COUNTING CARBON FOR OFFSET PURPOSES

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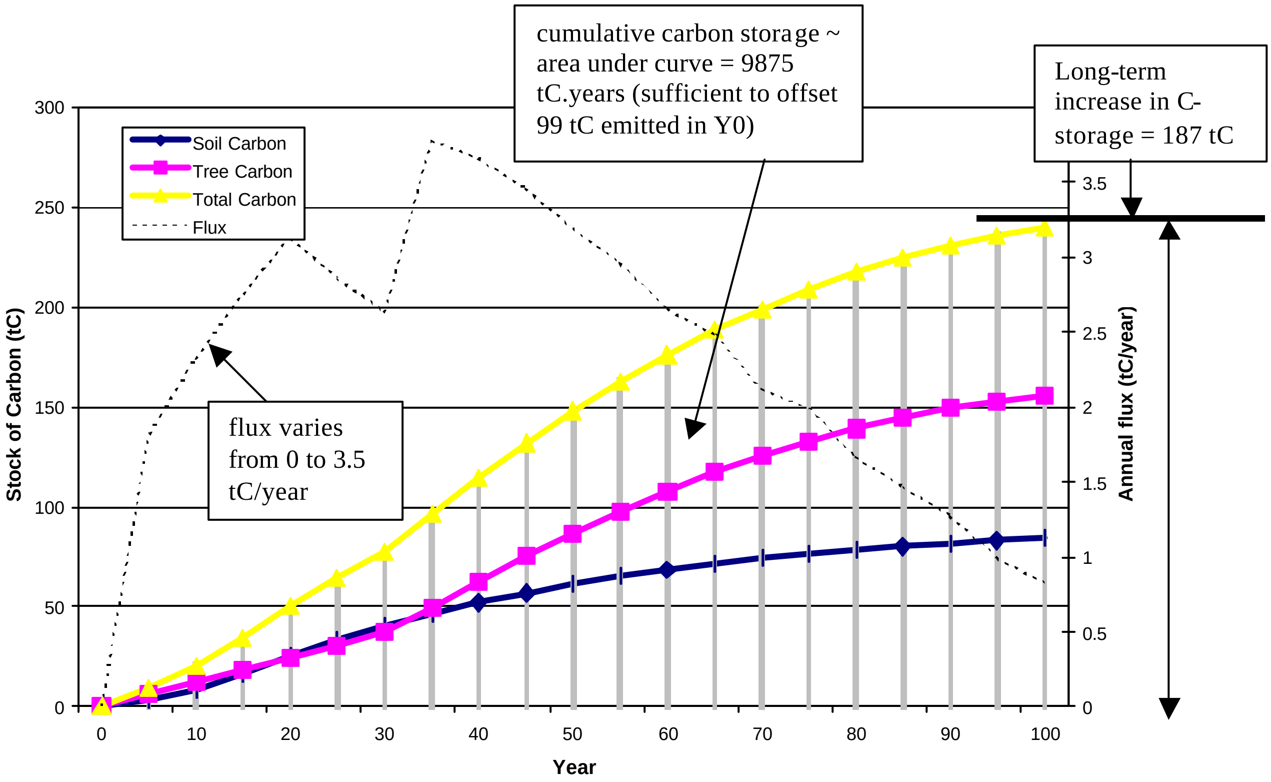
There are three main units which may be used to measure the carbon sequestration impact of a forestry activity:

- annual fluxes, expressed in tonnes of carbon per year (tC/year)
- long-term changes in carbon stocks, expressed in tonnes of carbon (tC)
- cumulative carbon storage – the area under the carbon storage curve, expressed in tonne carbon years (tC.years)

This document discusses the appropriate choice of methods for the following types of forestry activities:

- National scale forestry and land-use activities under articles 3.3 and 3.4 of the Kyoto Protocol
- Joint Implementation (JI) and Clean Development Mechanism (CDM) offset projects – Articles 6 and 12 respectively, of the Kyoto Protocol
- Voluntary Offset Projects – Voluntary actions not regulated by the Kyoto Protocol

Figure 1. Expected uptake and storage of carbon by a 1 ha stand of Oak (Yield Class 4) over 100 years established on grassland



(source data from Forestry Commission 1980; Cannell and Dewar, 1995)

Annual Flux Accounting (tC/year)

The annual flux (or uptake) of carbon (dashed line measured on the right hand axis) rises rapidly during the early growing phase of the stand, up to a peak of around 3.5 tC/year. It then declines as the trees mature and competition for light and nutrients increases. In the example shown here the stand is not felled for timber. However, if felling occurred, one would expect a negative flux of carbon for several years, before re-growth of the second rotation began to take up significant quantities of carbon.

The use of annual fluxes (uptake) measured in tC/year as a practical basis for measuring the offset potential of forestry activities presents certain problems:

(1) annual fluxes vary considerably from year to year making it very difficult to match a source of emissions to a particular forest;
(2) an emitter may not need to offset emissions every year for the life-span of the forest;
(3) it takes several years for a forest to become a significant sink of carbon - thus there will be no offset until several years after the initial investment;
(4) someone must be made liable for emissions to the atmosphere at time of felling, otherwise people will tend to abandon projects once uptake becomes low or potentially negative;
(5) it is not possible to determine the amount of forestry that can offset a single emission in year 0 – even if a corresponding amount is taken up in that year, it may be re-emitted the following year.

Application of Annual Flux Accounting

While there is still some discussion about the rules to be used for measuring carbon uptake and storage within the Kyoto Protocol, it appears that annual fluxes are to be used to account for carbon uptake and losses at the national level, by afforestation, reforestation and deforestation, as currently described under Article 3.3 of the Protocol. This may also be extended to include other land uses, under article 3.4, following discussions following on from CoP6.

For the reasons stated above there is some doubt as to whether flux accounting is appropriate for the assessment of project-based activities described under Articles 6 and 12 (Joint Implementation and the Clean Development Mechanism). Also, for the reasons stated above, the use of flux accounting for voluntary offset projects is not to be recommended.

Average, Long-Term Changes in Stocks (tC)

Most carbon offset projects developed under the UNFCCC's Programme for Activities Implemented Jointly use the ***average*** *long-term change in carbon stocks* (the "equilibrium" level of carbon storage in the new forestry system, with respect to the baseline) as the main measure of impact. The **total** long-term change in carbon stocks is shown by the vertical double-head arrow on the right hand side of Figure 1.

This measure is compatible with the aim of the Climate Change Convention – *to stabilise atmospheric concentrations of greenhouse gases at a safe level*, and recognises the importance of trying to ensure that projects are designed for sustainability. It also avoids the problem of having to match a source of emissions with a similar sink on an annual basis – essentially a one-off emission is re-captured over a certain timeframe (related to the time taken for the forestry system to reach "equilibrium". Furthermore, a single unit measure for the net effect of a project is conceptually preferable to a series of positive (and negative) values extending into the future.

However, the use of this approach has attracted criticism for the following reasons:
(1) it is likely to take several decades for a project to reach its equilibrium value and there are generally a number of uncertainties and risks associated with achieving the projected long-term storage;
(2) the definition of an "equilibrium" value implies that the new forest system will remain in perpetuity. In practice such an assumption may be difficult to enforce and its probability is difficult to assess;
(3) an emission delivered to the atmosphere at the beginning of the project will be having a warming effect for several years before it is "captured" by the forestry system.

Application of average, long-term changes in stocks

Despite the extensive use of this term as a measure of the offset potential of forestry projects, this method only provides a rough guide as to the amount of warming offset by a forestry activity.

Cumulative Carbon Storage or –GWP, (tC.years)

The IPCC currently defines the Global Warming Potential (GWP) of each greenhouse gas in the atmosphere as the cumulative presence of the gas (concentration x time) within specified timeframes (normally 100 years) multiplied by a radiative forcing coefficient (the amount of warming caused by the presence of one unit of the gas for one year) (IPCC, 1995).

In the case of carbon dioxide, the cumulative presence of a unit of CO_2 emitted to the atmosphere over time is determined by the strength of "natural" terrestrial and oceanic sinks, which capture a proportion of the gas each year. The dynamics of the global carbon cycle are therefore important in determining the warming effect of each unit of CO_2 that is emitted.

Similarly, if CO_2 is withdrawn from the atmosphere for a certain period, a cooling effect (or –GWP) is produced. The overall cooling effect caused by a forestry project within a specified time period (100 years is chosen for compatibility with the agreed IPCC GWP convention) is approximated by the area under the total carbon storage curve (shaded area in Figure 1), measured in units of tC.years.

For those who feel unfamiliar with multiplier units, it may be noted that the tC.year is analogous to energy units (e.g. Kw.hr) that are used for purchase and sale of electricity and gas.

The warming effect of an emission in year 0 can therefore be fully offset, according to the established GWP convention, by a forestry activity that creates a corresponding cooling effect within the specified timeframe.

Furthermore, with an understanding of the dynamics of the carbon cycle it is possible to calculate the number of tC.years that need to be accumulated within a 100 year period to offset a 1tC emission in year 0. Tipper and de Jong (1998) recommended a conversion factor of approximately 60 tC.years per tC emitted in year 0. A recent paper by Enting (2000) drew attention to possible feedback mechanisms between atmospheric and terrestrial carbon content. This would effectively reduce the capacity for carbon sequestration to reduce global warming. In response, Tipper and de Jong (2000) proposed revising the carbon year conversion factor to 100 tC.years to provide a more conservative estimate of the potential effect on global warming of carbon sequestered by woodlands over the next 100 years.

It should be noted that a factor of 100 for conversion of tC.years to tC emitted is equivalent to using the average increase in carbon storage over a 100 year period.

Application of the cumulative carbon storage or –GWP method

The –GWP method is the most practical and reasonable measure of impact for project-based forestry activities. While quantification procedures for forestry in the Kyoto Protocol are still under discussion, there is considerable interest within the IPCC in the application of this approach to projects developed under Articles 6 and 12.

While it seems reasonable to "give credit" to voluntary offset projects "up front" (at year 0), provided additionality concerns have been addressed, adequate funds have been set aside and adequate management plans have been developed, projects implemented for official credits under Articles 6 and 12 of the Kyoto Protocol may be credited in stages, for example, as in table 1, columns 5 and 9.

Organisations interested in expressing the offset in relation to the number of individual trees on a site should note that starting conditions (planting densities) vary considerably and are not good indicators of the final carbon stored or the amount of emission offset. A more reliable indicator is the number of trees on the site at 100 years, or at the end of a rotation (Table 1, last row of columns 6 and 10).

Table 1. Estimated Potential Carbon Accumulation and Carbon Offset (per ha and per tree) in a stand of Oak (Yield Class 4) using a tC.year factor of 100

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Year	Trees per ha	**Including soil**				**Excluding soil**			
		KgC stored		tC offset		KgC Stored		tC offset	
		per ha	per tree	per ha	per tree	per ha	per tree	per ha	per tree
0	4200	0	0	0	0.00	0	0	0	0.00
25	4200	33,800	8	2	0.00	23,600	6	2	0.00
50	1006	109,000	108	21	0.02	81,600	81	15	0.01
75	428	160,800	376	55	0.13	124,300	290	41	0.10
100	244	187,000	766	99	0.41	145,800	598	75	0.31

References

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