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ORIGINAL ARTICLE

Consistency and comparability of estimation and accounting of removal by sinks in afforestation/reforestation activities

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Abstract The Kyoto Protocol accounting system and its market mechanisms, Clean Development Mechanism (CDM) and Joint Implementation (JI), are built on the key principle that emission and emission reduction units generated by afforestation/reforestation activities under national systems and projects are fully comparable, no matter their origin. Lack of consistency in the quality of emission and emission reduction units can undermine the environmental integrity of the climate stabilization actions. Therefore, it is the ambition that units generated in the land-use, land-use change and forestry (LULUCF) sector are of similar quality with those from non-LULUCF sectors. In this paper, the authors pose the question of whether there is full estimation and accounting consistency between Annex I Party's national GHG systems and CDM projects methodologies in the LULUCF sector, in terms accuracy, completeness, levels of uncertainty and permanence risk. We focus on methodological aspects related to the applicability and practicability of using approved afforestation/reforestation CDM methodologies; estimation, reporting and accounting rules; the small pools and sources issue, uncertainty of removal estimate; leakage and handling of non-permanence risk. We conclude that there is significant scope for improving the consistency of greenhouse gas emission accounting from land use activities in the post-2012 climate change agreement, between Annex I domestic and project activities. As well, we conclude that the preparation and implementation of project activities has to be made simpler by a project framework guideline, which is then adapted to any project circumstances.

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1 Introduction

Land use, land use change and forestry (LULUCF) is responsible for 17.4% of the net annual global greenhouse gas (GHG) emissions (Barker et al. 2007). The sector is also recognized for its potential to contribute to climate change mitigation, more significant in developing countries (Brown 1998; Watson et al. 2000; Ravindranath et al. 2007). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) estimated that, by 2030, LULUCF could provide around 1.6 Gt CO_2-eq/yr of emission reductions at a cost of USD 20/t CO_2-eq (Nabuurs et al. 2007)—roughly 3% of current total global emissions. Even though there is a wide-range of LULUCF activities that can generate emission reductions, currently non-Annex I (developing countries without emission reduction commitment) may only host afforestation and reforestation (A/R)[1] via Kyoto Protocol's Clean Development Mechanism (CDM). For Kyoto Protocol (KP) compliance, there are additional limitations on the use of removal by sinks from CDM projects, as the total addition resulting from eligible LULUCF CDM project activities to an Annex I Party (developed countries, with emission reduction commitments) assigned amount, shall not exceed 1% of the base year emissions of that Party, per each year of the commitment period, according Decision 11/CP.7 (UNFCCC 2001). To stimulate the implementation of A/R projects under CDM, an Executive Board (CDM EB) under the authority of Conference of the Parties/Meeting of the Parties, has approved methodologies, tools and procedures to assist such projects in the estimation of net removals (http://cdm.unfccc.int/methodologies/index.html). An A/R methodology is a sound-scientific instrument which provides a step wise measurement, monitoring and computing procedure and that leads to accurate, consistent, cost-effective and conservative estimation of the net removal achievable by a project activity, over the crediting period.

One of the very first project methodologies was, in fact, developed for a JI project, namely Romania Afforestation of Degraded Agricultural Land Project, currently implemented by National Forest Administration of Romania and the Prototype Carbon Fund (administered by the World Bank). The methodology was developed in 2002 and officially recognized with the signing of the bilateral Emission Reduction Purchase Agreement in 2003. It is designed to estimate carbon stock changes in all pools and emissions from all identified sources (i.e. fertilization, fuels, removal of pre-existing vegetation) over the 15 years of the project implementation (Brown et al. 2002).

At the project level, joint implementation projects (JI, as a KP flexible instrument) and Green Investment Schemes (GIS, as non Kyoto but bilateral governmental agreements) are possible in Annex I countries. Both JI and GIS may develop a project methodology based on CDM one but do not to relay on a methodology approved by the Executive Board. Still, for Annex I Parties with weaker national GHG inventories, a methodology is required for the generation of emission reductions in JI projects (Track-II), just as in CDM projects.

[1] Under the Marrakech Accords, afforestation and reforestation activity (A/R) is defined as the conversion of land, that was not forest in 1990, to forestland, and each country has to define what is "forest" based on its own national circumstances (within certain ranges of area, tree height and canopy closure at maturity). This should ensure consistent definitions within the country and projects.

In Annex I countries, the GHG emissions/removals associated with LULUCF, are estimated and reported in the national GHG inventory. Supplementary, for commitments compliance, the removal/emission are estimated, reported and accounted[2] for some specific activities following internationally negotiated and agreed rules (Intergovernamental Panel on Climate Change 1997, 2003, 2006).

Overall, in essence, what a methodology does for an A/R project, the IPCC guidelines (1997, 2003, 2006) do for national GHG inventories. The question is if the two approaches are consistent in terms of estimates accuracy, completeness, uncertainty and permanence of relevant GHGs and pools/sources? Further on, are removal/emission reduction units fully homogenous and comparable? If not, then the ability to exchange emission reductions generated under the two approaches can lead to the erosion of environmental integrity of the Kyoto Protocol or the following commitments, also to undermine the idea of contribution of A/R projects to emission reduction effort, without additional negotiation and decision making effort at global level.

The paper analyses the methodological consistency of estimation, reporting and accounting of removal units from domestic and project based A/R activities and options for the improvement of removal units' comparability.

2 Research method

Afforestation/reforestation CDM methodologies were examined from the point of view of the consistency of approaches and UNFCCC's CDM modalities and procedures, both between themselves and in comparison to Annex I estimation guidelines and accounting rules. Currently approved A/R CDM methodologies, their evolutionary versions, the withdrawn and rejected ones, and the requests for clarification as available on UNFCCC site (http://cdm.unfccc.int/methodologies/), were reviewed. The criteria for the comparison were: applicability and practicability; completeness on pools and gases; consistency of the treatment of 'small sources' and 'small pools'; estimation methods; accounting options; approach of leakage and permanence.

3 Applicability and practicability of A/R CDM methodologies

To implement a CDM project, it is obligatory to estimate the net removals following a previously CDM EB approved methodology. If no previously approved methodology fits the project situation then a new methodology is developed and it is submitted for approval by CDM EB. In general, a methodology:

- describes conditions for which it is applicable;
- instructs on the assessment of additionality and testing the plausibility of the baseline/reference scenarios;
- suggests criteria for stratification of the project area: pre-project and with project;
- defines GHG emissions by sources/removal by sinks;
- identifies and assesses leakage;
- gives formulas for *ex-ante* assessment of the project performance;

[2] GPG LULUCF 2003 definitions: *Estimation* (the process of calculating emissions), *Reporting* (the process of providing estimates to the UNFCCC) and *Accounting* (the rules for comparing emissions and removals as reported with commitments).

- describes monitoring procedures (i.e. timing, pools to be considered, sampling, measuring approach) and
- computation procedure of *ex-post* net GHG project removals.

Currently eleven large scale, two consolidated and five small scale A/R methodologies have been approved.

Methodologies ensure that emission reductions or removals from A/R projects are not biased, while liability of the credits is safeguarded by an independent verifier (Designated Operational Entities, DOE). Methodologies are tools thought to ensure environmental integrity while not overburdening the project with scientific rigor or high costs. Also, they should be 'generic' so that they are not specific to a single project. Even so, a project is a 'bottom up' approach, with many particular aspects. As a result, a methodology designed for a specific project poorly responds the particular needs of other circumstances and the balance between environmental integrity, applicability and universality and cost-effectiveness of methodologies is often lost. As a result, there are a large number of similar methodologies, while there were only few projects approved. The overly scientific nature and specificity of methodologies has led to much difficulty for project proponents as shown by high number of requests for clarification or revision on application of some methodologies, as well as by rejected or withdrawn of submitted methodologies (http://cdm.unfccc.int/methodologies/AR). To further demonstrate climatic & non-climatic benefits CDM EB approved additional standard tools and procedures to support projects preparation and implementation (i.e. *Tool for testing significance of GHG emissions in A/R CDM project activities or estimation of direct nitrous oxide emission from nitrogen fertilization*). While these are meant to be helpful, they increase the burden on project proponents/implementers.

Currently, there is a step toward a necessary simplification, by introducing simplified methodologies for small scale A/R projects as well as consolidated methodologies, but even these may neither be simple enough in practical terms nor fully consistent on GHG estimation, as the improvements are related especially to accounting rules.

Finally, because of lengthy methodologies and an evolving process, there is inconsistency in methods, definitions and equations (i.e. numerous variants of 'gain-loss' or 'stock change' methods in biomass estimation; classic forestry terminology is not streamlined, i.e. what does a 'few trees' mean?), doubled by the complicated language (legalese), despite the best intentions of the CDM EB AR Working Group (ARWG).

4 Land issues under domestic Annex I and CDM projects activities

In Annex I countries, accounting for increases in carbon stocks by trees planted after 1990 by afforestation, reforestation and replanted of deforested land, is allowed under Article 3.3 of the KP. Removals by trees planted since 1990 on land that may not conform to the national definition of forest only if the Party has elected 'revegetation' (under Article 3.4 of KP). Lands that were pre-1990 converted to forest may be included if the Party has elected 'forest management' under Article 3.4. So, for accounting purposes, the tree establishment time is basically irrelevant to Annex I countries, which have voluntary elected both activities of revegetation and forest management under Article 3.4.

On the other hand, in CDM A/R activities, the host country must define the 'forest' specifically for CDM project purpose (according the UNFCCC's decisions 16/CMP.1 and 5/CMP.1), by specifying minimal area, crown cover and trees height. While minimal area

and tree height seems to not raise significant problems in implementation of CDM A/R projects, crown cover parameter threshold has a substantial impact on the land area available for projects. A lower forest cover threshold restricts the eligibility of land by excluding large areas from possible projects (Verchot et al. 2007). Also, a selected small threshold for minimal area allows non-Annex I Parties to include a range of small and discrete area of land. This has a similar effect to 'revegetation' by Annex I countries. Nevertheless, in practice, the issue of minimal land area may not be relevant for projects as in general large compact lands are included (with further benefits generated by administration, management, monitoring, etc).

Land eligibility is a main pre-condition in CDM project determination (i.e. land forested or not over last 50 years and land did not contain forest on 31 December 1989), supported by independent and transparent information sources. Also, project determination is *ante factum* assessed, which definitely leads to the assessment of the project boundary, as the geographical & economical impacted area of the project.

In an A/R project it is not only the total project that significantly affects the net removal/ estimation, but its fragmentation is crucial in terms of estimates uncertainty (also risks in C stocks permanence). In general, it may be expected that in non-Annex I countries the available land for afforestation is generally consolidated in larger pieces, in comparison to Annex I where it is sparse, more fragmented. Uncertainty of the estimation of net removal is dependent on the land fragmentation, thus decreasing with increasing land consolidation (Bogaert et al. 2005).

By domestic actions, European countries have increased their own national forest area annually since 1990 (Zanchi et al. 2007) at an annual total rate between 130–150 thousand hectares (kha). Accounting for the net removals on this area is mandatory during the first commitment period (2008–2012). On the other side, it is difficult to commensurate the total area and GHG benefits of all CDM A/R projects. For example, the total area of CDM AR projects currently under implementation or preparation by Prototype Carbon Fund and BioCarbon Fund amounts to some 160 kha (http://wbcarbonfinance.org), which accounts only some 5% of area afforested by European countries since 1990. As well, the total GHG net removals from afforestation/reforestation CDM projects will be less than in national domestic activities of European countries, under current accounting rules and small age of plantations (i.e. since 2000).

5 Estimation, reporting and accounting rules for emission reductions and removal from A/R activities

GHG estimation is in principle similar for afforestation under domestic Annex I and CDM projects activities, as based on repeated field inventories and measurement. One key difference is that the monitoring protocol in projects is fixed as part of the methodology before the project starts, while in domestic Annex I activities it is a part of national GHG inventory system (which is compliant with relevant requirements). CDM project methodologies correspond to highest estimation methodological tiers, while Annex I countries may report under either lower tiers in the GHG national inventory or higher tiers for emission reduction accounting purpose.

5.1 Assessment of the projects baseline and spatio-temporal boundary

In LULUCF projects, the baseline concept supports the additionally of emission reduction or removal to demonstrate the project's climatic benefit and environmental, economical and

social added value. It has to reflect the current trend of the land use and the CO2 removals 'without' proposed activity within the project boundary. Developing credible, accurate baselines remains key challenge in the implementation of the land use projects (García-Oliva and Masera 2004). In A/R projects the baseline assessment is methodologically sustained by various tools & procedures provided by CDM EB and the complete list of formulas for the estimation of emissions and removal are elaborated in an approved methodology. Practically, the more carbon-rich the pools are in pre-project, the more important the baseline assessment and estimation is, as the land use conversion to a new activity significantly affects all pools.

A fundamental problem with the CDM approach is that the baseline can only practically be re-assessed over time with large uncertainty. Also, any planned *ex-post* adjustment of the baseline makes the emission reductions difficult to transact because of the increased uncertainty for the investor. Consequently, CDM methodologies are built on a 'stationary' baseline principle, which assumes no monitoring of the initial conditions. More recently, 'dynamic methodologies' are being developed that assume change of the baseline emissions and removals (i.e. *AR-AM0010: Afforestation and reforestation project activities implemented on unmanaged grassland in reserve/protected areas*). A dynamic methodology implies a more conservative estimation of the baseline, under realistic assumptions for project particular applicability conditions (i.e. under removed grazing pressure and optimized use a degraded pasture will most likely recover). Such methodology may imply monitoring of both the land use and carbon pools within the project boundary, at least for carbon-rich strata in the baseline (i.e. on grassland). Thus, the project boundary should be re-defined so as to capture environmentally and socio-economically homogenous larger areas. This area should partially include land (i.e. non-project activity areas) that would serve as 'baseline control/proxy sample area', assuming that here activities occurs as before the project implementation. This approach would raise additional practical issues like compromising between methodological complexity (i.e. for forest and non forest lands) and costs of baseline estimation and monitoring, but it would improve uncertainty assessment of the estimate and possibly allows discounting environmental and socio-economic factors effect.

5.2 Baseline non-CO2 GHG emissions

Decision 19/CP.9 *Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol*, provides, in art 22, that only carbon sinks in the baseline are estimated, excluding estimation of non-CO_2 GHGs (UNFCCC 2003). This is a conservative approach. But is it equally an incentive for project developers, for further land improvement or sustainable land management? In most cases, A/R activities occur on lands (i.e. marginal cropland) where previously there were emissions from other land-use activities, as CO_2 (i.e. fossil-fuel use by agricultural machineries), N_2O (i.e. fertilization) and CH_4 (i.e. crop residues burning), with significantly stronger climatic effect than CO_2. Such emissions certainly decrease with the change of land use and management under conversion to forest land. This expected reduction is more significant the more intensive the former land use was. Additionally, these emissions reductions meet Kyoto Protocol eligibility criteria. There are anthropogenically induced; occur within defined project geographical boundary and are (likely) permanent since the land use and management have changed. Methodological difficulties could be indeed challenging (i.e. certainty of data, validation procedure, accounting duration), but it could be applicable under strict project applicability conditions.

In comparison, non-CO_2 emissions in A/R activities by Annex I parties count for both assigned amounts and commitment compliance. In JI projects, the baseline's non-CO_2 emissions may have not been accounted if the project started before the commitment period. Nevertheless, non-CO_2 GHG emissions in the baseline are indirectly estimated and accounted by the GHG national system, if the projects start in the commitment period.

5.3 Estimation methods of the carbon stocks and stock changes

Various types of carbon stock change estimates are crucial, in various stages of the project implementation, for contracting purposes (i.e. baseline GHG net removal by sinks; project's *ex ante* actual & net anthropogenic GHG removal by sinks) and for verification and delivery purpose (i.e. *ex-post* baseline-if any, project's *ex post* actual & net anthropogenic net GHG removal by sinks).

A/R CDM projects suffer a chronic lack of biometrical data (i.e. early growth of trees/stands, data on shrubs); a situation which is currently improving. To estimate the carbon stocks or changes associated either to baseline or project activity, mass balance method either as 'gain–loss' or 'stock change' is recommended by approved methodologies. In some methodologies, both methods are proposed, alternatively, as to provide them with more general applicability.

A/R CDM methodologies adopt a conservative approach. They make conservative simplifications to the baseline such as assuming that some pools are in steady state or increase more or decrease less in the baseline than in the project (i.e. "nil" for grass and non-tree strata). The methodologies set a priority to use in situ data and species & project specific measurements or local forestry inventory data (i.e. for BEFs, root-to-shoot ratios); before using global default values. As well, methodologies apply parameter values that will likely overestimate removals by sinks in the baseline (i.e. maximal values of the biomass expansion factors 'BEF' in non forest tress).

For project CO_2 removal projections, field measurements (i.e. ideally in cronosequence of stands) or yield tables are recommended with related shortcomings for site specific circumstances (i.e. data is certain for old stands, large scale averaged). Nevertheless projects methodologies correspond to higher tier for estimation methods and factors (only seldom relay on IPCC default).

Recent experience with projects in non-Annex I countries has brought about an improvement of the data availability on both carbon stocks (i.e. on soil, biomass stocks and increment) as well as on non-CO_2 emissions (i.e. burning). This may allow establishment of additional default factor to be used in the future (at least as benchmarks) for project's baseline or activity parameters validation or even for national GHG inventories of non-Annex I countries. Nevertheless, more research is needed in order to account for heterogeneity and dynamic of forests and non forest wood-chain related sinks (Watson 2009).

5.4 Omission of 'small pools' in afforestation/reforestation activities

The omission of carbon stock changes in some pools is possible both for CDM projects and under negotiated accounting rules for the national GHG estimation systems. Currently, it is considered a good practice that "selective or partial accounting systems of the pools may be appropriate for land use projects as long as all pools for which emissions are likely to increase as a result of the project (loss of carbon or emission of non-CO_2 greenhouse gases) are included" (Intergovernamental Panel on Climate Change 2003; García-Oliva and Masera 2004).

Practically, for A/R CDM projects, the approved methodology is an integrated tool serving both to 'estimation' of emission/removal (i.e. methods) and 'accounting' of emission reduction (i.e. deciding what pools to be considered). By approved methodologies, some pools may be *ex-ante* 'conservatively' omitted, assuming that they would be 'larger sinks or smaller sources' in the project activity than in the baseline. As a result, current methodologies mainly focus on the estimation of carbon stock changes in biomass (both below and aboveground). Soil organic carbon and dead organic matter pools are estimated in less than 33% of currently approved A/R CDM methodologies (Table 1).

By contrast in Annex I countries, soil and dead organic matter associated GHG emission/removal should be accurately estimated, reported in GHG inventories and accounted. The only option to not report a pool is to apply the transparently documented 'no source' principle (transparently demonstrating that it is not a source).

5.5 'Small sources' of CO_2 and non-CO2 emissions

Research shows that there are significant emissions associated with carbon stocks changes following land use conversions, at least in the short/medium term (i.e. beyond the first commitment period). A meta-analysis of different land use changes indicated that soil carbon stocks decline in the following cases: pasture to plantation (−10%), native forest to plantation (−13%), native forest to crop (−42%), and pasture to crop (−59%). Soil carbon stocks increase in land use changes such as: native forest to pasture (+8%), crop to pasture (+19%), crop to plantation (+18%), and crop to secondary forest (+53%). Broadleaf tree plantations after prior native forest or pastures did not affect soil carbon stocks whereas pine plantations reduced soil carbon stocks by 12–15% (Guo and Gifford 2002). In the case of plantations established on productive pastures in Australia, there are emissions from dead organic matter and soil organic matter pools for at least the first decade following the conversion (Polglase et al. 2000). These findings have been confirmed for organic matter in rich soils in Canada (Fuller and Anderson 1993; Pinno and Bélanger 2008) and in general in all soils in New Zealand (Davis and Condron 2002). In the case of afforestation of arable lands, research results are somewhat contradictory. There are reports on the increases in soil organic carbon over 30 years (Bowman and Leemans 1995) and a continuous loss of carbon or a balance of the forest floor with the decrease in mineral soils. In fact, in mineral soils there were recorded increase of carbon concentration and storage in the upper layer (i.e. 5 cm) and decreased in deeper layers (i.e. the 15–25 cm), with stand age up to 30 years (Richter et al. 1999; Vesterdal et al. 2002).

Consequently, A/R CDM methodologies generally do not consider yet soil emissions as a significant source, thus there is a consistency issue. Out of eleven approved

Table 1 Coverage of pools by the approved A/R CDM baseline and monitoring methodologies (in % of total number of methodologies)

Type of Activity	Coverage of carbon pools (%)[a]				
	AB	BB	L	DW	SOC
Large scale	100	100	33	33	25
Small scale	100	100	0	0	33

[a] Carbon pools: *AB* above-ground biomass; *BB* below-ground biomass; *L* litter; *DW* dead wood, *SOC* soil organic carbon

methodologies (as September 2009), four specifically are applicable for the conversion to forest land from grassland or grazing land, six from 'degraded' and one from 'agricultural' land. Unfortunately, definitions of 'degraded land' are inconsistent across activity sectors and countries (Wiegmann et al. 2008). Reference to *ex ante* estimation of dead organic matter and soil organic matter is made only in four approved methodologies (AR AM0006, 7, 9 and 11), with optional estimation. Recently, few of the small scale A/R CDM approved methodologies consider soil organic carbon.

Significant progress toward estimation of a project's full emissions in CDM A/R was recently made by introduction by CDM EB A/RWG, of the "*Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected in CDM A/R project activities*" and "*Tool for estimation of Carbon Stocks, Removals and Emissions for the Dead Organic Matter Pools due to Implementation of a CDM A/R Project Activity*". These instruments promote a conservative estimation by taking into consideration: land use type, type of soils and soil/land degradation status and direct soil/land preparation.

5.6 Neglecting of 'small sources' in A/R projects

In an afforestation/reforestation activity, there are numerous emissions that result, not all accounted in the projects. The approved methodologies may *ante factum* categorize some sources as 'small', while *post factum* additionally decide to neglect some other small sources from accounting.

Small sources are often not accounted, as being *ex ante* excluded by the project methodology. Overall, approved CDM methodologies are inconsistent with regard to small sources and GHG accounted (Table 2).

According to the "*Tool for testing significance of GHG emissions in A/R CDM projects*", approved by CDM EB, a source is 'small' if associated emissions are less than 5% of either lowest of 'sum of total emissions and C stock decrease' or 'less than 5% from net anthropogenic removal by sinks'. This threshold is actually derived from key category analysis in the national GHG inventories practice, where it is used to distinguish sources and sink categories based on their absolute individual contribution to annual or trend of total emission of the country. Originally, this system does not support 'accounting', but 'classifies' the sources and sinks showing where the Party needs to put more effort for improving the GHG estimation. The issue is that setting a relative threshold for omitting emissions has an absolute impact correlated with the project size and period of activity implementation. In A/R activities, significant GHG emissions occur in initial phases, which then decrease while CO_2 removals increase. The size of the emissions from project establishment depends on the size of the pre-existing C pools, land conversion technology (i.e. machinery, burning), planting technology (i.e. fertilization, irrigation), planted species features (i.e. early slow/fast growing) and activity intensity (i.e. gap filing, survival target). Thus, in order to account the small source emissions, the project monitoring schedule is crucial. Monitoring of the project in the 5th year may not adequately capture emissions from project establishment (Fig. 1).

The *ex post* decision to omit emissions from small source relies on a transparent procedure of assessment of the project emissions, based on project available records (i.e. amount of fuel consumed or/and fertilizers applied). Toward complete environmental integrity of the emission reductions coupled with the simplification of the methodologies implementation, there should be approved emissions factors for each region or country and type of sources, as well as a Tier 1 approach for full accounting of emissions form all 'small sources'.

Table 2 Completeness and consistency among CDM methodologies on small sources (number of approved methodologies)

Type of Activity	GHGs	Small sources[a]	Small source types coverage				
			Combustion of fossil fuels	Fertilizers application	Burning of biomass	Removal of pre-existing tree/non tree vegetation	Manure deposition and enteric fermentation
Large scale project activities	CH4	Included	–	–	11	–	1
		Not included	11	1	–	2	–
		Not specified	1	11	1	10	11
	CO2	Included	11	–	7	2	–
		Not included	–	1	4	–	1
		Not specified	1	11	1	10	11
	N2O	Included	–	2	9	–	1
		Not included	11	–	2	2	–
		Not specified	1	10	1	10	11
Small scale project activities	CH4	Included	–	–	–	–	–
	CO2	Not included	6	6	6	6	6
	N2O	Not specified	–	–	–	–	–

[a] Small source has to be estimated (Included) or non estimated (Not included) according the methodology provisions. In case of some pools there is no reference in the methodology to that specific small source or sink (Not specified)

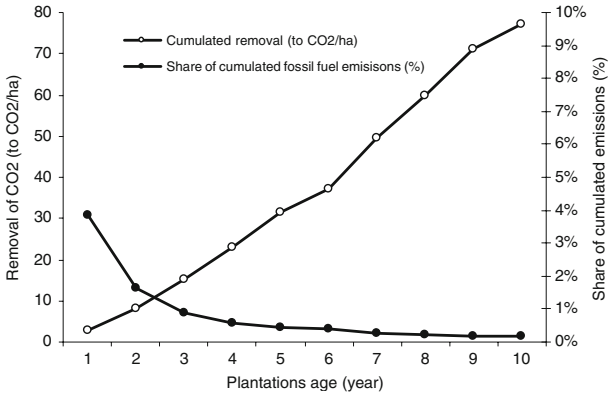

Fig. 1 Cumulated emissions by fossil fuel use as a share of emission removals in a typical A/R project (This figure assumes *Robinia pseudoacacia* of plantation (1 ha, average site conditions) in Europe. Diesel use is 120/40/10/10 liters/ha in the 1st/2nd/3rd/4th year old plantations, with an emission factor of 2.63 kg CO2 / l liter Diesel)

5.7 Accuracy of emission/removal estimates

The accuracy of the estimate of emission reductions is calculated using different approaches in national GHG systems and projects methodologies. To ensure accurate estimates of CO2 removals, the general approach is to stratify the project lands on various criteria (i.e pre-existing land uses and soils, species, age classes) and the accuracy is accomplished by appropriate sampling methodology. In general, in forestry (i.e. National Forest Inventories), the uncertainty of estimation is significant, both because of errors associated with land identification (7% or higher) and wood volume estimation (20% or higher), according their National GHG inventories, submission 2009 (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/4771.php).

Generally, in A/R projects a 10% measurement accuracy of the mean with 90% confidence is expected according Meeting Report EB31 of the CDM EB (UNFCCC 2009). In fact, in very young plantations, such accuracy requires a significant monitoring effort because of heterogeneity in survival rate, repeated gap filling and soil/site heterogeneity (Blujdea 2007). Current practice shows that, the Designated Operational Entities[3] do not credit A/R CDM or JI projects with 'average' estimates, but with an amount corresponding to lower bound of the 95% confidence interval of the estimated average, so called 'reliable minimum estimate approach' (Intergovernamental Panel on Climate Change 2003). There is practically no official provision for such approach and it provides a very conservative estimate of the removals from a project even though projects deliver statistically 'higher quality' emission reductions/removals than similar activity in Annex I countries.

In REDD framework (reducing emission from deforestation and degradation), as a potential mechanism to be developed in the future to contribute to the reduction of GHG

[3] Accredited Operational Entity is a legal organization accredited by Executive Board to validate and subsequently request registration of a proposed CDM project activity, verifies its emission reduction and certifies as appropriate and requests the Board to issue Certified Emission Reductions of the project (http://cdm.unfccc.int/DOE/index.html)

emissions on lands, there is proposed a 'conservativeness principle' approach related to high uncertainty of the input data (Grassi et al. 2008).

On the other hand, Annex I national accounting systems will generate 'average' estimates of removal by sinks from mandatory and any elected activities, as considered that 'uncertainty' was dealt upon over the negotiation process (i.e. cap) or in accounting (i.e. any adjustment).

5.8 Accounting duration of removal/emission

There are significant differences between Annex I and CDM projects in the duration of the accounting of removals for AR activities. These differences create a disadvantage for CDM activities. In domestic Annex I A/R activities the removals from net change in C pools are accounted for only over the commitment period (i.e. 2008–2012), but they are permanent. Meanwhile, in CDM projects net project removal is accounted since the project start to either the end of one commitment period or project crediting period. As well, projects might have started as early as year 2000 (Art 12.10 of the Kyoto Protocol), while domestic activities are accounted if established since 1990. Current accounting duration of CDM removal units (CER) is limited (max 30 years) which affects the permanence of emission reduction achieved by such activities in non Annex I countries.

5.9 Emission reduction accounting in projects and national GHG inventory systems

An A/R project's approved methodology is a 'cook-book' for estimating the net anthropogenic removals by the activity. Part of the methodology refers to estimation methods while other parts are derived from modalities and procedures for CDM (i.e. non permanent certified emissions reduction) and accounting rules (i.e. as one defines pools and GHG to be included or omitted).

For the national GHG systems, the accounting rules observe 'conservativeness' in the sense that a change in a C pool which is not a source (so demonstrated as being either neutral or sink) for the elected activities under Art 3.3 and 3.4 need not be accounted by a Party complying with its emission reduction target (Decision11/CP7/Add1). Here the estimation, reporting and accounting are separated. Practically, an Annex I Party shall account for changes in all C pools: aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon for mandatory and elected activities, as well as changes in emissions of non-CO_2 gases (CH_4, N_2O). The changes in emissions or removals associated with all LULUCF activities are accounted by either gross-net (net removal over the commitment period); or net-net (annual net removal in the commitment period against the base year's one). In some cases removals are 'capped' (allows the use of only a share of the net removal in the commitment period). The adoption of clear definitions and criteria, as well as their consistent use at the national level is essential toward consistent monitoring and accounting of LULUCF activities, since different rules apply to different activities. For an Annex I Party, a reduction in removals from LULUCF activities (i.e. due to forest age class distribution) may mean an increase in the net emissions even though gross emissions may decrease (Ward 2004). Under relatively constant rate of afforestation/reforestation in the Annex I countries over last two decades, it is likely that over the first commitment period, Annex I countries will include removals from a wide range of different aged plantations and stages of afforestation work (i.e. starting with the oldest established in 1990 to the youngest since 2011/2012).

6 Estimation and accounting of leakage

Leakage is emissions that occur outside the project boundary as a result of the project activity. For example, leakage could occur from a chain of land use changes (i.e. entire or partial pre-project activities and related emissions are shifted on other lands), therefore net losses of carbon stocks (i.e. emissions) as a result of an A/R activity. In measuring projects' attributable leakage there are two key issues: identification of baseline drivers that may turn in sources of leakage (i.e. grazing, fuel wood collection, fertilization, drainage) and develop estimation methods for the calculation of their associated emission/removal effect.

Generally, leakage should be addressed in a CDM AR methodology, but of the eleven approved A/R CDM methodologies for large scale projects, seven do not identify any sources of leakage. In general, leakage can be ignored because of applicability conditions imposed by the methodology. The applicability conditions ensure that there is no leakage (for example, the AR activity occurs on degraded lands without any agriculture activities). According to Decision 19/CP.9, positive leakage (i.e. spill-over) shall not be accounted for in A/R CDM projects, while negative leakage must be identified and discounted from the project removal. This means, for example, that the decrease in upstream emissions from the production of fertilizers cannot be considered if the project reduces fertilizer use or even the fertilizer associated emissions by newly introduced technology. Similarly, the decrease in emissions from deforestation induced by fuel wood use cannot be considered even if the project is designed to supply fuel wood (that replace eventually fossil fuels). For a period of time equal to the project crediting period, the amount of emissions from fertilization and fuel consumption avoided would be very significant. An identical activity in an Annex I country would create a benefit that would either be credited to the activity or captured in the country's GHG inventory and accounted for the commitment compliance.

But inconsistency with leakage has a much larger implication, as large scale leakage. Since 1990 Annex I countries afforested land has increased by 12%. Since 1993[4] in the EU 27 forest land has increased by 3%, with majority of this land coming from permanent pastures and meadows. Meanwhile harvested forest area decreased in EU 27 by 3% and 12% at global Annex I level and grassland by 4% in EU 27 and 24% in all Annex I countries. Such land use changes create significant amount of credits from afforestation activities over first commitment period, but also not accounted emissions as grazingland management was not elected. Since 1993, production of cattle meat in the EU 27 has increased by 8% but consumption of bovine meat has increased by 13% (FAOSTAT 2009). Essentially this means that a large portion of the Annex I afforestation activity has caused international leakage by increasing overgrazing and deforestation in non-Annex I countries. This is not captured in Annex I GHG inventories. So there is a double standard and one needs to wonder why CDM projects are burdened to estimate the amount of leakage that they may cause when leakage from Annex I activities is not included?

7 Permanence issue in CDM A/R projects and domestic Annex I activities

Emission reductions from LULUCF activities are unlike those from other sectors. The emissions reductions can be lost due to natural (fire, pests or wind throw) or human

[4] 1993 has specifically be chosen because of the consistency of the data in FAOSTAT, http://faostat.fao.org/default.aspx

(harvesting, deforestation) disturbances. For these reasons, in the CDM, A/R removal units are 'temporary'. A/R CDM issued credits are considered under high risk of non-permanence and issued as tCERs, that expire at the end of next commitment period, or lCERs that expire at the end of crediting period of the project. Once these emission reductions expire, they must be replaced by permanent units, which may have higher climatic, social and environmental integrity than the current emission reductions. The temporary nature makes A/R removal units from A/R CDM unattractive to parties in need of credits to meet an emission target.

CDM project's methodology only provides guidance on methods for calculation of net removal, but current approach is that the control of permanence of emissions reduction cannot go beyond the project lifetime. Within that period, the issue of non-permanence is directly addressed by methodologies (i.e. include relevant sources/sinks, monitored GHG) and by the monitoring protocol which is set sensitive to activity's parameters, thus to temporal and spatial activity's emission/removal (i.e. disturbances).

Once again, the approach of permanence between CDM and domestic Annex I activities is inconsistent. For A/R in Annex I countries, only the emissions and removals during the commitment period are used for accounting purposes and A/R is subject to a specific rule that "debits resulting from harvesting during the first commitment period following afforestation and reforestation since 1990 shall not be greater than credits accounted for on that unit of land", according Decision 16/CMP.1, Annex, paragraph 4 (UNFCCC 2005b) This makes sense since no credits were generated for the sequestration since planting and before 2008, so why should there be a debit for these if they are lost. But it does not create an incentive to protect these removals. When the removals are used to balance against emissions from non-LULUCF during the commitment period, then these emission reductions are permanent. That is, unless in a post-Kyoto agreement, there is a special provision for losses of LULUCF credits already generated.

The risk of disturbances in A/R areas has a greater effect in projects than in domestic Annex I activities. CDM projects are smaller in area and they do not benefit from spatial diversification that a whole country can take advantage of, as being in nationally/regionally widespread plantations under all range of ages and various environmental and socio-economic conditions (i.e. across country's regions). In CDM/JI, the effect of disturbances within the project boundary is estimated and discounted within the project net removal. For Annex I activities, under national inventories and accounting, there is a much better mechanism to offset disturbance's effects (by larger distribution A/R areas, various age sinks/plantations, less vulnerable to climatic hazards due to larger geographic distribution).

Another remarkable issue is that, in most non-Annex I countries, wood fuel is still a major source of energy. This creates a large demand on existing forest resources (causing degradation and deforestation). Even so, CDM A/R projects, that create a new forest resource that is used as a wood fuel source, must still face the loss of credits when the forest is harvested. The new wood fuel would likely displace fossil fuel use or non-sustainable timber extraction, as well as reduce wood collecting pressure from existing natural forests. In fact harvesting in A/R CDM plantations can significantly contribute of the permanence of emission reductions in other forests (i.e. protected) as sustainable fuel wood can be provided. As emissions from deforestation/degradation are higher, their cumulative impact on the atmosphere is very significant. Perhaps a special 'permanence' should be issued for harvesting losses on plantations created for wood fuel use, addressed in future accounting rules for such projects (i.e. crediting projects with higher 'time averaged C stocks').

Finally, addressing permanence should be analyzed under a wider scope. Carbon is stored in different pools on earth, be it in the biosphere (e.g. trees); the lithosphere (e.g. crude oil or

natural gas); or technosphere (e.g. buildings, plastics or wood products). Similar to carbon storage in the forest pools, oil and coal deposits can be potentially emitted at any time, depending on extraction and transformation technology and the market conditions. In the forestry sector, C stocks are measured in the original (natural) pool (i.e. above ground biomass, belowground biomass, litter, dead wood and soil organic carbon), while in the other sectors GHG emissions are measured in intermediate or final pools, however their original pools are not included in estimation and reporting of GHG (e.g. oil deposits). Increasing carbon stocks in the technosphere does not prevent from later by reemitted. To address permanence in A/R CDM projects, temporary credits (tCER) have been included in the modalities and procedures according the Decision 19/CP.9 (UNFCCC 2003) and Decision 5/CMP.1 (UNFCCC 2005a). However no corresponding agreement has been achieved for the other sectors creating a lack of consistency in the whole system. More thoughts are needed to deal with permanence in a coherent manner among sectors so that environmental integrity of the climate stabilization actions can be ensured and elaborate an adequate framework to address it.

8 Compatibility options and conclusion

A/R CDM projects were hoped to be a large and convenient source of emission reductions/removals for Annex I countries while at the same time providing an incentive for non-Annex I countries to increase forest cover and possibly contribute to local/regional sustainable development. They were thought to be a 'win-win-win' situation. Unfortunately, during the lead-up to the first commitment period of the Kyoto Protocol, this has not been the case and CDM A/R might be viewed as a weakness (also for LULUCF's JI with only the Romanian project). Also, CDM A/R was hoped to drive more LULUCF project activities into future climate agreements. Nevertheless significant experience and data with existing projects, including using methodologies, has been accumulated. This experience shows that there is a lot of room for improvement and strength the consistency and comparability of the emission reductions generated, while at the same time, needed simplification of the accounting system.

Estimation and reporting must be totally separated by accounting rules, as they are currently both integrated within the A/R CDM methodologies and procedures/tools. Thus, accounting rules and modalities must be reviewed, together with the re-assessment of the issue of baseline non-CO2 emissions. So, inclusion or exclusion of 'small' sources or sinks may be done neither *ante factum* (based on subjective assumptions) nor *post-factum* (when the data is already collected), but based on a set of general accounting rules to be negotiated and agreed upon.

There is a glaring inconsistency in the treatment of additionality and leakage. The inconsistency allows Annex I countries to enjoy an emission removal for the business-as-usual abandonment of agricultural lands due to the low income the lands produce. This agricultural production is then transferred to non-Annex I countries causing deforestation (thus leakage). But at the same time, A/R projects in non-Annex I countries are carefully scrutinized for their additionality and possibility of leakage. Global impact of projects in non-Annex I countries has still to be determined in leakage terms.

Given these problems, in A/R activities, there is a consistent pattern of operations, no matter the location, technologies or species used: land preparations, soil preparation, planting, maintenance, etc. This suggests that a unique standard methodology could be developed, negotiated and agreed upon, to replace current numerous methodologies. Thus, such a standard methodology could be developed as to be more consistent with

national systems of Annex I Parties and responding to the variety of applicability conditions. Then it has to be adapted to any project circumstances. Such a tool would be similar of and equivalent to IPCC's guidelines for the national GHG Inventories, allowing specificity in methods upon project circumstances, while promoting equal treatment of sources, pools and gases in the project specific methodology. As well, any data and information acquired in projects could be a good start for the development of GHG inventories in non Annex I countries, under further commitment of emission reductions (additional to other proxy which may be relevant for that, like reducing area of deforestation).

On the other hand A/R, or in general, land use projects should to be considered as main contributors to local sustainability in non Annex I countries, a reason to be further refined and promoted. Under this perspective, politically decisions on specific accounting rules may be taken as to reduce project costs (i.e. allocating funds for covering related estimating costs) and to reduce monitoring burden from the project, but environmental integrity and climatic objective must be fully underpinned.

This approach would fully acknowledged the need for a compromise between project easiness of preparation and implementation (including financial aspects), and the environmental integrity of the emission reductions. Currently accumulated experience in projects would significantly support international debates on LULUCF projects contribution to climate stabilization target.

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