Scientific and Technical Issues in the Clean Development Mechanism

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This discussion paper originated from a workshop in Wageningen, The Netherlands, April 2003, a contribution to the project *Concerted Action CarboEurope-GHG*, which is part of the CarboEurope Cluster

Published May 2003

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• Executive Summary

This report presents the results of a workshop on Inclusion of sinks in the CDM in Wageningen, The Netherlands, 23-25 April, 2003. The workshop was organised in the frame of the European Concerted Action *CarboEurope-GHG* (EVK2-CT-2002-20014) supported by the European Commission, DG Research, under the Fifth Framework Programme, *Key Action Global Change and Ecosystems*. The results do not necessarily reflect the Commission´s views or the view of the Carboeurope Cluster of Projects and in no way anticipate the Commission´s future policy in this area.

The Clean Development Mechanism (CDM) has been defined in Article 12 of the Kyoto Protocol. According to the Marrakech Accords, terrestrial carbon sink projects, limited to afforestation and reforestation (AR), are allowed to be used under the CDM. Such activities could stimulate other environmental benefits through private investments in developing countries but can also have adverse effects on biodiversity, environment and local socio-economic structures. Rules for CDM sinks projects are planned to be decided at COP9 in December 2003.

This discussion paper aims to contribute to the negotiations a scientific perspective on critical issues related to decisions to be taken during SBSTA 18 and COP9 and addressing the eligibility and implementation of CDM sinks projects, but also addresses more general scientific and methodological issues related to the Kyoto process:

- Definitional and GHG accounting rules for sinks in the CDM in the First Commitment Period,
- Evaluation of project plans for eligibility in the CDM,
- Monitoring and Verification of carbon sinks in CDM projects
- Looking ahead: beyond the First Commitment Period
- Frequently asked questions about sink capacity in the CDM and tropical forestry.

The following summary comments directly on issues related to the SBSTA mandate: definitions, leakage, permanence, additionality, environmental and socio-economic issues.

1. Definitions of 'Forest, Afforestation, Reforestation'

The adoption within the CDM of the current forest definition agreed for Articles 3.3 and 3.4 of the Kyoto Protocol would be a transparent, feasible way to ensure consistency in sink activities. It will allow inclusion of agroforestry projects but may create disincentives to invest in dry or degraded areas with marginal forest cover (where forest cover is below the country-specific threshold of between 10 and 30%).

In order to avoid perverse rewards for recent deforestations for other reasons, sticking to the base date 31.12.89 is essential (Schulze et al., 2003). The global coverage of freely-available remotely sensed land cover images such as the 1990 LANDSAT images allows, in the absence of official national data, determination of the presence or absence of forest for any piece of land within six months around the base date (***Section 1.1, Appendix I***).

2. Non-permanence

The Colombian proposal of 'Temporary Emission Reduction Units' (tCERs) seems practical and transparent, easy to monitor and verify, avoids the need for long-term insurance against forest loss due to natural or human-induced events, and has minimal risk of over-crediting. tCERs would be renewed periodically following certification of carbon stock changes and greenhouse gas emissions (***Section 1.2***). Non-permanence of carbon sinks can be minimised by proper project framework and design with strong involvement of and benefits for local stakeholders.

3. Additionality and Baselines

Among the options for defining additionality (FCCC/SBSTA/2003/4) a definitions should be chosen that avoids that any afforestation, irregardless of its original purpose, meets the additionality criterion. A good definition is given in Ellis (2003): *An afforestation or reforestation project activity is additional if the net enhancement of sinks is higher than those that would have occurred in the absence of the registered CDM project activity, if the project activity itself is not a likely baseline scenario, and the project activity is governed by the principle that its undertaking contributes to the conservation of biodiversity and sustainable use of natural resources*. Additionality (***Section 1.3***) is a key criterion for project evaluation in the scheme we propose in ***Section 2 (Evaluation Criteria Figure 3)***. A spatial concept for baselines is proposed in ***Appendix II***.

4. Leakage and project boundaries

It is difficult to trace all pathways of possible leakage, particularly through market pathways. Leakage regarding carbon stock changes on land outside the project boundaries could be monitored by remote sensing and statistical surveys to determine the local and regional magnitude of shifted activities and changes in ARD rates (***Section 1.4, Appendix II***). The risk of leakage can be minimised by a proper project framework and design and is a key criterion for project evaluation in the scheme we propose in ***Section 2***.

5. Pools and fluxes

CDM projects are likely to lose environmental integrity if only carbon stock changes, and no other greenhouse gases are accounted for. N_2O emissions in plantations in which management includes fertilization or introduction of leguminous trees or on wet soils can easily offset the carbon sink in the growing trees (***Section 1.5***). We propose technical solutions to this problem in ***Section 3, Level 3***.

6. Monitoring and verification of carbon stock changes and Non-CO_2 GHGs

AR projects will need to be monitored by staff of the project and verified independently by an external agency, known as the Designated Operational Entity (DOE). Costs are incurred at these stages, to be added to the establishment costs. The difficulties of measurement are not always appreciated. Standardised procedures are described in the *IPCC Good Practice Guidance* (under development). However, there is an inevitable trade-off between accuracy and costs. Efficient sampling procedures will be needed to detect changes over the five-year commitment period. Various levels of complexity for observational strategies applicable to monitoring or verification are described with their advantages, disadvantages and pitfalls in ***Section 3***. More elaborate monitoring schemes will increase the cost but reduce the uncertainty in the carbon sink estimate. This should be reflected in the achievable carbon credits of a project.

7. Socio-economic and environmental aspects

AR projects must contribute to the conservation of biological diversity and the sustainable use of resources (COP 7, Marrakech). This has been taken by some to mean that monocultures of non-native species are disallowed in AR projects, as they are

generally lower in biodiversity than native vegetation. Moreover, monocultures in tropical conditions are sometimes harmful to soil, causing erosion; and fast growing trees (whether non-native or native) usually utilise large amounts of water that can adversely affect the yield of catchments. In some cases plantations may displace local communities. On the other hand, monocultures of fast-growing trees have been studied extensively and their growth is therefore relatively predictable, making them attractive in carbon sequestration projects. Sometimes they contain significant biodiversity, especially if present as several age classes in one location. Moreover, they may provide a ready supply of timber and fuel, relieving pressure on the native forest.
In ***Section 2***, we propose a decision framework for CDM project evaluation which allows a ranking of projects, including their rejection, with regard to socio-economic and environmental criteria (***Evaluation Criteria Figure 2***).

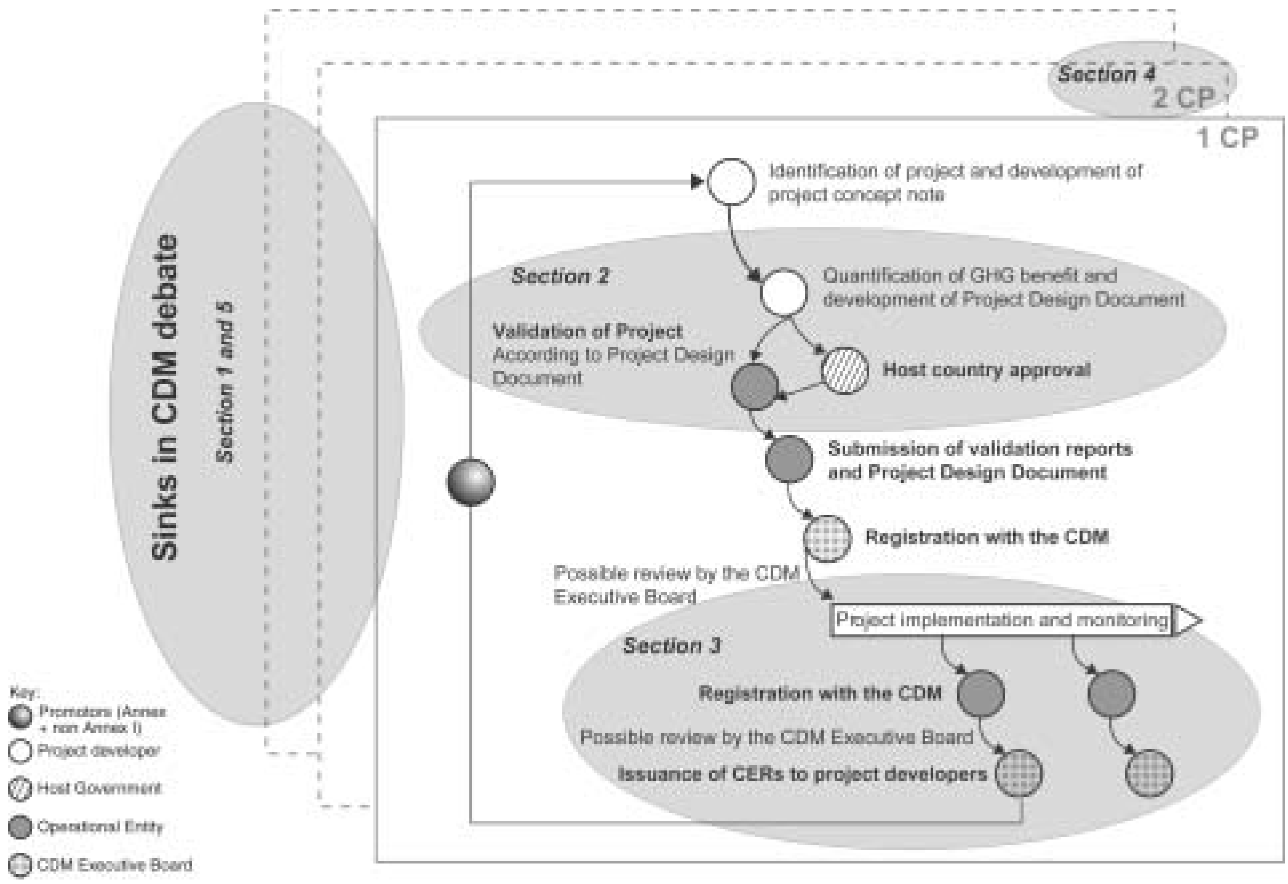
8. Crediting period

Projects that start with involvement of local people or have a significant investment in technology transfer, training and capacity building, such as agroforestry, forest restoration or low-input AR projects in marginal areas will be encouraged by long crediting periods. These project types are likely to produce the highest socio-economic and environmental benefits and involve a lower risk of trade-off regarding Non-CO_2 gases than intensive plantations.

The start of the project should be defined such, that the GHG accounting encompasses any initial losses of carbon (or emissions of other GHGs) from, for example, site preparation or clearing of previous vegetation. Monitoring should be as intensive as possible in the start phase of AR projects to avoid overcrediting associated with the rapid changes in GHG sources and sinks associated with disturbances at this stage in the life cycle.

The following sections address some of the aspects summarized above in more detail. Figure 0 illustrates the relation between the documents structure and the CDM project life cycle, and the role of negotiations, respectively.

Fig. 0 Relation between the documents structure and the CDM project life cycle, and the role of negotiations



• 1. Rules for sinks in the CDM in the First Commitment Period

The Clean Development Mechanism (CDM) in the Kyoto Protocol allows and encourages Annex I countries to assist the sustainable development of non-Annex I countries by installing certain kinds of 'clean' projects in return for carbon credits. Such projects range from those that directly reduce the emissions of greenhouse gases to those that create carbon sinks by afforestation or reforestation. Annex I countries will be credited for carbon sequestered in approved projects, and the credits will count towards their national emission targets.

It has been agreed that in the First Commitment Period (2008-2012), activities involving land use, land-use change and forestry (LULUCF) will be limited to afforestation/reforestation (AR), and that the carbon absorbed in these projects will attract Certified Emission Reduction units (CERs) to be traded with other countries (Decision 11/CP.7, FCCC/CP/2001/13/Add.1. paragraph 13). The quantity of carbon that might be involved worldwide is potentially significant in relation to national emission reduction targets. Countries with difficulties in meeting their targets domestically may take advantage of the forestry options within the CDM.

The use of AR as part of the CDM as a means of achieving emission reduction targets, and the rules that govern the actions, have been controversial and are still being debated. Some of the main issues are discussed below.

1.1 Definitions of 'Forest, Afforestation, Reforestation'

It is a cause of much confusion that different international agencies have adopted different definitions of terms such as 'forest', 'afforestation' and 'reforestation', as pointed out by IPCC LULUCF Special Report (2000). For the purposes of forestry and forest activities in the Kyoto Protocol (Articles 3.3, 3.4), it was agreed at COP 7 (Annex of Decision 11/CP./7) that forest is defined by the respective host country within the ranges of "an area of at least 0.05-1 hectares of trees, with a canopy cover of at least 10-30%, and with trees capable of reaching 2-5 m"; and that afforestation should mean that "the site has not been forested for at least 50 years"; and that reforestation refers to "the planting of trees on sites which were not forested on 31 December 1989". Although these definitions are accepted for application in Articles 3.3/3.4 (referring to Annex I countries) they have been challenged for use in Article 12 (non Annex I, CDM activities). The justification for the challenge is that official records in non-Annex I countries are imperfect. Probably the challenge should be resisted, because although official government records may be unavailable, satellite remote sensing provides the possibility of independent checking of the land surface cover for any region of the world. Because of missing data caused by cloud cover and satellite outage, not every month may be represented by an image, but it is certain that the presence or absence of forest can be detected to within six months (***Appendix I***).

The present proposal to accept as 'forest' any stand of woody vegetation with a canopy cover exceeding 10 – 30 % will ensure that most agroforestry projects count as 'forests' for CDM purposes, although many will be marginal. Substantial woody vegetation which does not grow to 2-5 m but has the potential to sequester appreciable quantities of carbon will unfortunately be excluded (this includes some forms of savanna, and scrubland vegetation world-wide).

1.2 Non-permanence

It is clear that forests have the potential to remove carbon dioxide from the atmosphere by photosynthesis, and that the removal of a ton of CO_2 in this way has the same effect on the climate as reducing the emissions of a power station by one ton. It is however argued that they are not truly equivalent, because forests are not always permanent. Forests are vulnerable to destruction by natural and man-made causes. In the case of a forest fire, for example, almost all of the carbon fixed over several decades would be returned to the atmosphere as CO_2. Therefore any initial benefit of afforestation to the climate would be reversed. Real reductions in fossil fuel emissions, achieved for example by replacing fossil-fuel power stations by sources of renewable energy, will on the other hand have a permanent beneficial effect on the climate. The EU has developed the proposal, that was tabled in its original form by Colombia, for dealing with non-permanence risk in a way that avoids penalising projects where reversal does not occur, and guarantees complete replacement (with a delay of at most one commitment period) of the lost carbon if there is reversal. The possibilities of insuring forests against destruction seems less practical than the Colombian proposal of 'Temporary Emission Reduction Units (tCERs)' which in trading would be worth less than CERs themselves, and which could be renewed periodically following verification that the carbon stocks have not declined. Practical solutions for the implementation of the tCER concept are in progress (Dutschke and Schlamadinger, in prep.).

1.3 Additionality and Baselines

One of the principles that underlies the CDM is that any emission-reducing or carbon-absorbing project should be additional to what would have happened in any case, during 'business as usual'. Projects should also be financially additional (*i.e.* that extra costs need to be made for long-term carbon sequestration).

It may be difficult to define the tests for additionality. Most areas of deforestation will tend to regrow of their own accord, and so it might not be acceptable to count natural regrowth as a contribution to carbon absorbed under CDM. Even this is quite debatable because regrowth will not occur where 'as normal' continuing population pressure prevents regeneration, and projects are often on degraded land that would not regrow unless additional inputs are applied. Another concern relates to elevated CO_2 and N-deposition. Forests worldwide are probably growing faster now than they would have grown 20 years ago, as a result of elevated CO_2 and N-deposition, but it would not be practical to try to make an allowance for this anthropgenic boost when attributing carbon sequestered to a particular project. The way this is overcome is to define an agreed baseline as the pattern of C-uptake expected if there were no project at all. Baselines would have to be decided at the outset, and might be difficult to agree. Baselines should best be part of the project monitoring (***see Section 3, Levels 2-4***), e.g. as control plots or reference areas inside or outside the project area. Bias or manipulation could be avoided by a careful verification of the representativeness of these control areas, to be performed by the Designated Operational Entity (DOE).

In ***Section 2***, a detailed project evaluation scheme including additionality is proposed (***Evaluation Criteria Figure 3***).

1.4 Leakage

The term leakage refers to effects on emissions or carbon fixation that occur outside a project's spatial boundaries and which are directly attributable to the project. These effects can be either contributing to climate change mitigation (which is called *positive* leakage or *spill-over*) or can partially or totally invalidate the effort (*negative* leakage). Some examples are given here (Table 1).

Table 1 Leakage potential of afforestation and reforestation projects

Causes	Negative leakage	Positive leakage (spill-over)
Market effects	AR projects cause scarcity in arable lands, thus inducing the population to cut down natural forests.	Project improves landscape management, leading to higher productivity and less erosion.
	Increased timber availability depresses market prices and leads to decreasing afforestation activities elsewhere.	Increased wood availability alleviates the pressure on natural forests.
Activity shifting	Local population looses the livelihoods and moves to the cities.	The project creates job opportunities, thus attracting people who formerly cleared natural forests.
Life-cycle emissions shifting	The afforestation increases the operation of fossil fuel operated machinery.	Fuelwood plantation lays the basis for bioenergy projects.
Ecological leakage	A plantation introduces a pathogen to surrounding forests.	A plantation includes ecological reserves for legally required watershed protection, that are not enforced in the baseline case.

These examples show that occurrence and direction of leakage depend largely on the project design, but also on the socio-economic environment of the project. Sometimes, positive and negative leakage even have the potential to cancel each other out. Market leakage is most difficult to quantify. At the utmost, there may be a chance to quantify local firewood availability, but national or international markets are subject to so many other factors that it will be impossible to single out the effects of one project. Some analysis, however, could be performed about the sum of effects of all CDM projects in a country on national markets and trade balance.

It is further questionable if accounting for negative and positive leakage should be symmetric. *Not* accounting for spill-over effects does not harm emissions integrity, while not accounting for negative leakage does. Positive leakage can only be verified if its occurrence is predicted in the monitoring protocol, and it cannot be based on pure assumptions. If it is measurable, the project boundaries could have been designed to include these carbon gains. Negative leakage can in most cases not be quantified exactly, as it is beyond the reach of the project participants, which is why a conservative discount will be made from the project's carbon uptake. The risk of leakage is reduced by a *proper project framework and design*. The detailed project evaluation scheme proposed in ***Section 3*** implicitly addresses leakage by various criteria which help to achieve a well-designed, sustainable project with multiple non-carbon benefits. We propose that careful, conservative accounting for leakage is mandatory. Activity shifting and ecological leakage should be included in the project monitoring.

1.5 Pools and fluxes

The environmental integrity of CDM projects may not be ensured in all cases if additionality, leakage and monitoring requirements are limited to carbon stock changes only. Warm and moist conditions favour N_2O emissions (Granli and Bøckman 1995), and tropical ecosystems tend to be limited by phosphorus rather than nitrogen,

enhancing the risk of N_2O release from excess mineral nitrogen in soil. Tropical primary and secondary forests have been reported in the literature to emit N_2O in rates between 0 and 1.3 t C-equivalents ha^{-1} a^{-1}. N_2O emissions are stimulated by fertilizer addition and by introduction of leguminous species (Erickson et al., 2001). For instance, Erickson *et al.,* 2001 found that N_2O emissions from a mid-successional subtropical forest increased with more leguminous trees by almost 1.1 t C-equivalents ha^{-1} a^{-1}, and after fertilizer addition by more than 2.5 t C-equivalents ha^{-1} a^{-1}. Management-related N_2O emissions may easily negate or even reverse the carbon sink in CDM projects. The effect on CH_4 sources and sinks is likely to be minor and restricted to areas which are waterlogged for at least part of the year.
Three risk classes for environmental integrity of CDM projects may be distinguished:

1. Low-input AR projects on well-drained upland soils, without leguminous trees or fertilization: Non-CO_2 emissions are not likely to compensate the carbon sink, except for the establishment phase of the plantation
2. AR projects including leguminous trees or fertilization: Non-CO_2 emissions are likely to compensate partly or fully the carbon sink. Environmental integrity must be proven by careful monitoring of N_2O emissions against a baseline.
3. AR projects on areas which are waterlogged for at least part of the year, especially on organic soils (peat soils): GHG emissions are likely to rise above the baseline. Projects should be avoided.

• 2. Evaluation of project plans for eligibility in the CDM

The Kyoto Protocol has set limits on the type of projects eligible under the CDM (afforestation and reforestation). It also requires projects to address those issues discussed above. However, guidelines on how projects should tackle these issues are still under discussion. Forestry projects developed under the AIJ pilot phase have presented a range of highly case-specific, narrative arguments as evidence of their additionality and sustainability. A structured, consistent and credible framework for assessing the eligibility of projects would provide guidance to project developers and exclude unsuitable projects at an early stage. Most of the issues discussed above can be addressed through appropriate project selection, design and management.

Guidelines and criteria for sustainable forest management (SFM) have already been developed by several international organisations, including the Forest Stewardship Council (FSC), Center for International Forestry Research (CIFOR), International Tropical Timber Organisation (ITTO), Pan European Forest Certification (PEFC), Convention on Biological Diversity (CBD), Global Environment Facility (GEF). Guidelines and criteria being developed by the UNFCCC, through the AIJ pilot phase and by private companies, such as SGS, have a great deal of overlap with SFM criteria (Waterloo *et. al.*, 2001).

A framework which assesses eligibility and provides guidance to project developers should:

- allow project developers to assess the project additionality and eligibility for receiving CERs prior to implementation;
- minimise the risk of project failure;

enhance the lifetime of the carbon sink and carbon stocks through socio-economic and environmental sustainability;

- ensure proper project management;
- encourage technology transfer, training and capacity building;
- minimise and account for leakage at the project level and to a lesser extent at the regional, national and global level.

The framework should be clear and guide project developers through the various requirements for carbon forestry projects. A decision tree as proposed by Tipper *et. al.* (2002), allows a structured assessment of projects with a binary (pass/fail) conclusion against the criteria. This approach allows the setting of basic standards which a project has to attain. There is however a huge variety of projects and for some criteria a scoring system is more appropriate, and allows the overall benefits of the project to be assessed. For example, a plantation may not have the environmental and biodiversity benefits of a forest restoration project, but could bring many benefits to the local community by providing sustainable livelihoods or providing an alternative resource to pristine forests.

An example of a structured approach to assessing project eligibility is illustrated below. The first stage is an overview of the main requirements for CDM projects. Each of these questions is broken down into further criteria. These show the key criteria which a project has to meet to fulfil the top-level requirements. Further detailed assessment is carried out through scoring the added benefits which a projects will provide. This scoring could be used to provide a minimum level which projects are required to achieve and to rank projects should the limits for the CDM set by the Kyoto Protocol be exceeded.

The basic decision tree model for determining the eligibility of an AR project in CDM is shown below. Within this flow chart, reference is made to additional flow and score charts that are customised for the three different project types that will lead the evaluating authority to accept or reject the project.

The project evaluation itself consists of two steps. The first step is an evaluation of the project framework (*i.e.* the management plan). This step is the same for both new and existing projects that aim to sequester carbon under the CDM. New projects may use these CDM AR project evaluation criteria as a basis to the formulation of a management plan that will pass the CDM project eligibility test.

For existing projects, the second step deals with how the issues related to long-term carbon sequestration in the management plan are implemented in the project field operations. This requires visits by experts of the verifying authority to the project site to check how well the project management plan is implemented.

The first condition to which any CDM forest project should comply to is that the project area will be, or has been established on land that was deforested before 1 January 1990, as specified in the Kyoto Protocol. How to test whether this condition is fulfilled (remote sensing) is described in Appendix I.

If the project meets the condition above, the type of project should be determined to evaluate project-type specific criteria related to the nature of the project (e.g. commercial versus non-commercial). Three eligible types of forest projects may be distinguished. These are:

- Plantation forest projects. These are production forest (timber or non-timber forest products) projects that should be commercially viable
- Forest restoration projects. These projects are largely non-commercial and the forests are established on degraded areas for conservation purposes
- Agro-forestry projects. Trees are planted in agricultural systems to enhance the functioning of the agricultural system (*e.g.* by providing shade, protection to erosion, fuel wood, soil nitrogen, etc.).

Other forest projects, including forest conservation projects, are **not eligible** in CDM under the present rules for the first commitment period.

Eight general criteria that a CDM project should aim to fulfil in order to be eligible as a CDM AR project have been formulated by Waterloo et al. (2001). These are:

1) **Project framework:** projects should have comprehensive management plans describing how long-term carbon sequestration is achieved through adherence to the criteria listed below. Both the management plan and its practical implementation need to be evaluated.
2) **Compliance:** to national and international laws and treaties
3) **Additionality:** the project should be additional to “business as usual”
4) **Verifiability:** the sequestration rates should be monitored and verified
5) **Transparancy:** insight should be given to the methods of verification and project management to reproduce results
6) **Sustainable forest management:** to avoid negative impacts on soil structure and

fertility, water resources and biological activity within and outside the project area
7) **Environmental sustainability:** to conserve or contribute to biological diversity and strive toward economic viability
8) **Socio-economic sustainability:** to minimise negative effects on local communities and promote technology/knowledge transfer

These criteria address the project formulation, compliance to the laws, risk reduction, knowledge transfer and capacity building, competence of the project staff, available infrastructure (including fire and pest control units), socio-economic, political and environmental factors, accounting and verification methods, leakage, permanence, credit sharing and sovereignty issues (Waterloo et al., 2001).

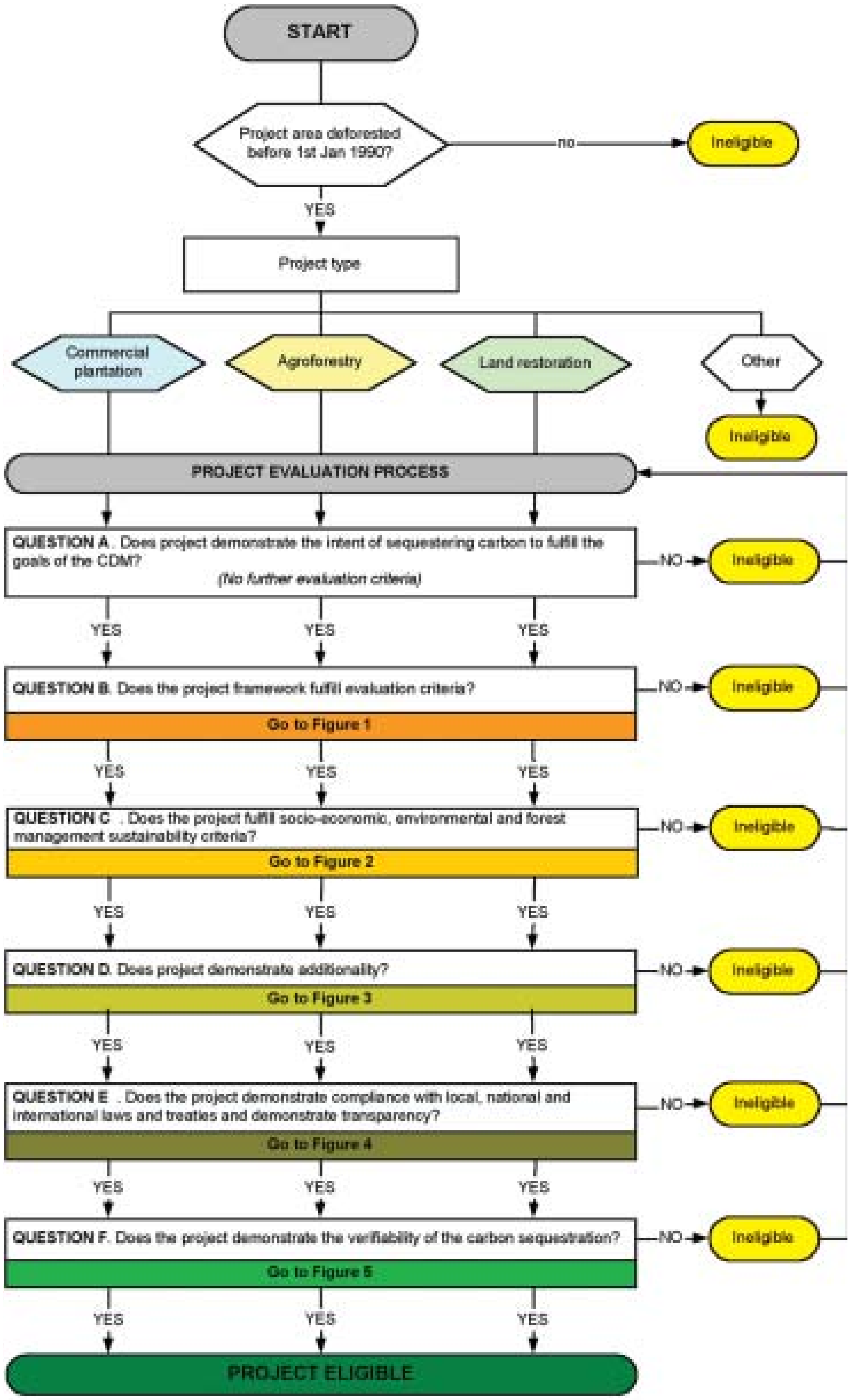
At this point the project evaluation continues by evaluating the project management plan for explicit references to carbon sequestration for the purpose of mitigation of climate change and steps that have been taken to address forestry operations, permanence and carbon monitoring issues.

The evaluation then continues to address environmental and socio-economic sustainability, compliance, additionality and verification issues. The end result of the evaluation provides the answer to whether the project is eligible and, if so, how much carbon has been sequestered that can be used for receiving CERs.

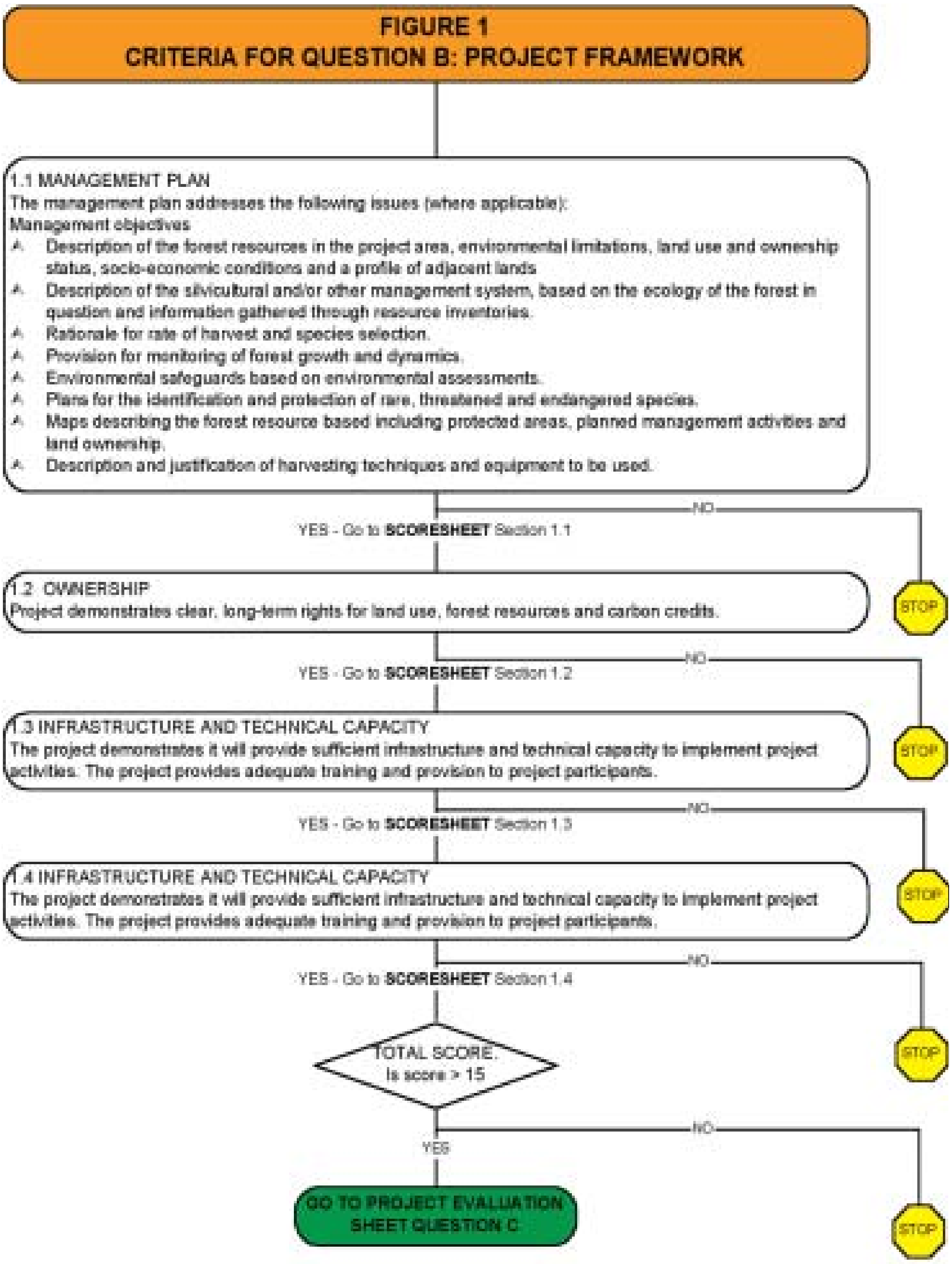
Transparency is demonstrated by the project through detailed descriptions of conflict resolution procedures, procedures related to all project field operations (planting, weeding, use of chemicals, etc.) and carbon sequestration monitoring and verification procedures.

The future of a project, and therefore the permanence of the carbon stock, depends to a some degree on whether the project complies with national and international laws and treaties. This aspect can be evaluated by checking the management plan for provisions addressing landownership laws, labour laws, environmental laws, etc. In some countries (*e.g.* Cameroon) government laws on landownership may conflict with tribal laws leading to conflicts between the government and local residents. Such conflicts often result in the destruction of part of the forest estate through intentional fires. To enhance the overall feasibility of a project, the management plan should therefore contain detailed information on how conflicts regarding landownership, labour issues, etc. are resolved and aim for participation of the local population.

PROJECT EVALUATION SHEET



EVALUATION CRITERIA



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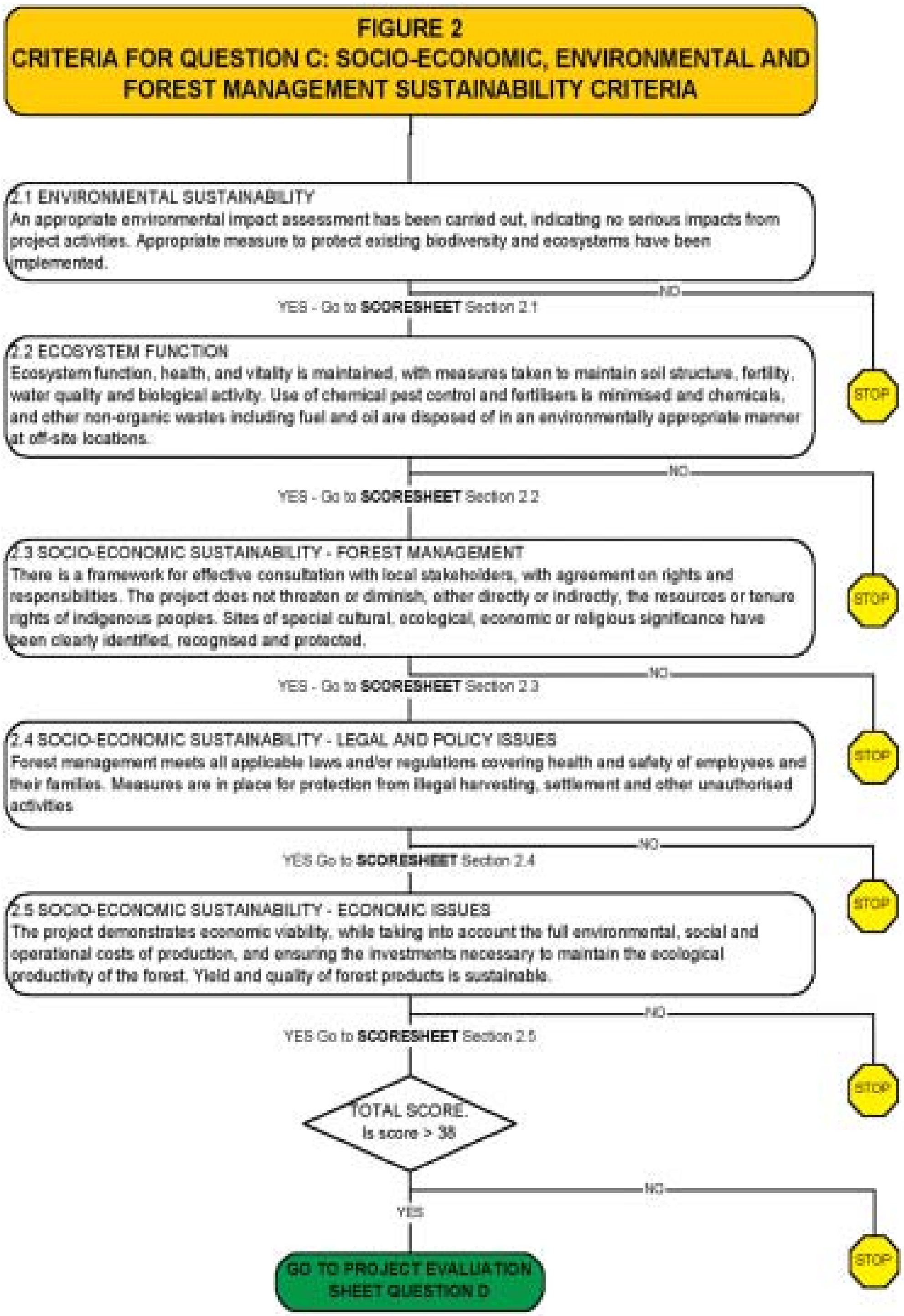

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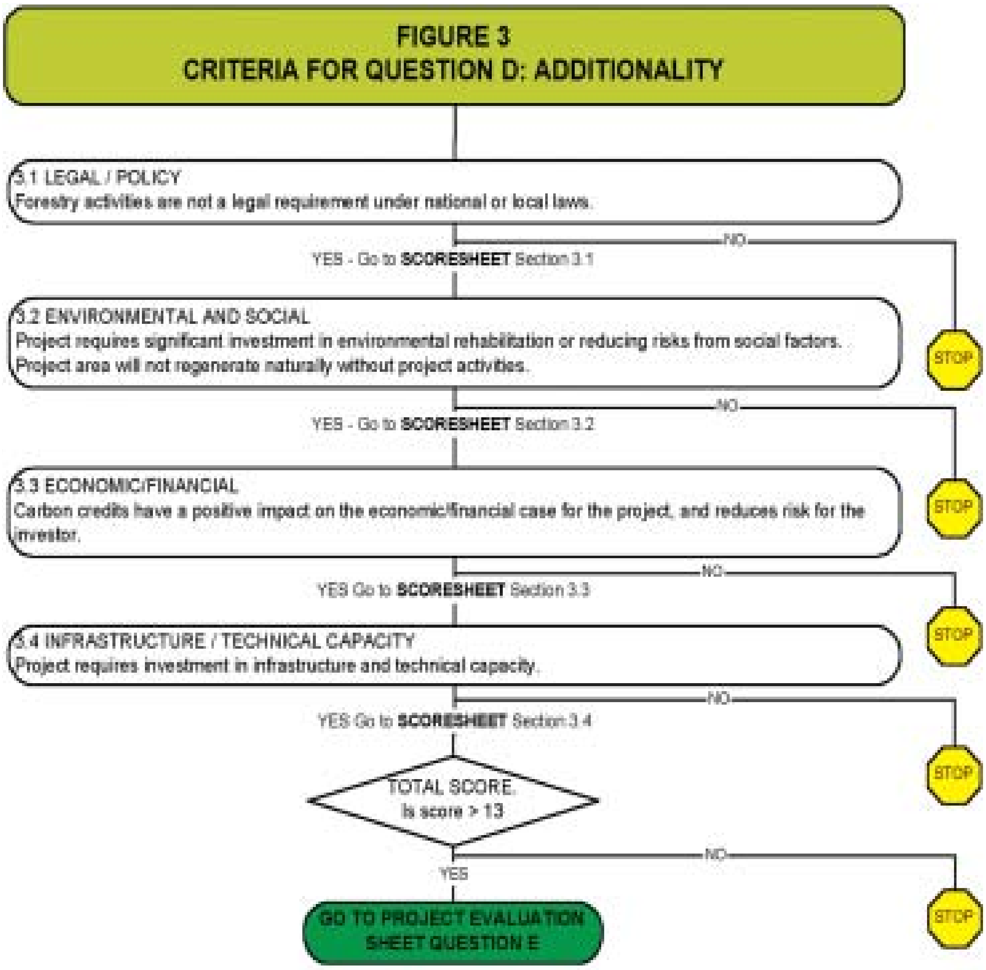


EVALUATION CRITERIA

FIGURE 4
CRITERIA FOR QUESTION E: COMPLIANCE

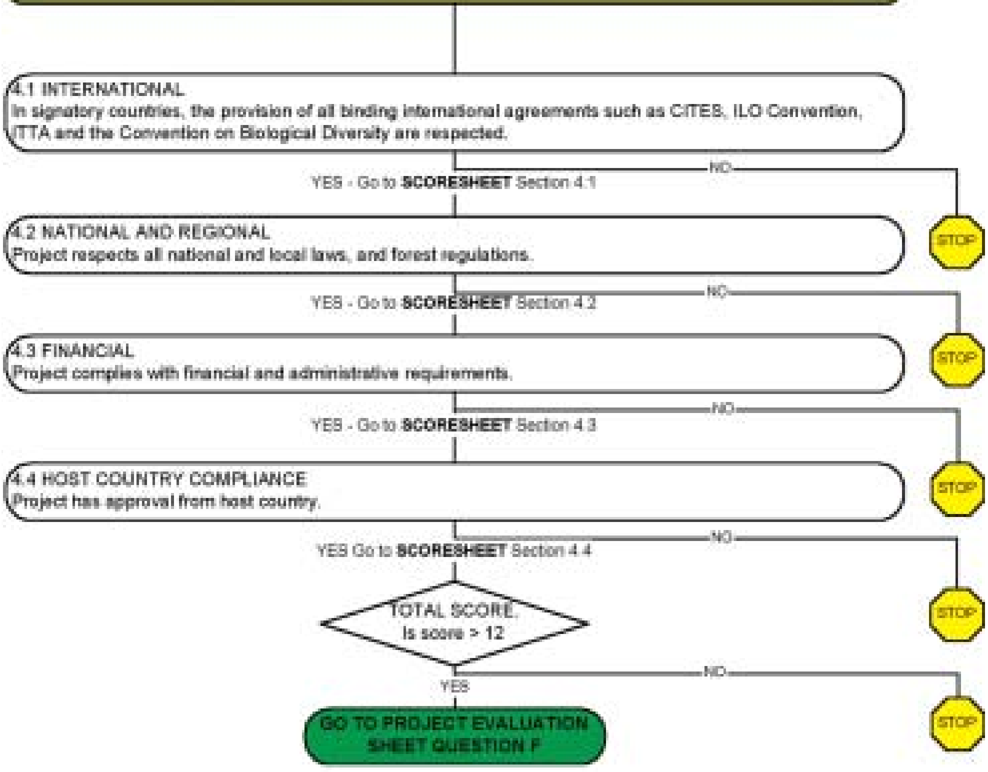
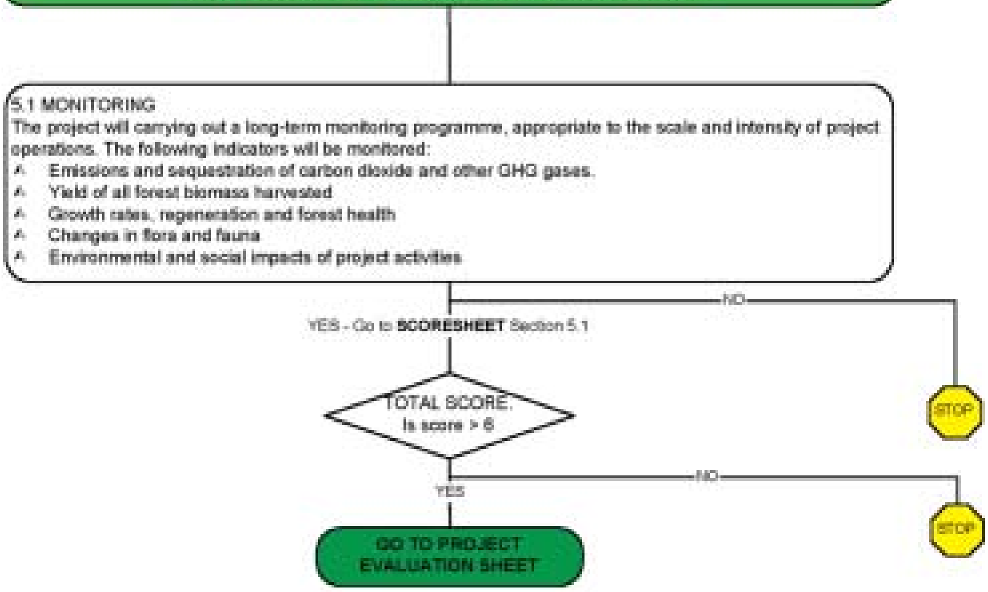


FIGURE 5
CRITERIA FOR QUESTION F: VERIFICATION



SCORESHEET

The project validator should score each section. Each section or sub-section has a minimum score which projects must achieve to meet validation requirements. The gradings below are used to assess the level to which the project meets the criteria.

0 - the project plan fails to address this criterion or cannot be assessed due to missing or incomplete information
1 - acceptable
2 - fair
3 - good
4 - very good
5 - excellent

SECTION 1 SCORESHEET: PROJECT FRAMEWORK		
Criteria	Maximum score	Project score
SECTION 1.1: Management Plan • The project framework addresses the required elements of the management plan.	5	
SECTION 1.2: Ownership • The project framework demonstrates security over land, forest resources and carbon credits.	5	
SECTION 1.3: Infrastructure / Technical Capacity • Project activities will provide infrastructure and technical capacity to enable implementation of project activities	5	
• The project will provide necessary training to project participants.	5	
SECTION 1.4: Economic / Financial. • Levels of funding are adequate and sustained for the lifetime of the project.	5	
• Project framework outlines provisions for funding to maintain carbon sink once the project is completed.	5	
SECTION SCORE Minimum score = 15	30	

SECTION 2 SCORESHEET: SOCIO-ECONOMIC, ENVIRONMENTAL AND FOREST MANAGEMENT SUSTAINABILITY CRITERIA		
Criteria	Maximum score	Project score
SECTION 2.1: Environmental Sustainability		
1. Conservation zones to protect examples of existing ecosystems are included in the project area.	5	
2. Project will protect rare, threatened and endangered species and their habitats.	5	
3. Project activities will enhance and encourage biodiversity.	5	
4. Plantations will directly alleviate pressure from exploitation on local pristine forests/forest reserves	5	
Sub-section Score — **Minimum score = 10**	**20**	
SECTION 2.2: Ecosystem Function		
5. Project will directly protect and enhance forest services and resources, eg watersheds and fisheries	5	
6. A proportion of the forest management area will include the restoration of natural ecosystems	5	
7. Forest management activities will cause minimal impacts on ecosystem function and vitality	5	
8. Species selection is appropriate to the site conditions and forest management objectives, maximise the use of native species.	5	
Additional factors (scored from 0-3)		
9. Natural regeneration is promoted	3	
10. Project promotes use of environmentally friendly non-chemical methods of pest management	3	
Sub-section Score — **Minimum score = 13**	**26**	
SECTION 2.3: Socio-Economic Sustainability – Social Factors		
11. The local community is formally involved in the management and implementation of the project (from consultation to overall control of management)	5	
12. Forest resources are used for the benefit of local stakeholders.	5	
SECTION 2.4: Socio-Economic Sustainability - Legal and Policy Issues		
13. Project implements health and safety policies for employees and their families which exceed applicable law/regulations	5	
14. Opportunities for employment, training and other services are provided to local communities	5	
SECTION 2.5: Socio-Economic Sustainability – Economic		
15. Project demonstrates economic viability, ensuring necessary future investments	5	
16. Project strengthens and diversifies local economy and maximises benefits from the forest, including non-timber forest products	5	
Sub-section Score — **Minimum score = 15**	**30**	
SECTION SCORE — **Minimum score = 38**	**76**	

SECTION 3 SCORESHEET: PROJECT INTENT		
Criteria	Maximum score	Project score
SECTION 3.1: Legal • Afforestation / reforestation being undertaken by the project is not currently nor will become a legal requirement under forestry or other regulations	5	
SECTION 3.2: Environmental / Social • Project activities require investment in environmental rehabilitation • Project activities require investment in community relations / support to reduce risk of project failure and/or leakage	5 5	
SECTION 3.3: Financial • Carbon finance makes a positive impact on the economic/financial case for the project	5	
SECTION 3.4: Infrastructure / Technical Capacity • Project will implement new infrastructure / technology and provide appropriate training to project participants	5	
SECTION SCORE Minimum score = 13	25	

SECTION 4 SCORESHEET: COMPLIANCE		
Criteria	Maximum score	Project score
SECTION 4.1: International • Project management respects the provision of all binding international agreements such as CITES, ILO Convention, ITTA and the Convention on Biological Diversity, where applicable.	5	
SECTION 4.2: National and Regional • Project management and forestry activities comply with national and local laws and forest regulations.	5	
SECTION 4.3: Financial • Project complies with applicable administrative and financial requirements.	5	
SECTION 4.4: Host Country Compliance • Project has received approval from host country.	5	
SECTION SCORE Minimum score = 12	20	

SECTION 5 SCORESHEET: VERIFIABILITY		
Criteria	Maximum score	Project score
SECTION 5.1: Monitoring • The monitoring plan outlines an effective monitoring strategy, covering key indicators and following best practice guidelines. Justification is provided for any exclusions (e.g. soil carbon). • The monitoring plan includes monitoring of leakage from project activities	5 5	
SECTION SCORE Minimum score = 6	10	

TOTAL SCORE Minimum score = 84	166	

The framework presented above is an example of how a project could be assessed for validation. Adjustments could be made to the required criteria, the scoring criteria and to the minimum acceptable scores. These could also be varied by project type. This illustrates a detailed approach, particularly when compared to non-forestry projects, but is intended to be a detailed response to the concerns raised over forestry projects in the CDM. The framework could be easily adjusted for new project types that may become eligible in future commitment periods.

• 3. Monitoring and verification of carbon sinks in CDM: levels of complexity

Monitoring is the legally required process underpinning the reporting, verification and certification of carbon sequestration leading to credits. It is carried out by the project's own staff. The allowed project designs and monitoring options will be tightly specified in the treaty texts, accompanied by the *IPCC Good Practice Guidance (GPG).*

Verification is defined in the Marrakech Accords as "*the periodic independent review and* ex post *determination by the designated operational entity of the monitored reductions of anthropogenic emissions by sources of greenhouse gases that have occurred as a result of a registered CDM project activity during the verification period*". In practice, it is the periodic auditing of the data on emission reductions achieved by a CDM AR project and the project's compliance with other relevant requirements by a 'certifier'. Verification is a "reality check" on the books. It involves physical, on-site inspection, or where useful, deployment of techniques such as remote sensing, or interviewing relevant personnel in person or otherwise.

In designing a CDM AR project, various levels of technical complexity can be envisaged. The resources invested in a carbon sequestration project, and the infrastructure required, are also related to the complexity of the proposed monitoring and verification scheme.

As a minimum, CDM AR projects should monitor

1) Forest/ non-forest map of project area in 1990
2) Boundary of the project (preferably through GPS, but at least reporting through maps), at the beginning and during the entire lifetime of the project
3) Land use/cover of project area throughout the lifetime of the project to check whether in the future the project area is still subject to land use/cover according to project plan
4) C stock changes and all non-CO_2 emissions on the project site (all five pools as defined by the *IPCC Good Practice Guidance*, aboveground biomass, belowground biomass, litter, dead wood, soil carbon). Pools that can be proven to increase in size can be omitted from monitoring.
5) C stock changes and non-CO_2 GHGs in the baseline
6) Land-use patterns in the vicinity (as basis for estimating leakage)
7) Timber and agricultural outputs of project site in the baseline and project cases (as basis for estimating leakage)
8) Indicators for environmental and socio-economic effects.

Project types (e.g., agro-forestry), frameworks and designs (cf. Section 2) with clear positive environmental and socio-economic effects and small risk of leakage could be promoted by reduced monitoring requirements regarding the criteria 6) to 8).

Chapter 4.3 of the *IPCC Good Practice Guidance (GPG)* discusses project monitoring in its Second Order Draft with a notion of feasibility rather than environmental integrity. In particular, no minimum requirements, default methods and higher Tier options are presented. This is an inconsistency with the way *IPCC Good Practice Guidance* treats the reporting under the UNFCCC (Chapter 3 of the *IPCC Good Practice Guidance*).

In the following, we present observational strategies applicable to monitoring and verification of carbon sinks and non-CO_2 GHG emissions in CDM projects. We comment on possible methods, their pitfalls, advantages and disadvantages, as well as likely uncertainty levels associated with them. Each of the methods can serve as tool to fulfil part of the minimum requirements for monitoring land cover and GHG sources and sinks. The levels are translated into the Tier structure of the *IPCC Good Practice Guidance*.

Level 0: Reforestation or afforestation followed by minimal local monitoring

In projects with the lowest levels of resource, an approach based on remote sensing could be considered. The basic data requirements are: location as set out in the project plan, preparation and main species planted. Even low resolution data is useful to give a country-wide impression of the state of the forest resource (Foody et al 2003). From the existing 1990 LANDSAT images and from other remote sensing resources like SPOT and RESOURS it can be determined whether the project area was forested in 1990 or not (see Appendix 1). Similar images with global coverage are available for 2000 to prove that by that date the land was still not forested; and images could be obtained at the end of the project to show that the area is still covered by forest. High spatial resolution satellite images are now available for commercial use from many sensors (IKONOS, Quick Bird, EROS A-1, Orbview 3, Spot 5, IRS, etc.). These high-resolution images should be used to give proof of the project development during all its lifetime, showing activities such as establishment of nurseries. Attributes of the data other than reflectance may be used: for example the shape of the terrestrial element can help one to discriminate between plantation (which is angular) and native woodland. Once the project is identified on the image, it can be monitored. Using information on the rates of growth of forest for that specific region, the carbon gain could then be estimated from the AR area with a minimal amount of ground-truthing. However, the Level 0 approach may not necessarily meet the minimum requirements of a Tier 1 approach of the *IPCC Good Practice Guidance*. Level 0 can serve to fulfil the monitoring requirements 1, (2), 3, and 6.

Advantages:

- The method is cheap and simple, the images are available and applicable to any place on earth.

Disadvantages:

- The uncertainties in land use conversion factors are high, so the allowable credits should be low.
- In attesting the land use change process (1990 and 2000), the minimum detectable AR area using LANDSAT images is 1 ha, and the minimum detectable canopy coverage is around 30%. So this level 0 could not be used for some particular kind of woodland ecosystems and for projects in which change in canopy coverage is small.
- Non-CO_2 emissions cannot be monitored, and might be large.

Pitfalls:

Although a change in reflectance in a single area is unequivocal proof of land-use change, it is more difficult to statistically prove that in a particular area AR has actually occurred. In principle it would seem straightforward to assign pixels to forest or non-forest at two moments in time, and hence to identify how much afforestation or reforestation has occurred in the interval. However, there is not usually a precise geographical one-to-one correspondence of pixels of the 'before'-image and the 'after'-image, so the comparison may be flawed. Moreover (and much more serious): if a pixel has been assigned as 'forest', immediately an uncertainty is introduced because we don't know if the area represented by this pixel is completely or only partially filled with forest. This aspect has also been discussed in the IPCC Special Rerport on LULUCF. Special procedures would have to be developed to deal with such situations. Because of the limited resolution of the method, there is scope for fraud or even perverse activities.

Level 1: Standard AR relying solely on tree mensuration techniques

In this case, there may be activities in a populated area where there is enough man-power, but the level of training is not very high. The carbon gains will be moni-tored using forest mensurational techniques, and a standard (e.g. regional) baseline will be assumed. Such techniques depend on the measurement of stem diameter at 'breast height' of 1.3 m, and the application of standard methods as described in the *IPCC Good Practice Guidance*. There is also a requirement to prove that there have been no net losses of carbon from other carbon pools, e.g. the soils over the project period. So, in addition to above-ground stock taking of trees, samples of the other carbon pools (dead wood, litter, understory vegetation, soil) before and after the project will be needed. In many cases the sampling problems are formidable because of spatial variability. When random samples are taken, very large soil sam-ples are often needed (range n=100-1000) to overcome the inherent spatial vari-ability, but this number can be substantially reduced by adopting a paired com-parison approach, as outlined in the *IPCC Good Practice Guidance.* Stratification of sampling can help to reduce the number of replicates. Level 1 could be seen as a minimum requirement for CDM sinks projects and would be equivalent to a Tier 1 approach as defined in the *IPCC Good Practice Guidance*. Level 1 can serve to fulfil the monitoring requirements 3, 4 and 5 at a basic level.

Advantages:

- This method is closest to conventional forest mensuration, so the maximum (although possibly still limited) amount of information will be available on e.g. historic data, and the so-called 'expansion factors' which are used to estimate the whole tree biomass from the above ground measurements.
- The training required for project staff is relatively small
- The treatment of soil carbon is at its simplest.

Disadvantages:

- Default values for scaling from breast height diameter of stems to carbon, e.g. biomass expansion factors, carry substantial uncertainty, especially in chang-ing climatic conditions, and in types of forest where data have not previously been collected.
- Athough allometric equations have been developed widely, and are used wide-ly, the basic data from which they are derived is relatively sparse (often the trees in the sample were small trees) and normal statistical errors are large when the trees come to maturity.

- Default baselines carry high uncertainty, which will be overcome by higher levels of complexity.
- The results of the soil carbon stock changes could be used to determine N_2O emissions from soil carbon losses if applicable using the default method of the *IPCC Good Practice Guidance.*

Pitfalls:
Especially over organic (peaty) soils, small changes in soil depth cannot be detected but are associated with very large carbon emissions. The *IPCC Good Practice Guidance* treats organic soils differently from mineral soils and recommends the measurement and calculation of CO_2 emissions from peat drainage directly as CO_2 flux rather than as a stock change. However, no default data can be provided for the tropics. Afforestation of peat soils in the tropics may produce C losses as great or greater than the C gains from tree growth over an extended period and should best be avoided.

Level 2:
Standard AR project with inclusion of soil carbon stock changes and specific accounting for baseline

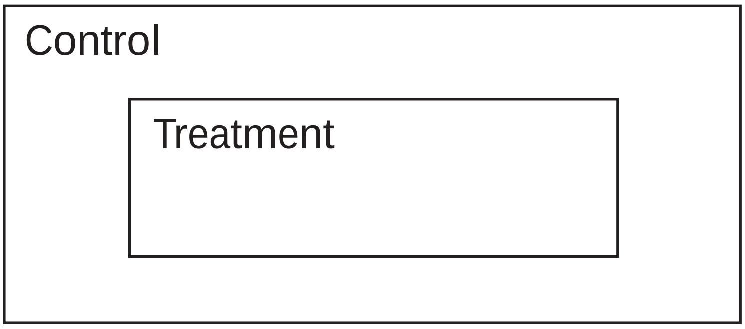
This is similar to level 1, but with substantial resources to be invested in training local personnel to perform monitoring tasks and manage the project carefully. Here the difference between the individual project baseline and the AR activity is determined. There is a need for an elaborate and unbiased statistical design, comparing treatment plots and control plots, located at random in a homogeneous area. At level 2, soil carbon stock changes are quantified with much more accuracy, and this will also affect the required sample quantity and analysis precision. Similarly, emissions of non-CO_2 gases would be considered. This level should be seen as the default requirement for eligibility of CDM sinks projects and is equivalent to a Tier 2 method as defined in the *IPCC Good Practice Guidance*. Level 2 can serve to fulfil the monitoring requirements 3, 4 and 5 at a satisfactory level.

Over and above those mentioned in level 1:
Advantages:
- If carried out properly, the uncertainties are much less so the potential credits should be higher
- There would be substantial investment in local development and education.

Disadvantages:
- The sample design is difficult:

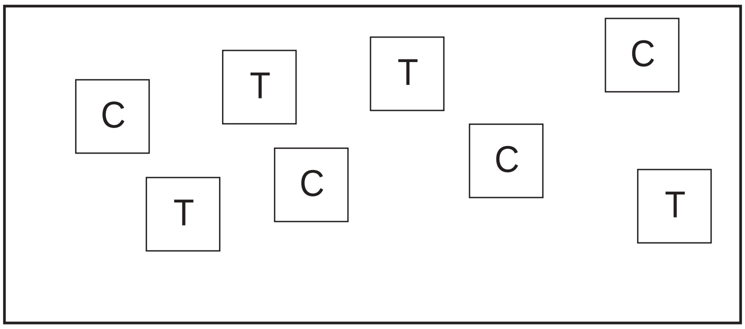
At a first sight, one might imagine a very simple statistical design like:

OR:



where the project area has been divided in two parts ("plots"). The "Treatment" will be randomly assigned to one of the plots, the "Control" will be given to the other plot. However, this is a poor experimental design, as there are only two so-called "experimental units". A sound statistical inference in this case is not possible. Nevertheless, at a spatial scale beyond the project area, this set-up could be developed to a pragmatic approach for the determination of baseline and leakage (Appendix II).

A much better (but more elaborate) experimental design is the following (C=control, T=Treatment):



In this case, treatment and control are to be randomly assigned to the plots as selected in the project area (in this case there are 8 plots; 4 have to become "treatment" and the remaining have to become "control"). The Control plots serve as a (stochastic) baseline.

A two-sample statistical test has to be carried out. If the null hypothesis ('no difference between the distributions of treatment and control') has been rejected in favour of the alternative hypothesis ('treatment leads to higher carbon sequestration than control'), the difference of the averages of Treatment and Control carbon sequestration can serve as an unbiased estimator of the extra Carbon gain due to the Treatment.
The main advantage of this method is that no conservative method need to be used; the unbiased estimation leads to the highest obtainable credits.

- Analysis cost can be high
- Project boundaries will be less clear, and, in practice, allocation of sample plots cannot always be done at random as many other factors are involved in locating plots.

Level 3:
As level 1 or 2, but now including more advanced technology and options for independent cross-checking of carbon fluxes

One important risk in AR projects is that the soils may loose carbon during project preparation or during the period immediately following this. It may be very difficult to detect such changes from soil carbon analysis. However, emission fluxes can be measured directly using soil respiration chambers. This is relatively new technology relying on simple mobile or fixed chambers and Infrared Gas Analysers (IRGA) or Multi-Gas Monitors. Although more expensive, the method is likely to be competitive with laboratory costs for soils analysis. To prove that measured soil CO_2 or N_2O emissions are lower than the baseline there would be a need for data collected prior to the project installation, or, as in level 2, a well-designed spatial sampling of treatment and control plots. This approach would be equivalent to a Tier 3 method of the *IPCC Good Practice Guidance*. Level 3 can serve to fulfil the monitoring requirements 3, 4 and 5 at an adequate level.

Advantages:
- The method gives emission fluxes to an accuracy never achievable with soil samples
- This is a relatively easy and cheap means for third parties to travel around and check on many projects
- There is no need to specify soil depth.
- All greenhouse gases could be screened simultaneously.

Disadvantages:
- As these are point measurements just like soil samples, there is a need for well-designed statistics accounting for spatial variability and differences with pre-project conditions
- A fraction of the soil emissions comes from root respiration, not simply the breakdown of soil organic matter. As a default, based upon only a few studies published so far, this may be assumed to be half.
- It is very difficult to measure respiration continuously, so the methods are less suited for integration over time and full accounting. The main use should be to signal high emissions.

Pitfalls:
- There is also small-scale temporal variability of soil respiration fluxes. Diurnal variation, temperature sensitivity and seasonal variation need to be accounted for.

- There is still discussion in the scientific community on which is the best method, although rigorous calibration test are currently being carried out on several designs.

Level 4:
Use of tower-based eddy covariance for cross-checking of carbon fluxes

As noted under level 3, during project preparation and during the first project years, the ecosystem is in transition and the soil is usually profoundly disturbed. In these circumstances 'standard' allometric and expansion factors, allowing estimation of changes in carbon stocks from changes in tree dimensions, are likely to be very unreliable. An ecosystem might be emitting much carbon from older organic matter even though newly planted trees may be growing well. Or, *vice versa*, the build-up of carbon stocks in litter and soils may be greatly enhanced if little organic material was available before the AR project started. Therefore, it is useful to employ methods that account for *all* components of carbon fluxes, including soil processes that are hard to detect otherwise. The use of soil flux chambers has already been discussed; however these only measure soil fluxes and are associated with spatial sampling limitations. An alternative is the use of *eddy covariance* (EC). EC is a method in which vertical exchange of CO_2 (and also energy and water vapour) are measured continuously *above* a vegetation canopy, usually from a tower that protrudes above the canopy. The measurement is made in one point, but due to advection by the air flow represents an upwind area of several hectares to km^2, depending on tower height. Measurements have a very high temporal resolution (30 min to 1 hour) and are therefore often used in ecological science where the environmental responses of the whole ecosystem are studied. However, measurements can also be integrated over time and then represent seasonal or even annual carbon exchange of the full ecosystem. Use of this method would enable identification and understanding of short, distinct 'bursts' of emissions or uptake as well as provide independent corroboration of annual uptake claims. EC has now for the past 10 years successfully been used in many long-term monitoring studies.

There is a perception that EC is extremely expensive. However, experience with the method has now progressed to such a degree that equipment and maintenance can be simplified and systems can operate remotely with only once-or twice monthly basic maintenance. One other limitation is the need to use a tower. But especially in young forests, up to about 15 m height, easily movable, light towers can be used. This makes the method especially useful for temporary deployment by verifying entities wishing to check on a number of projects. Specialist organisations offering measurement services could be temporarily employed to perform this task.

As with all methods, EC has some uncertainties and unresolved questions about its interpretation. Experience in many sites all over the world indicate that EC tends to produce higher carbon uptake estimates than those made from differential stock taking (even if all components are accounted for). Reasons for this are sought in poor reliability of EC during calm nights, but also to the difficulty to define the exact spatial boundaries of the measurement domain. The latter of course makes EC less suitable for formal carbon accounting. However, if an ecosystem is measured by EC to be carbon neutral or even emitting, this can be at lest used as strong qualitative evidence that no net sequestration is taking place.

Advantages:
Measurement of the full net ecosystem carbon exchange
High temporal resolution: enables detection of short-duration or seasonal phenomena
Currently increasingly affordable especially in not-so-tall forest.
Provides independent assessments of carbon exchange
Data can be used to calibrate models
Can generate spin-off of highly trained technical persons

Disadvantages:
Requires high skills levels or hiring external specialists
Not yet suitable for formal accounting
Lateral boundaries are indistinct
Mainly suitable for either high-resource projects or for larger independent verification entities or organisations

Level 5: Regional atmospheric carbon balances from 'atmospheric stock taking'

Apart from hard-to-detect losses from soils and dead material, there are several other potential risks from 'project leakage'. One way to account for leakage at regional scales is, in principle, to increase the geographical scale of projects to include all or many of the leakage 'footprints'. The problem then becomes, of course, that it is more and more difficult to monitor of verify all carbon exchange in such a region.

The most direct solution to this problem is to monitor the atmospheric budget directly. This is precisely what several studies at global or continental scales aim to do (atmospheric inversion studies). Using repeated and spatially distributed measurements of atmospheric CO_2 concentrations, one can determine net losses over time or between two points and deduce whether there is a net input of output of carbon from a region. To do this, measurements must be combined with accurate models of atmospheric airflows and mixing.

Although the principle of this method is very simple, accounting for all transport and inferring fluxes accurately is still very difficult. Moreover, the number of sampling points is still low, especially in the tropics. There exist small-scale versions of such methods, where over limited time the atmospheric composition is mapped in detail vertically and horizontally, giving estimates of CO_2 exchange of small (100 km^2) regions (CBL budgetting). However, this requires very expensive and intensive, airborne sampling and is only suitable for short-term research.

One possible future development is that CO_2 concentrations and profiles in the atmosphere may be mapped from satellites. If and when this becomes reality, it will be possible in principle to infer CO_2 exchange globally at fine spatial resolutions. This approach goes beyond the project level.

Advantages:
This will enable full accounting of carbon exchange, however still excluding trade and large-scale leakage effects.
Effects of CDM projects can be verified at regional scales, moving outside the project boundaries.

The method is not invasive, requires simple data collection or (in future) is remote.

Disadvantages:
Not yet possible to implement due to poor sample density and underdeveloped atmospheric models
There is no spatial resolution at project scale: not suitable for CDM monitoring
The method requires global exchange of air samples, which is a problem for some countries with restrictions on specimen exports.

Role of modelling

The understanding of forest functioning, at short and long time-scales, is steadily improving as a result of much scientific work world-wide. Models of growth and C-flux to trees are well developed and often work very well. Models of the associated fluxes from the soil are less well-developed. All such models are likely to be improved through comparison with real data and through the process of data assimilation or 'training' of the model. More work is needed in developing models that are coupled to mesoscale models of the atmosphere, and global models of the atmosphere. Without such models, the significant interactions between the land surface and the atmosphere (the 'feedbacks') are obviously ignored.

• 4. Looking ahead: beyond CP1

Beyond the First Commitment period (2008-2012), the Kyoto Protocol and its implementation is expected to evolve in several ways in response to technical developments, new science, and to general perceptions of ‘what is wrong’ with the Protocol. Here we highlight some of the likely developments.

4.1 Methodology

Advances in Remote Sensing. Verification methods are likely to develop in response to an enhanced capability in Earth observation. In the future, land use changes will be tracked routinely using satellite remote sensing. This has been technically possible for some time, but only a few countries are using remote sensing to assist the preparation of their national inventories. In generally, there is a resistance by Annex I countries to use innovative techniques which might produce different results from those of ‘conventional’ inventory-based reporting, because systematic errors in either approach may lead to difficulties in detecting trends. But remote sensing can provide much-needed information in non-Annex I countries in relation to specific projects. Some projects in non-Annex I countries are indeed using remote sensing to detect dates of planting (Schulze *et al.* 2003). Most of the remote sensing that is discussed in this context is optical remote sensing, which is available to well before 1990. As well as optical remote sensing, there are possibilities of using radar techniques.

Synthetic Synthetic Aperture Radar (SAR) makes use of the long-range propagation characteristics of radar signals and the highly developed capability of signal processing to provide high-resolution imagery. In optical remote sensing the satellite merely looks at the solar radiation reflected from the land surface. In SAR, it is the satellite instead of the sun that is the radiation source: electromagnetic radiation of a waveband in the range 3 cm- 3 m is emitted from the satellite, and the backscatter from the land surface is analysed. The radiation penetrates clouds and to some extent (depending on the wavelength), it penetrates vegetational canopies. Thus, in future there are possibilities of using SAR to measure biomass from space. Pilot studies are complete (La Toan *et al.* 2003). Aircraft-borne sensors show that the optimal wavelengths for sensing biomass are in the VHF frequency, and thus conflict with the use of those wavebands for communications (radio and TV). Shorter wavebands produce a signal that saturates at around 50 ton biomass ha^{-1} (Fig 6).

Shortly the NASA ALOS satellite will be launched. It will carry polarimetric L-band radar, and acquire data over S. America every three weeks:

http://lcluc.gsfc.nasa.gov/products/pdfs/GOFC/GOFC-Chapman2000.pdf

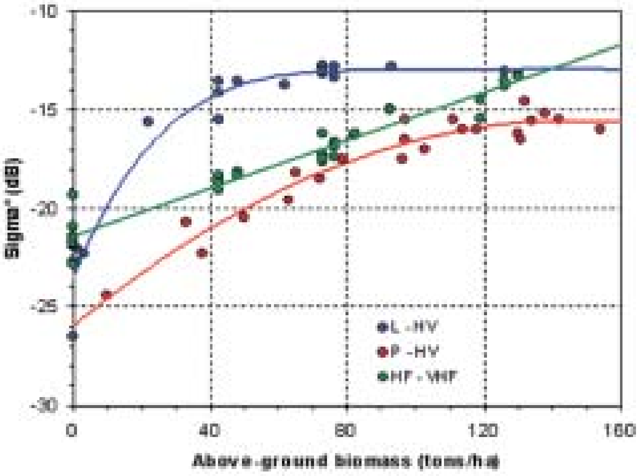


Fig. 7. Relationship between above-ground biomass and backscatter obtained with Synthetic Aperture Sensors. The target was pine forest, SW France. Source: T La Toan. Wavebands: L band is centred on 27 cm, P band on 70 cm and HF band is about 3 metres.

Spectroscopic measurements. The measurement of CO_2 from space to a precision of 2 parts per million or better would greatly enhance the possibility of calculating sources and sinks by reference to the depletion and enrichment patterns of the gas in the atmosphere. The SCIAMACHY sensor on ENVISAT (launched March 2002) contains a high precision, high resolution spectroradiometer which offers the possibility of measuring the radiatively-active trace gases in the atmosphere. Although early results from this sensor are not very encouraging, it seems that future generations of satellites will be able to carry out such measurements which will revolutionise our knowledge of the distribution and activity of sources and sinks.

LiDAR. Not all remote sensing projects need to use satellites. At a more local scale, rapid progress is also being made towards using airborne sensors which can be operated from light aircraft such as dual-camera videography and LIDAR to measure the height of the trees (Lefsky *et al.* 1999). From this, biomass can be estimated using regression equations.

Advances in Atmospheric Observation Systems. Instead of measuring carbon gains and losses at the ground, it is equally possible to measure changes in concentrations of carbon dioxide and other gases in the atmosphere. The atmosphere 'sees' a large swath of the landscape, and so it integrates over large areas. Atmospheric methods were developed strongly in the early 1990s in relation to the global atmosphere (Gurney *et al.* 2002). This approach depends on obtaining a time series of gas concentrations at different places on the Earth's surface, and then inferring the fluxes that must have occurred to account for those concentrations. However, in principle they may be applied on a national or local scale, and in several cases this is happening already. For example, in the UK greenhouse gas reporting, this approach is used to verify the fluxes derived from an inventory approach.

Upscaling, models and the dual-constraint approach

It turns out that the various methodologies operate and different scales of space and time, and none of them happen to co-incide perfectly with the 'target' of being able to report C-fluxes over several years on local and national scales (Fig 7). Indeed, dealing with this mismatch of scales is a scientific challenge in itself. The 'dual-constraint' approach of CarboEurope is an attempt to control error by using more than one method at more than one scale to understand the carbon balance of regions (Fig 8). In this approach, ground based techniques including plot inventory and eddy covariance for different land surfaces are used to parameterise models. With remote sensing data such models may be used for up-scaling to entire regions. At the same time, atmospheric observing systems which measure at the regional scale will provide data directly. The important question is, do these two sets of data agree? If they do, one's confidence in both systems is increased.

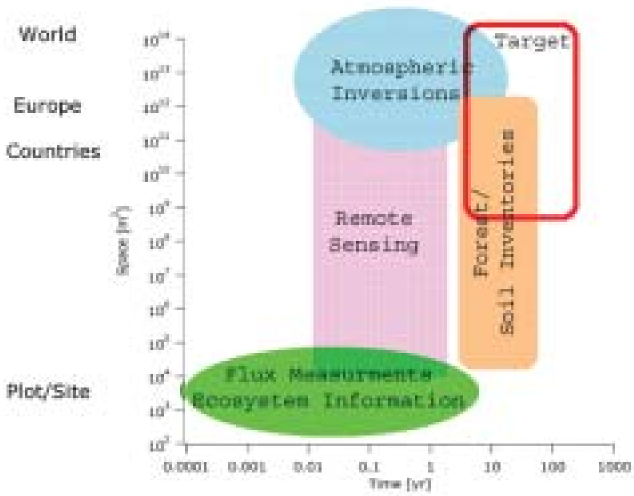


Fig. 7. Characteristic scales of space and time of measurement approaches in relation to the 'target' of what is needed for CDM AR.

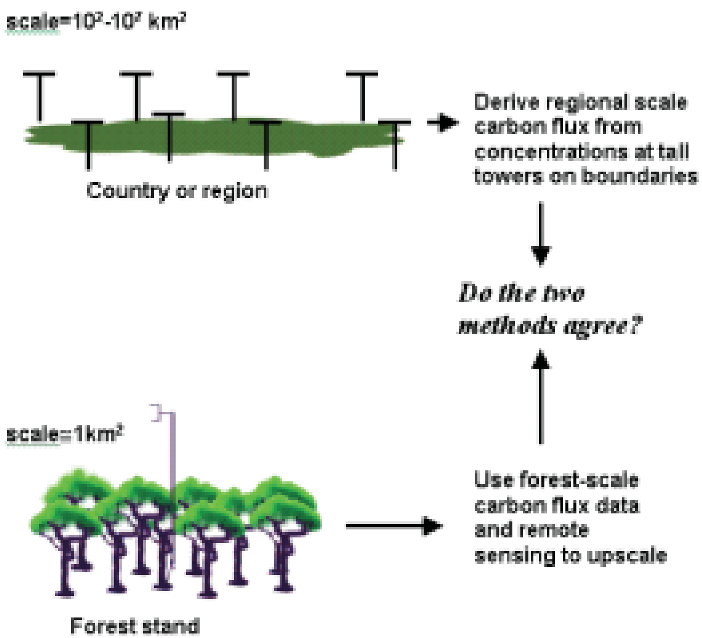


Fig 8. The dual constraint carbon balance approach of CarboEurope. Two independent methods are used, operating at different characteristic scales. The flux data at the forest scale are used, with remote sensing data on land surface cover, to parameterise models for scaling up.

Full carbon and GHG accounting: the vision

Much of the effort by national negotiators has been driven politically, to secure the 'best deal' for their own national position. The complex rules relating to AR, and the fact that there are still unresolved issues and open questions about implementation of CDM is largely because conflict-resolution is inevitably time-consuming. As a result of the complex (and strict) rules, a large and expensive bureaucracy will be needed to deal with the first commitment period. Given the rapid rate of progress in measurement techniques, it is considered that 'full carbon accounting' is likely to be possible within a decade. This should simplify reporting, monitoring and verification. It would entail the automatic and continuous measurement of the greenhouse gas budget for any country, based on the global and national atmospheric observing networks, satellite remote sensing and data assimilation by models. These methods are completely independent of each other. The advantages of using as many methods as are technically possible means:

- All available data are used
- The full carbon budget integrates all processes
- Several estimates are produced, and may be checked against each other
- Arbitrary rules are no longer necessary
- It would be possible to detect leakage
- N_2O and CH_4 monitoring can be easily integrated in this approach.

4.2 Addressing 'What's wrong with the Kyoto Protocol and CDM'

Biodiversity, goods and services

Because their benefits are invisible to most people, forests have been undervalued by society. Recently, several studies have tried to place value on tropical forests, based on the natural capital they contain and the goods and services they provide for mankind (Costanza et al 1997, Daily 1997). These calculations include valuation of the biogeochemical processes which the ecosystems provide and the biodiversity they contain. Such studies come to startling conclusions: the world's ecosystems for example, are said to be worth 33 x 10^{12} US Dollars per year, much greater than the world's gross national product (18 x 10^{12} US Dollars per year). The Kyoto Protocol does not place emphasis on conserving biodiversity, although there are other international agreements that do. Most notably, the Convention on Biological Diversity (CBD) was, like the UNFCCC, open for countries to sign in 1992. Article 1 includes the conservation of biological diversity, the sustainable use of all its components and the fair distribution of benefits resulting from its use. Those people and NGOs who argue that forest must be protected – to preserve biodiversity and retain environmental services – cannot be ignored. The destruction rates could be markedly reduced if forest protection could have a role in CDM, and there could be substantial economic gains by host countries (Swingland 2003).

Clearly there is a potential synergy between the Kyoto Protocol and the CBD in relation to the protection of rain forest. However, in the first commitment period, as we have seen, forest protection is not included in the Kyoto Protocol. It is widely expected that in some form it will be included in the subsequent commitment periods, either directly or, if full carbon accounting is adopted, indirectly.

Evaluating the full climatic impact of AR

The science that underpins the Protocol reflects the state of knowledge in the early 1990s. Our understanding of the influence of forests on the atmosphere has increased since then, and will continue to increase. It is realised now that the effect of planting a forest is different in different regions of the world, as the change in land surface cover effects the radiation balance and hence the climate in different ways (Betts 2000). It is also realised that non-CO_2 trace gases may be highly significant in tropical regions (Erickson *et al.* 2001). Concepts such as Global Warming Potential are recognised by atmospheric scientists to be a simplification of a complex set of reactions whereby radiatively-active gases are eventually removed from the atmosphere; and many non-greenhouse gases may be transformed into greenhouse gases later (Derwent *et al.* 2002). At the very least, it will be necessary to base our estimates of the climatic effect of forests on a metric that takes into account processes other than the uptake of carbon.

• 5. Frequently Asked Questions

5.1 The role of sinks in the CDM

What is the global magnitude of the sink strength that could be utilised under CDM?
The *IPCC Third Assessment Report*[1] suggests that there are 190 Mha available for afforestation in China, India, Indonesia, Mongolia, Pakistan, Cameroon, Ghana and Mexico. It has been suggested that total available lands in all non-Annex I countries is as high as 420 Mha. If all that land were afforested, assuming a sink strength of 10 t C ha^{-1} a^{-1}, the sink would be massive, 4.2 billion t C a^{-1} which is about two-thirds the fossil fuel emissions. This is however an unrealistic rate, best regarded as the potential rate.

Currently about 120 Mha of the tropics are covered by plantations, with an annual planting rate of 4.1 Mha a^{-1}. This planting rate has increased rapidly since the 1960s, but is still small in relation to the deforestation rate of 15.2 Mha a^{-1}. Most of the deforested land is converted to agriculture, a process which is driven by demographic and economic trends, but as much as 1.0 Mha^{-1} a^{-1} is actually converted to plantations. One way to make first estimates of the global magnitude of the sink strength is simply to suggest a 25 % increase in the current plantation rate. This additional forest, about 1.0 Mha a^{-1}, might function as a sink of 10 Mt C a^{-1} over a 20 year rotation. However, project failure might reduce this rate to 5 Mt C a^{-1}. This is quite small in relation to the total emission reduction targets that the Kyoto Protocol has assigned to the Annex I countries. They have been asked to reduce their emissions by an average of about 5% relative to the 1990 level, amounting to about 200 Mt C a^{-1}. It is obvious from this rough calculation that CDM will be only marginally useful to countries in their efforts to reach targets.

Will sinks in CDM make a real difference to the climate?
The amounts of carbon that will be taken up are small in relation to release by fossil fuel burning. Waterloo *et al.* (2001) think that 10 Mha might be available for sink projects over 12 years. This could absorb about 5 Mt C a^{-1}. Tropical deforestation amounts to 200 times this value and fossil fuel emissions are more than 1000 times this value, so the benefit of CDM as presently defined is rather small.

Is agroforestry an option in CDM?
Agroforestry is popular and successful in the tropics. Compared to other forms of land use, it is sustainable and provides both timber and food. The carbon content of agroforestry schemes is not very high, but is likely to persist because it is highly valued by the local community. Yes, it is a good option.

Why not include forest protection in CDM?
Many people have pressed for this, arguing that the carbon to be counted for CERs should be the carbon that is retained in the forest relative to what would be there under normal deforestation rates. Deforestation continues as a result of powerful economic drivers. Preventing deforestation completely is completely unrealistic, but even slowing down deforestation by protecting the forest provides a very useful carbon sink (relative to the no-project baseline), and protects biodiversity. Perhaps forest protection will be allowed in the second period. The potential to protect the climate by ceasing deforestation on a large scale is large. It could save a massive 1-2 Gt C a^{-1} for the world as a whole. Currently fossil fuel emissions are about 6.5 Gt C a^{-1}. There are arguments for not adopting this strategy: one of the most compelling is, ironically, that it might be so cheap to do that Annex I countries would meet a large part of their

reduction targets and thus continue ‘business as usual’ at home. Another argument is that non-Annex I countries are opposed to it: they wish to continue to develop their lands economically and as a means of food production just as Annex I countries historically have done.

What is the real climatic effect of planting forests?
The use of carbon sequestration as a measure of the climatic effect of plantations is a simplification. Forests influence the climate in other ways as well as removing carbon from the atmosphere. For example, they affect the hydrological cycle and the energy balance of the landscape. Model studies suggest that removal of forest cover from large regions of the tropics such as the Amazon will cause an increase in temperature and a decrease in rainfall of that region, and knock-on effects that spread to other parts of the world. There may be effects on climate from emissions of other greenhouse gases N_2O and CH_4 especially during disturbance of the soil. We know rather little about these emissions. Often, they are less significant than CO_2, but not when N-fertilizer has been used and not when a large fraction of the vegetation is made up of members of the Leguminoseae, which fix N_2. Knowledge of the non-CO_2 effects of forest on climate is rapidly increasing, and ought to be taken into account in crediting for CDM sinks projects.

5.2 AR activities in the tropics

At what rate do forests take up carbon?
It varies. Some trees are inherently slow growers, and others fast. However, growth in the humid tropics is throughout the year, so trees planted there generally absorb more carbon than trees in other regions of the world. Some of the fastest rates of growth are by *Eucalyptus*, which can attain 15 ton C ha^{-1} a^{-1} over a 10-year rotation period. Tropical pines would be expected to achieve 5 ton C ha^{-1} a^{-1} over a 20 year rotation, which is about twice as fast as managed forests in Europe.

How expensive is it to capture carbon using a tropical plantation?
Costs are incurred during site preparation, forest operation, and ‘transaction costs’ (Waterloo *et al.* 2001). For CDM projects, transaction costs include certification of the project as a whole and verification that the carbon has indeed been taken up. In Waterloo’s study, the range total costs was 2.2 – 25.7 $ per ton C.

How often are tropical plantations destroyed?
One of the criticisms of CDM and the use of forest sinks is that forests are not always permanent. Plantations may be destroyed through fire, climatic extremes, storms, grazing, and by outbreaks of pests such as fungi or insects. Plantations with a perceived value in the community may last for a long time, and if they are sustainably managed, eg for firewood production or as part of an agroforestry scheme, there may be a permanent change from a form of land where agriculture is no longer economically viable to forest, with a corresponding permanent uptake of carbon.

Is it hard to establish plantations of tropical species that are native rather than exotic?
Establishing any plantation in the tropics is challenging: ground preparation and weed control is more difficult than in temperate regions. To increase the planting rate of native species would however usually require more trained people in the host countries, running programmes for seed collection/storage and tree improvement based on selection and vegetative propagation.

Is it true that exotic plantations are harmful to the environment?

Exotic plantations are used because they grow fast, tree form is straight, and their growth and timber quality is predictable. They have the reputation of using too much water. However, all fast-growing trees use much water, whether native or non-native (exotic). Exotic trees tend to have markedly fewer animals living in their canopies than native trees. Some of the most productive exotic tree species negatively affect soil productivity by allelopathic substances (*Eucalyptus* species) or acidification (e.g. *Pinus radiata*).

Do mature forests take up carbon?

It was formerly thought they do not, but now it is realised that they may, and many in the Amazon are. Increased growth rates are thought to result from increasing rainfall or CO_2 fertilization.

What environmental services do forests provide, other than absorbing CO_2?

Pristine forests are the most valuable in terms of biodiversity, and they are likely to contain populations of large and charismatic animals and very large trees. They are a storehouse of species that mankind may eventually use for food, fibre and pharmaceuticals. They are places to visit and so they have potential for ecotourism. Many are protected as reservations for indigenous human populations. Old secondary forests can be almost as valuable as pristine forests. They can be managed to prove a steady supply of timber, they protect the soil from erosion. Plantations on the other hand contain less biological diversity, although by careful management of the cutting cycle at a landscape level they can contain a remarkable number of species. Plantations of native trees contain more species than those made of exotics. Almost any forest cover in the humid tropics protects the soil against erosion.

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In the context of Kyoto Protocol CDM Land-Use, Land-Use Change and Forestry

• Appendix I: Remote sensing for CDM in the First Commitment Period

***by* Danilo Mollicone**

(LULUCF) activities, satellite remote sensing data and applications are powerful tools to assess land use change process and to monitor LULUCF projects development.
Even if remote sensing techniques are now very well developed, especially for all the application that use optical remote sensing data (passive remote sensing), further important development of useful applications for Kyoto Protocol purpose will arrive from the ongoing technique progress in radar satellites (active remote sensing). Most likely in few years biomass stock changes in CDM project areas would be measured, with good accuracy, using these types of radar remote sensing data.

Historical remote sensing data could be used to determine land use change processes in relation to the reforestation time limit date (31.12.1989) and to the date limit for project eligibility (after 1.1.2000). Multispectral images of the world are provided since 1975 by the MSS Landsat sensors, but two particular available dataset, 1990 and 2000 Global GeoCover Landsat mosaics by NASA and EarthSat, are especially useful to monitor land use change at the landscape scale (Figure 9). From these datasets, global land cover maps with ground resolution of 0.08 and 1.4 ha, respectively for raster and vector maps, are already partially available (http://www.geocover.com/). Soon NASA and EarthSat will distribute the entire world maps.

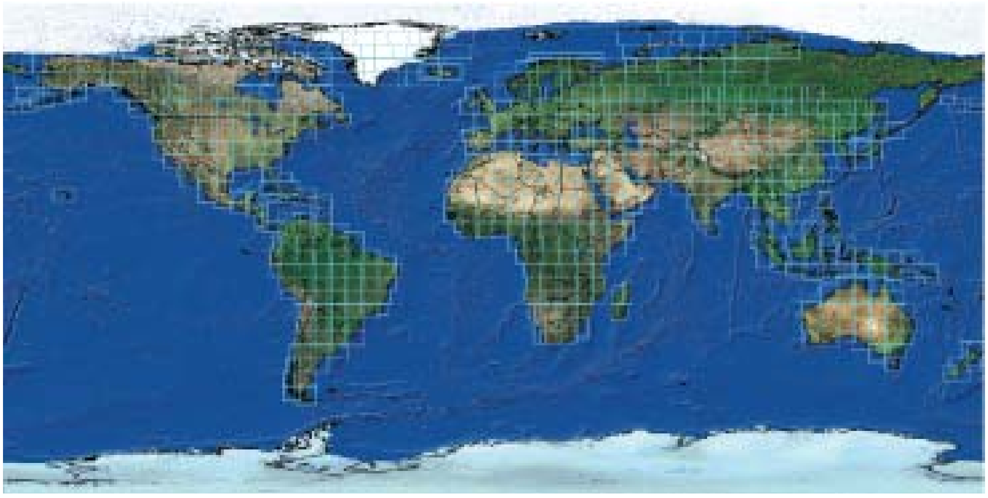

Fig. 9. Data coverage of 1990 Landsat TM Global Mosaic. Image data are free available through NASA web site: https://zulu.ssc.nasa.gov/mrsid

Historical information on land cover may be retrieved not only from Landsat satellite images (http://landsat.usgs.gov/), but also from other high-resolution satellite images like the French, Swedish, and German SPOT satellites (http://www.spotimage.fr) and the Indian IRS satellites (http://www.csre.iitb.ac.in/isro/irs-1d.html).

Once an AR CDM project has started all its land use activities could be documented through very high-resolution satellite images. In the last three years, companies like Spaceimaging, Digitalglobe, Spotimage, and Orbital lunched with successful in the space many commercial satellites; so now very high-resolution satellite images are available with a good range of options (Table 2). These satellites have also a good temporal resolution, and so with a scheduling time of few days, these satellites are able to get images of any area in the world. This technical aspect permits to get images avoiding disturbance of the cloud coverage.
Thanks in particular to the high ground spatial resolution these images are extremely

useful tools to certify during all the life of an AR project the area extension and type of LULUCF activities. The following image is an example of what it is possible to monitor with this kind of data.

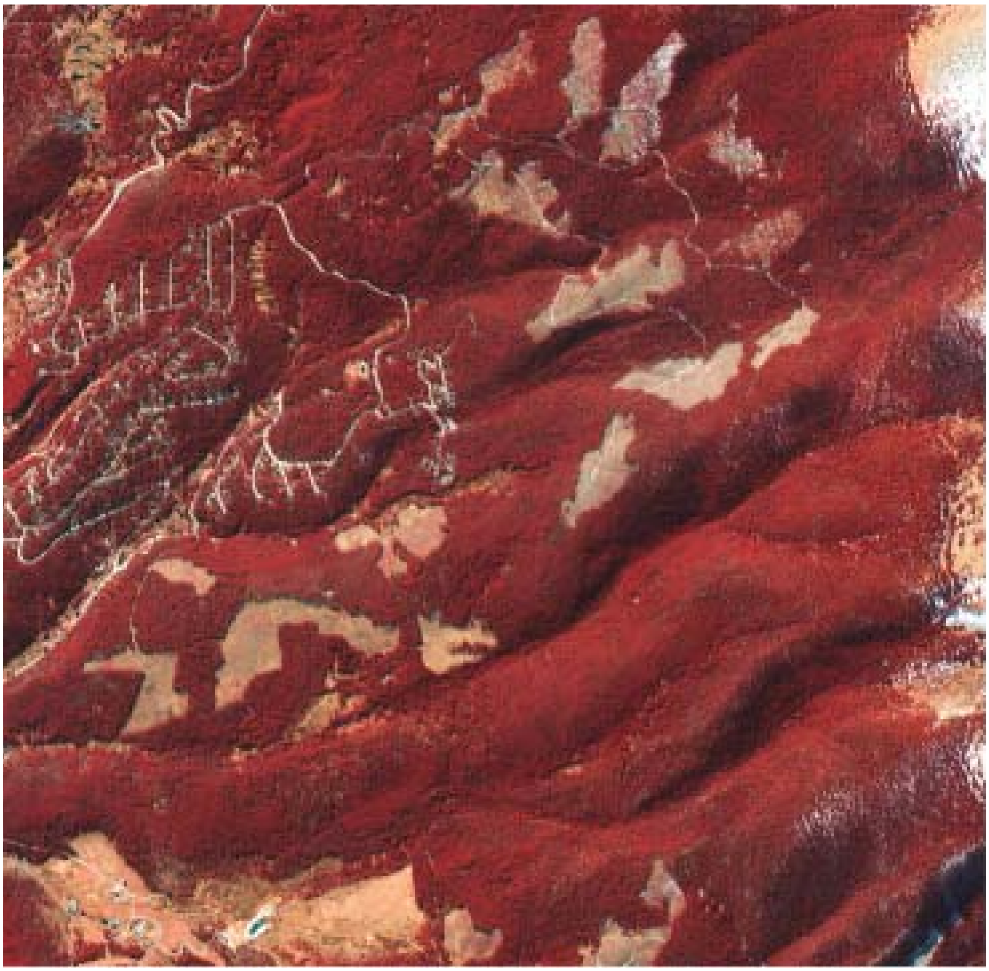

Fig. 10 Forest Depletion Mapping - 1-meter IKONOS False Color (from http://www.spaceimaging.com/solutions/forestry_ecosystems/index.htm#)

Table 2 Very high-resolution available satellites

Satellite	Spatial Resolution m	Imaging Channels nm	Radiometric Resolution bit	Temporal Resolution day
IKONOS 2 http://www.spaceimaging.com/	1 4	445 – 900 445 – 515 506 – 698 757 – 853	8 or 11	11
Quickbird 2 http://www.digitalglobe.com/	0.61 2.44	450 – 900 450 – 520 520 – 600 630 – 690 760 – 900	8 or 16	1-3
Orbview 3 http://www.orbital.com/	1 4	450 – 900 520 – 600 600 – 695 695 – 900	8	3
SPOT 5 http://www.spotimage.fr/spot5	2.5 – 5 10	510 – 730 500 – 590 610 – 680 790 – 890	8	3

Appendix II A spatial concept for baseline design and monitoring

***by* Michael Dutschke**

1. Purpose

Compared to most energy-related CDM projects, afforestation and reforestation (AR) projects are more closely related to their direct environment. Land use strictly depends upon local factors like growth conditions, water availability, and road infrastructure, settling structure. Therefore, country baselines or benchmarks in many cases are of little use for evaluating AR projects. This is all the more true for conservation of natural forests, in case this project category was made available in future commitment periods.

This chapter depicts a standardized procedure of how to account for spatial factors in project design without loosing sight of the legal and regulatory environment.

2. Definition of spatial system boundaries

The definition of an appropriate project area is much more important and complex for forestry projects than for technical emission reduction projects. First of all, there is the issue of spatial resolution within the concrete area of project activity, which may strongly affect the amount of credits that can be earned by a project. Next, the project area - i.e. the geographical boundaries of the project activity - is an important parameter for baseline determination and the calculation of carbon sequestration. Project boundaries therefore need to be accurately defined for all forestry project types. Finally, the area will play an important role in leakage determination. As the leakage potential of forestry projects is generally assumed to be higher than in the energy sector, one needs to carefully estimate the area levels that are influenced by the project.

For all those purposes, we propose to apply the PARAPIA concept of concentric areas (Figure 11), differentiated by:

- the project area (PA),
- the reference area (RA), and
- the project influence area (PIA).

Direct effects of the project activity will appear in the PA itself, whereas most of the project's indirect effects (leakage) will appear in the RA. The RA is also relevant for the baseline choice. The PIA allows the incorporation of political and national circumstances and may also help to quantify leakage.

Requirements for data collection and monitoring differ between the three areas. Whereas in the PA several direct measurements are necessary, one can often use cadastral or statistical data in the outer circles.

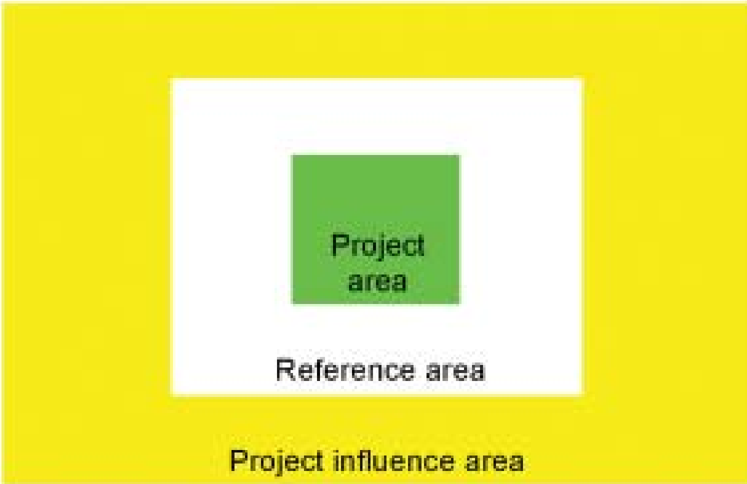

Fig. 11. Project area levels

2.1 Project area

The project area (PA) is identical with the geographic boundaries of the project, i.e. the area under direct control of the project operator. The characteristics of the PA can be described in detail - covering ecological, social and economical structures. In the PA, the project's effects are directly measurable and attributable to the project activity itself. Concerning monitoring, direct measurements should be the rule, i.e. by taking soil and vegetation samples. The same goes for the control of fuel and energy consumption, etc. Population that stays on the area can be registered, staff and its families' emissions behaviour is observable.

For the purpose of monitoring, the area needs to be stratified, and representative samples determined. On these samples, a full initial inventory is performed on all pools that are likely to be influenced by the project activity. Another set of samples may be set aside to observe undisturbed succession on the area, according to the project design. These should not be directly adjacent to the activity area, as soil preparation and planting may influence on the characteristics of the set-aside areas.

2.2 Reference area

The reference area (RA) shall be a circular area of 5-10 times the project area around the geographic centre of a contiguous project area. If the project consists of several areas, each area has to develop its own RA. If various RAs of one project overlap, a contiguous RA for all the PAs can be chosen. Protected areas and CDM forest conservation projects in the RA will be deducted and the area extended accordingly. Doing so, "late" forestry projects in a given area will not be disadvantaged. The same procedure is to be applied if the area reaches the national border in order to determine leakage correctly (Figure 12). As a maximum, the RA is identical to the PIA.

In case the "most economically attractive" land use is chosen as the baseline option, the RA can help to define the baseline on a standardised basis and concurrently reflect local and regional conditions. The RA also serves as a reference to estimate both positive and negative leakage effects of a project. The project's regional economic influence (forward and backward linkages) can be observed either by direct monitoring or by statistical means. If appropriate, even the population's mobility within the area and an eventual activity shift may be traced. In order to avoid gaming, a specification and monitoring of the RA should be mandatory.

The monitoring plan will determine sample areas within the RA that are representative for the different strata of the PA before project start. In case there are unprotected natural or secondary forests, these need to be included in the samples. These areas will be geo-referenced, but not disclosed to the public. It is important that none of the project participants owns these sample areas. These areas serve as an observable baseline element and will be checked without any at every verification and when reassessing the baseline. The checks are carried through as site inspections without physical intervention. On these occasions, an evidence-based assessment of their current use is given. Carbon density on the area is estimated based on experience and samples from the PA.

Why is the RA so small? Can an area as little as five times the PA represent the project's environment? Spatial leakage is in most cases very limited. If it does not occur close to the PA, it will not occur in other sites. Data for any larger area beyond administrative boundaries are difficult to obtain, while the RA can in most cases be inventorised with the help of the municipalities. On a local level, this effort can be limited, and data precision will be higher.

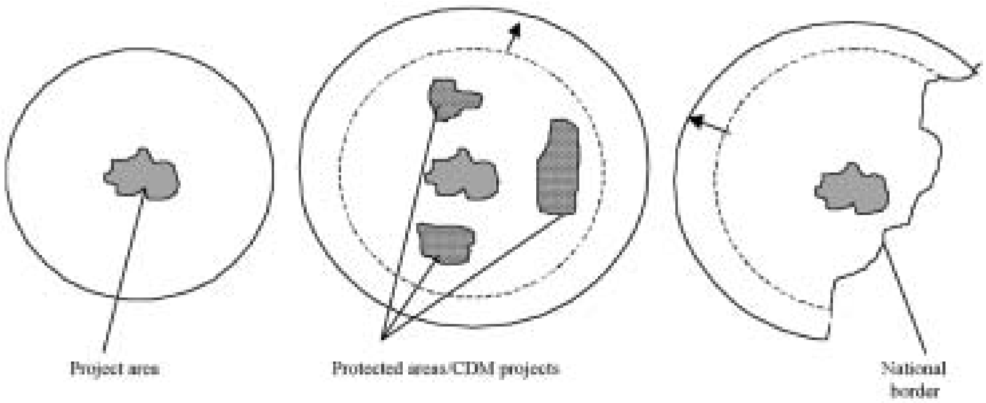

Fig. 12. Determination of the reference area

2.3 Project influence area

The widest circle is the project influence area (PIA). Data from the PIA is used to calibrate data obtained on PA and RA, thus eliminating statistical noise.

The PIA is generally defined by national legislation, administration and economics. In countries with highly autonomous federal states or special social and environmental conditions, the PIA can be considered to be a subset of the national territory. This might be argued for the states of the Brazilian Amazon, although federal legislation still is a constituent factor for them. Arguments in favour of doing so may be e.g. that relevant data are only available for the federal state, or that there are differences in precision levels or methodologies to collect them, or that social conditions differ strongly between neighbouring regions.
On the national level, the statistical data obtained in PA and RA need to be confirmed. Land-use changes observed in the RA can be due to national trends, or they can be induced by the project. While the change in any specific activity in the RA is not greater than the one in the PIA, it is unlikely that the project activity is the underlying cause. Such data can relate to migration, deforestation, afforestation, soil erosion, per-capita emission factors, timber imports and exports.

Alternatively, the PIA could stretch beyond the national level. The advantage of choosing a cross-national reference area would be that the results due to good or bad national climate policies may be less skewed. This approach is however very far-fetching and not in conformity with the nation-state approach of the Kyoto Protocol. It should however be discussed if cross-national baselines could be made optional for well-argued cases, assuming project developers are willing to collect the necessary data.