sequestered carbon is lost. If, however, the harvested wood goes into some form of long-term storage (e.g. housing timber or furniture), then a large portion of the stored carbon will remain sequestered, and new tree growth in the regenerating forest will remove additional CO₂ from the atmosphere. If the cut tree decomposes quickly, or is burnt, then new tree growth is only replacing part of the previously sequestered carbon.

It is estimated that a total of 11.8 Gt C (or 11.8 x 10¹⁵ tonnes of carbon) has been sequestered in tree plantations in the tropical, temperate, and boreal forest regions (Winjum & Schroeder, 1997), and that the annual rate of sequestration is about 0.2 Gt C yr⁻¹. The total carbon stored in plantations is equivalent to a 2% reduction in the total CO₂ stored in the atmosphere. This represents an 8% offset to the anthropogenic emissions to the atmosphere over the last 100 years, and is a 4% offset of the current annual CO₂ emissions from fossil-fuel combustion.

Figure 2. The sequestration of carbon by a tree occurs in the living biomass of the tree and in the soils. The total amount of carbon sequestered is the amount of carbon stored at ecosystem maturity in the sum of the carbon in the standing trees and the soils. The rate of annual carbon sequestration is the amount of carbon stored in any one year.





The Sequestration of CO₂, by an “Average” Canadian Tree

There is little readily-available data regarding the amount of carbon sequestered by single trees, but Freedman & Keith (1995) used forest-productivity data of provincial forest agencies to develop growth and carbon sequestration curves for major tree species of the provinces of Canada, under different site conditions (poor, moderate, and good). The carbon sequestration was derived from above- and below-ground biomass estimates, assuming that carbon is approximately 50% of the dry biomass of a tree. There is a very large range of carbon uptake and storage among tree species, regions, and site conditions in Canada. To simplify these calculations, however, we have computed the carbon sequestered by an “average” Canadian tree. Such a tree does not really exist, but it represents the typical carbon sequestration rate reported by Freedman & Keith (1995) for many species of trees, in all geographic regions of Canada, under moderate soil conditions, assuming it takes 80 years for the tree to reach maturity. In the urban environment, it is assumed that the annual litter fall from the tree is removed, so no carbon is added to the soil. In rural and afforestation areas, however, litter is not removed, so we assume a typical added component of carbon stored in the soil. Overall, our calculations suggest that the “average” Canadian tree will sequester about 200 kg C over an 80-year period in an urban environment, and 225 kg C in a rural environment. On an annual basis, this is equivalent to storage of 2.5 kg C yr⁻¹ in an urban environment, and 2.8 kg C yr⁻¹ in a rural one. (See *TCF Carbon Offset Worksheet, next page*).

Acknowledgements

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Carbon Offset Worksheet #1



Carbon Offset Worksheet #2

Lifetime Carbon Removal				
<i>Location of planting</i>	<i>Number of trees planted</i>	<i>Division factor</i>	<i>Survival factor</i>	<i>tC removed over 80 yrs</i>
Urban	_____	÷ 5.0	x 1.0	= _____
Rural	_____	÷ 4.4	x 1.0	= _____
Afforestation	_____	÷ 4.4	x 0.7	= _____

Annual Carbon Removal				
<i>Location of planting</i>	<i>Number of trees planted</i>	<i>Division factor</i>	<i>Survival factor</i>	<i>tC/yr removed for each of 80 yrs</i>
Urban	_____	÷ 400	x 1.0	= _____
Rural	_____	÷ 360	x 1.0	= _____
Afforestation	_____	÷ 360	x 0.7	= _____

Based on the average biomass of trees in Canada (derived from tree growth estimates published by the provinces), and a multiplier for carbon stored in the soils, we have developed the following worksheet to help you determine the amount of carbon removed by your tree planting efforts.

There are two ways to calculate the amount of carbon removed. The first is the total amount of CO₂ fixed over the lifetime of the tree: In these estimates we have assumed a life of 80 years, since after this age, a typical tree in Canada sequesters little additional carbon (though trees from B.C. coastal and some interior forests continue to grow and sequester CO₂ to 100+ years). The second calculation is based on the amount of carbon removed annually by trees that have been planted. This removal would occur for 80 years.

The carbon removed is expressed in t C (x 10⁶ g C). To compute the mass of CO₂ removed you need to multiply the carbon removed by a factor of 44/12 or 3.67, which is the ratio of the mass of a CO₂ molecule to the mass of carbon atom in each CO₂ molecule.





Notes

Series of horizontal dotted lines for writing notes.



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