Project duration and accounting methods[1]
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1) Project duration

For how long do projects have to be run?

A requirement of the Kyoto Protocol is that Land Use, Land Use Change and Forestry (LULUCF) projects must result in long-term changes in terrestrial carbon storage and CO_2 concentrations in the atmosphere. The definition of "long-term", however, varies substantially, and there is no consensus regarding a minimum timeframe for project duration.

During the AIJ Pilot Phase, projects have been conducted for a variety of timeframes, from 20 years (e.g., the Protected Areas Project in Costa Rica, Trines, 1998a) to 99 years (e.g., the Face Foundation's projects, Verweij and Emmer, 1998). Most projects state that their greenhouse gas (GHG) benefits are expected to be maintained beyond the project timeframe (see list of AIJ projects in UNFCCC website or in UNFCCC, 1999) although their contractual arrangements are finite. This lack of definition has caused uncertainty to all parties involved, from regulatory bodies to project developers and investors.

There is a need, therefore, to agree on what timeframe should be used as the basis for quantification of GHG benefits of a project. Different timeframes or approaches have been proposed to define the duration of projects:

a) Perpetuity - the environmental benefits of projects have to be maintained forever. This argument is based on the assumption that the "reversal" of GHG benefits of a project at any point in time would totally invalidate a project (Maclaren, 1999; Carbon Storage Trust, 1998), and that only maintenance of carbon stocks in perpetuity could counter the environmental effects of GHG emissions from fossil fuel sources. It is also argued that this is the only approach which is compatible with the stock change method currently used by the IPCC for National GHG Inventories (Houghton et al., 1997). Criticism of this approach includes: 1) it is impossible to guarantee that a project will be run in perpetuity; 2) maintenance of projects in perpetuity may create conflicts with other land uses in the long term; 3) because of the decay pattern of GHGs in the atmosphere, there is no need for mitigation effects to be perpetual (see ***c)*** below);

b) 100 years – the GHG benefits of a project have to be maintained for a period of 100 years to be consistent with the Kyoto Protocol's adoption of the IPCC's GWPs (Article 5.3) and of a 100-year reference timeframe (Addendum to the Protocol, Decision 2/CP.3, para. 3) for calculation of the Absolute Global Warming Potential (AGWP) for CO_2. While this concept has limitations (IPCC, 1996), it has been adopted for use in the Kyoto Protocol to account for total emissions of the greenhouse gases on a CO_2-equivalent basis.

c) Equivalence based - the GHG benefits of LULUCF mitigation projects have to be maintained until they counteract the effect of an equivalent amount of GHGs emitted to the atmosphere, estimated based on the cumulative radiative forcing effect of a pulse emission of CO_2 during its residence in the atmosphere (its AGWP; IPCC, 1992). Variations of this concept have been developed, proposing minimum timeframes of 55 years (Moura-Costa and Wilson, 2000) or 100 years (Fearnside et al., 2000).

d) Variable - acknowledging that different projects may have different operational timeframes. Given the wide range of timeframes of projects carried out to, it can be implied that this has been the approach adopted during the AIJ Pilot Phase.

The adoption of a standard definition of the minimum required timeframe for project duration would greatly facilitate consistency in accounting for GHG benefits of different projects. It would also reduce the uncertainty of all parties involved in project development (project developers, investors, certifiers, regulatory bodies, and the general public).

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How should projects with shorter timeframes be treated?

Once the minimum project duration has been defined, it is also important to decide how to treat projects that have a shorter duration than the minimum required timeframe. The options can be divided into two main approaches:

a) Full liability – in the event of 'reversal' of GHG benefits, projects should return an amount of credits equal to the total amount of GHGs released. This approach is consistent with the stock change method, which consists of giving credits to projects as carbon is fixed, and removing credits if stocks of carbon diminish. In essence, this approach does not recognize the temporal value of carbon storage. This is the only method possible if it is decided that projects have to be run in perpetuity.

b) Proportional liability - projects should be debited an amount of credits proportional to the difference between the minimum required timeframe and the actual project duration (the "period of non-compliance'). This method is only applicable if a finite minimum project duration is adopted. If, for instance, a minimum timeframe of 100 years is adopted, a plantation project which is harvested at 60 years (assuming that all carbon is released to the atmosphere), would be liable for not maintaining carbon stocks for the last 40 years of the required timeframe. Different methods have been proposed for calculating this proportional liability, such as:

- Linearly – dividing the 'period of non-compliance' by the required timeframe. In the example above, the project would have to return 40% of the credits that it earned/claimed.
- Ton-year based – calculating the liability based on the ton-year approach (Moura-Costa and Wilson, 2000; Fearnside et al., 2000).
- Adjusted for time preference – using any of the methods described above, but applying discount rates to reflect time preference.

The choice of method for dealing with liability is linked with methods chosen for accounting for GHG benefits, and when credits are given to projects.

2) Accounting

2.1. Carbon Accounting Methods

Various approaches have been used to measure the GHG mitigation effectiveness of LULUCF projects. Some are based on absolute measurements at a point in time, while others take into account the time dimension of carbon sequestration and storage. These methods are discussed below and a comparison of results using different methods is given in Table 1 below.

Stock change method.

The method most commonly used for expressing carbon storage is based on calculating the difference in carbon stocks between a project and its baseline at a given point in time. This method is referred to as the *stock change method* (previously referred to as the *flow summation method,* Richards and Stokes; 1994), and measurements are usually expressed in t C ha^{-1}. However, it is limited in so far as it provides only a 'snap shot' of the carbon fixed such that resulting values will vary depending on the often arbitrary decision of when to account for the project's benefits. Furthermore, this method does not differentiate between projects that earn credits earlier rather than later. For these reasons, this method does not provide a useful tool for comparison between projects.

For example, Figure 1 illustrates a projection of carbon stored in two hypothetical tree plantation projects, with different growth rates. The arrows illustrates that stock change measurements carried out at time *t1* would provide different results between the two projects, but the same result would be reached if measurements were carried out at time *t2*. If measurements were carried out at time *t3*, after harvesting, a totally different result would be reached for both projects, in relation to measurements at *t2*.

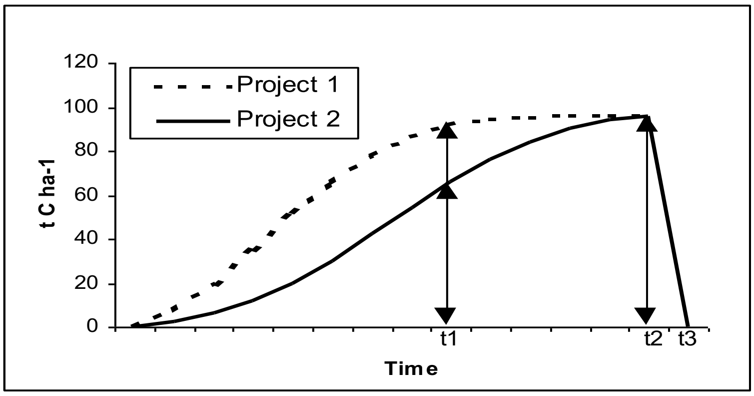

Figure 1. Projection of carbon stored in two tree plantation projects with different growth rates. For simplicity, it is assumed that the baseline is zero and that harvesting leads to an immediate release of all carbon stored. Arrows illustrate the net carbon storage of the projects at different points in time, calculated by the stock change method.

Average storage method

To account for dynamic systems, e.g., afforestation projects, in which planting, harvesting and replanting operations take place, an alternative approach has been used (e.g., Dixon *et al.,* 1991; Masera, 1995), called the *average storage method* (Schroeder, 1992). This method consists of averaging the amount of carbon stored in a site over the long-term according to the following equation:

$$Average\ net\ carbon\ storage\ (t\,C) = \frac{\sum_{t=0}^{t=n} (carbon\ stored\ in\ project - carbon\ stored\ in\ baseline), in\, tC}{n\ (years)}$$

where t is time, n is the project time frame (years), and measurements are expressed in t C ha^{-1}. The advantage of this method is that it accounts for the dynamics of carbon storage over the whole project duration, not only at the times chosen for accounting. This method is also useful for comparing different projects with different growth patterns. As shown in Figure 2, the average storage over three rotations of project 1 is higher than that of project 2. However, a weakness of this method relates to the still subjective time frame, n, chosen for running the analysis. In the case of Figure 2, e.g., the average net carbon storage in either project would be equal whether the calculation was performed for one, two, or infinite rotations, as long as the denominator chosen for equation above coincided with the last year of a rotation..

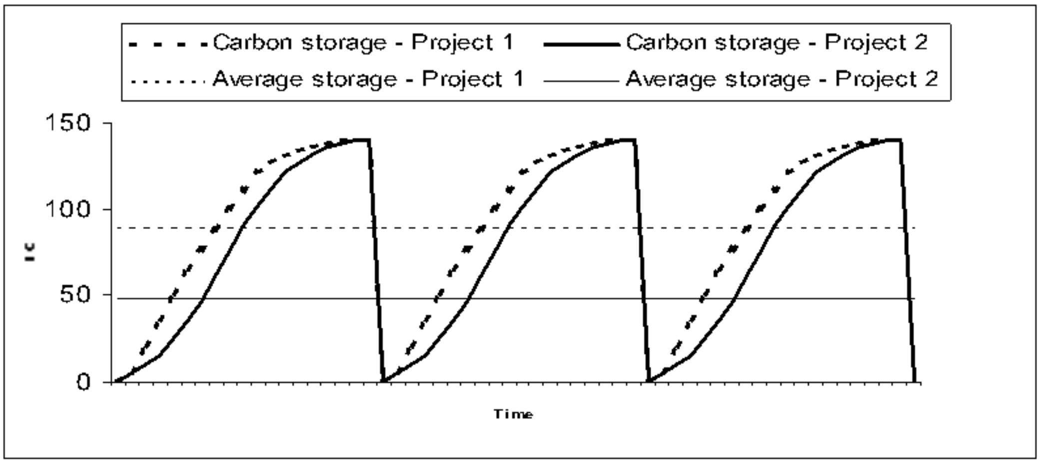

Figure 2. Projection of carbon stored in two tree plantation projects over three rotations. For simplicity, it is assumed that the baseline is zero, that harvesting leads to an immediate release of all carbon stored, and that

equilibrium of carbon pools is reached in the first rotation cycle. The curves illustrate carbon storage over time, and straight horizontal lines show the average storage calculated for the two projects.

Alternative approaches

Alternative approaches have been proposed to better address the temporal dimension of carbon storage. Most of these are based on adopting a two-dimensional measurement unit that reflects storage and time, i.e., the ton-C year. The concept of a ton-year unit has been proposed by many authors (Moura-Costa, 1996; Fearnside, 1997; Greenhouse Challenge Office, 1997; Chomitz, 1998; Tipper and de Jong, 1998; Dobes *et al*., 1999; Moura-Costa and Wilson, 2000; Fearnside et al., 2000). The general concept of the ton-year approach is in the application of a factor to convert the climatic effect of temporal carbon storage to an equivalent amount of avoided emissions (this factor is referred to as the *equivalence factor*, or E_f, for the rest of this Section) and vary from 0.007 to 0.02 (Dobes *et al*., 1999; Tipper and de Jong, 1998; Moura-Costa and Wilson, 2000). This factor is derived from the "*equivalence time*" concept (referred to as *Te* for the rest of this Section), i.e., the length of time that CO_2 must be stored as carbon in biomass or soil for it to prevent the cumulative radiative forcing effect exerted by a similar amount of CO_2 during its residence in the atmosphere (Moura-Costa and Wilson, 2000). The definition of the theory and methods used for determining E_f are given in Moura-Costa and Wilson (2000).

Irrespective of the method used for calculating the equivalence factors , they could be useful for the accounting of GHG benefits of LULUCF projects. Different applications have been proposed (Moura-Costa and Wilson, 2000), and in practice a combination of approaches can be used, as follows:

- *Equivalence-adjusted average storage,* using T_e as the denominator of the *average storage* equation (see above). This method could be used to standardise the way in which the average storage method is currently used;
- *Stock change crediting with ton-year liability adjustment* – giving projects credits according to the stock change method, but using ton-years to calculate the amount of credits to be removed in the case of any non-compliance (in the case of occurrence of risk-related events);
- *Equivalence-factor yearly crediting (ton-years),* by which a project is credited yearly with a fraction of its total GHG benefit, determined by the amount of carbon stored each year, converted using the equivalence factor E_f (Figure 3). This approach would greatly discourage the implementation of LULUCF GHG mitigation projects;
- *Equivalence-delayed full crediting,* only recognizing the full benefits of carbon sequestration after storage for a time period T_e (Figure 4). It is likely that this delayed crediting would discourage the implementation of LULUCF GHG mitigation projects;
- *Ex-ante ton-year crediting* – giving projects an amount of credits at the beginning of the project, according to the planned project duration, using the ton-year approach. This would reduce the disadvantages that delayed crediting would create to project developers.

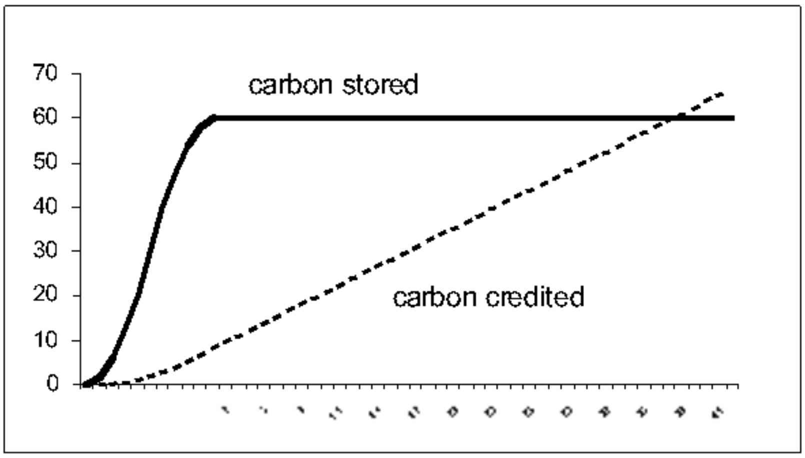

Figure 3. Projection of carbon stored in an afforestation project (with baseline assumed to be zero), illustrating the concept of *equivalence-factor yearly crediting (ton-years)*. The project receives yearly credits calculated as

the total amount of carbon stored in any given year, multiplied by an equivalence factor, E_f. Alternatively (in the case of *stock change crediting with ton-year liability adjustment*), credits could be given as carbon is stored (solid line), and in case of any event leading to the release of carbon stored, the amount of credits to be returned would be calculated as the difference between the solid and the dotted line at that point in time.

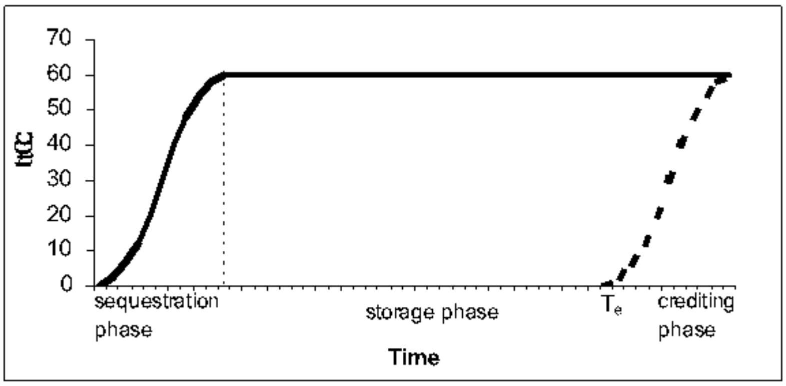

Figure 4. Projection of carbon stored in an afforestation project (with baseline assumed to be zero), illustrating the concept of e*quivalence-delayed full crediting*. In this example, the project only receives credits after planted trees have grown and been kept for a period of time, T_e.

If an *equivalence factor* ton-year approach is used, carbon storage could be credited according to the time frame over which storage takes place. Such a crediting system would reduce the need for long-term guarantees and hence the risks associated with long time frames. If the forests storing this carbon pool suffer any damage, the proportion of carbon credits lost could be easily calculated. This method also allows for comparisons between projects. The main disadvantage of this method is that that there is still much uncertainty in relation to the permanence of CO_2 in the atmosphere, and consequently the values of the equivalence parameters T_e and E_f. Depending on the manner in which ton-years accounting is used (see list above), there may also be disadvantages in relation to the timing when crediting occurs, discouraging the implementation of LULUCF GHG mitigation projects (particularly in the case of the *equivalence factor yearly crediting* and *equivalence-delayed crediting* approaches). A comparison of the GHG benefits of each method is shown in Table 1.

Whichever method is chosen, it would need to be made compatible with the FCCC reporting requirements.

Comparison of methods

Table 1 shows a comparison of the GHG benefits attributed to the sequestration project illustrated in Figure 2. The example assumes that the project is:

- run for three rotations of 18 years each,
- that at the end of each rotation the carbon stock in the forest reach 140 t C/ha,
- that harvesting reduces carbon stocks to zero and that the baseline is zero.

Calculations were conducted assuming both a minimum required project duration of 55 years (based on the equivalence time *Te* of 55 years [Moura-Costa and Wilson, 2000]), and 100 years (based on the equivalence time of 100 years [Fearnside et al., 2000]). It is clear from this example, that depending on the accounting method used, different amounts of carbon benefits accrue to the project, as is shown by the following results:

1. According to the ***stock change method***, this project would receive 140 t C/ha during the sequestration phase of each rotation, and would need to return an equivalent amount after each harvest.
2. The ***average storage*** calculated for the duration of this project is 84 t C/ha (using the traditional average storage method, <u>without</u> a fixed minimum project duration), that is reached before the end of the first rotation and remains the same irrespective of the duration of the project. If a set timeframe is adopted for the calculation of the average storage (i.e., <u>with</u> a pre-determined denominator in the average storage

equation), the GHG benefits of a project would increase proportionally to the time frame under which the project is conducted.

3. If a minimum project duration of 55 years was required, the ***equivalence-adjusted average storage*** of this project (which is conducted for 54 years) would be 83 t C/ha, while if the minimum time frame required was 100 years, the equivalence-adjusted average storage would be 45 t C/ha. Furthermore, if this project was conducted only for one rotation, the project's benefits would be lower (see values in parentheses in Table 1).
4. Another accounting option (the ***stock change crediting with ton-year liability adjustment method***) is to use the stock change method for calculating the benefits of the projects during the sequestration phase, and to use ton-years to calculate the "loss" of benefits when emission take place. Using this approach, the calculated GHG benefits of the project at the end of the first rotation would be 140 t C/ha (the same as in the stock change method), but when emissions take place after harvesting the calculated GHG benefits "lost" is either 112 t C/ha (if a ton-year equivalence factor $E_f = 0.0182$ is chosen, based on Te=55) or 136 t C/ha (if a ton-year equivalence factor $E_f = 0.010$ is chosen, based on Te=100). The longer the project duration, the smaller becomes the amount of GHG benefits "lost" after harvesting.
5. If the GHG benefits of the project are calculated using the ***equivalence-factor yearly crediting method (ton-year accounting)***, the GHG benefit attributed to the project would increase gradually as the project is conducted for a longer time frame. Because it is assumed that the ton-year equivalence factor reflects the GHG benefit to the atmosphere derived from temporary storage, no loss of benefits is assumed when emissions take place.

Table 1. Comparison of GHG benefits (t C/ha) attributed to a sequestration project at different points in time, according to different carbon accounting methodologies. Positive values denote GHG benefits (crediting), and negative values denote "reversal" of benefits (removal of credits). The calculations are based on an example of an afforestation project conducted for three rotations of 18 years each. It is assumed that at the end of each rotation, the carbon stock in the forest reaches 140 t C/ha, and that harvesting reduces carbon stocks to zero. For simplicity, it also assume that the baseline is zero. Figures in parentheses refer to GHG benefits accumulated until that point in time, in case the project was terminated at that time.

Method	Year 20	Year 20 after harvest	Year 60	Year 60 after harvest	Balance
Stock change	140	-140	140	-140	0
Average storage with the end of each rotation as denominator	84 (84)	0 (84)	0 (84)	0 (84)	84
Equivalence-adjusted average storage with minimum required project duration of 55 years (Te=55)[a]	83 (28)	0 (28)	0 (83)	0 (83)	83
Equivalence-adjusted average storage with minimum required project duration of 100 years (Te=100)	45 (15)	0 (15)	0 (45)	0 (45)	45
Stock change crediting with *ton*-year liability - Te=55	140	-112	140	-57	110
Stock change crediting with *ton*-year liability - Te=100	140	-136	140	-100	44
Ton-year yearly crediting - $Te = 55$; $E_f = 0.0182$[b]	28	28	83	83	83
Ton-year yearly crediting - $Te = 100$; $E^f = 0.010$	3	4	38	40	40

a. Minimum project duration values were chosen based on different proposed *equivalence time* factors (*Te,* the length of time that CO_2 must be stored as carbon in biomass or soil for it to prevent the cumulative radiative forcing effect exerted by a similar amount of CO_2 during its residence in the atmosphere). Moura-Costa and Wilson (2000) propose a Te = 55 years, and Fearnside et al. (2000) propose a Te = 100 years.
b. In both cases, E_f (the *equivalence factor* used to determine the GHG mitigation benefit of a ton-year of storage) is calculated linearly by $1/Te$.

2.2. Accounting for Risks and Uncertainty

Projects have dealt with risks and uncertainty in different ways, depending on the type of uncertainty. *Mensuration error*, can be dealt with by:

- *Error acceptance* –acknowledging that measurement error is inevitable and listing a range of acceptable errors for different pools;
- *Error minimization* – by setting acceptable errors at a low level, forcing projects to engage in more effective inventorying and monitoring exercises; more samples, larger sample size, and more frequent

sampling. This may affect the eligibility of certain types of projects that present mensuration difficulties;
- *Error deduction* – this method consists of deducting the error from a carbon estimate. This approach has the advantage that it allows the project to decide what is more cost effective: data gathering or carbon claims. This approach was used by the international certification company SGS in the certification of the Costa Rican national carbon offset program (SGS, 1998; Moura-Costa *et al*., 1999).

Methods to account for baseline uncertainty include estimation of effect of different uncertainty assumptions on the baseline adopted and deduction of the claims. In the case of quantifiable risks, these can be accounted for by keeping a portion of the project's GHG benefits as a reserve to ensure for any shortfalls. This reserve could be financial or in kind (GHG benefits). This latter approach was used by the national program of the Costa Rican Office for Joint Implementation that was requested by its certification agency to place about 40% of the GHG benefits derived from this project in a self insurance buffer reserve (SGS, 1998). In case of non-occurrence of damage, this reserve may be used at the end of the project life time.

2.3. Accounting for Time (Discounting)

The timeframe of project benefits can affect their attractiveness. Projects that bring benefits at an earlier stage may be favored by some, and this raises the point of *time preference*. Time preference relates to the preference of society to benefits that accrue at an earlier rather than a later stage. In the context of climate change, time preference can be used to introduce a sense of urgency in relation to GHG emission mitigation measures. Not using it implies an endorsement of the assumption that a GHG mitigation activity can be postponed indefinitely without any effect on the overall objective of reducing the impacts of GHG concentrations in the atmosphere.

To account for the value of time and include the concept of time preference, the *discounting method* has been proposed (Richards and Stokes 1994; Fearnside 1995). It consists of using a discount rate to calculate the present value of the total amount of carbon stored over the lifetime of a project, according to the following equation:

$$\text{Present Value of carbon storage } (tC) = \sum_{t=0}^{n} \frac{\text{carbon stored by a project } (tC)}{(1+i)^t}$$

where *i* is the discount rate and *n* is the project's timeframe (usually in years).

One problem of using discounting, however, relates to the selection of an appropriate discount rate to reflect financial (interest rates), economic or social degrees of time preference attached to the carbon mitigation benefits of a project. High rates favor short term projects, discouraging long-term sustainability and forest maintenance. Too low rates discourage efficiency and approaches that promote more rapid results. Discounting, however, favors activities that prevent the release of carbon, such as conservation or reduced impact logging, instead of activities which actively remove carbon from the atmosphere over a longer period (*e.g.,* forest establishment). This is because conservation activities internalize large amounts of carbon at the beginning of the project cycle, therefore suffering less from the effects of discounting.

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