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Article

Forest Carbon Leakage Quantification Methods and Their Suitability for Assessing Leakage in REDD

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Abstract: This paper assesses quantification methods for carbon leakage from forestry activities for their suitability in leakage accounting in a future Reducing Emissions from Deforestation and Forest Degradation (REDD) mechanism. To that end, we first conducted a literature review to identify specific pre-requisites for leakage assessment in REDD. We then analyzed a total of 34 quantification methods for leakage emissions from the Clean Development Mechanism (CDM), the Verified Carbon Standard (VCS), the Climate Action Reserve (CAR), the CarbonFix Standard (CFS), and from scientific literature sources. We screened these methods for the leakage aspects they address in terms of leakage type, tools used for quantification and the geographical scale covered. Results show that leakage methods can be grouped into nine main methodological approaches, six of which could fulfill the recommended REDD leakage requirements if approaches for primary and secondary leakage are combined. The majority of methods assessed, address either primary or secondary leakage; the former mostly on a local or regional and the latter on national scale. The VCS is found to be the only carbon accounting standard at present to fulfill all leakage quantification requisites in REDD. However, a lack of accounting methods was identified for international leakage, which was addressed by only two methods, both from scientific literature.

Keywords: forest carbon accounting standards; scientific literature; primary and secondary leakage; international leakage; national-scale accounting

Supplementary Materials

SM1. Leakage quantification methods described in peer-reviewed scientific articles. Square brackets indicate the reference as presented in the reference list in the article.

Author, Year	Title	Short description	Leakage caused by
[18] Gan and McCarl, 2007	Measuring transnational leakage from forest conservation	Analytical framework for measuring international leakage and estimation of leakage magnitude through general equilibrium model GTAP v6.0.	Forest conservation
[23] Sun and Sohngen, 2009	Set-asides for carbon sequestration: Implications for permanence and leakage	Leakage modeling through global land use and forestry model (FASOM), looking at three crediting schemes for set-asides in carbon sequestration	Forest set-asides: REDD, AR, IFM
[24] Sohngen and Brown, 2004	Measuring leakage from carbon projects in open economies	Market leakage assessment of the Noel Kempff forest conservation project in Bolivia, with the help of a dynamic optimization model of the national timber market affected by reduced supply.	Forest conservation
[25] Murray, *et al.*, 2004	Estimating leakage from Forest Carbon Sequestration Programs	Combination of analytic, econometric and sector-level optimization models to estimate leakage from different forest carbon sequestration activities in the US.	Forest conservation and Afforestation
[26] Ewers and Rodrigues, 2008	Estimates of reserve effectiveness are confounded by leakage	Develop a simple approach to quantifying leakage from activity shifting out of nature reserves; create a landscape-wide baseline deforestation rate and compare it to actual rates to determine increases due to leakage.	Forest conservation
[27] Dutschke, *et al.*, 2006	A spatial approach to baseline and leakage in CDM forest carbon sink projects	Semi-standardized approach for calculation of baseline for CDM A/R projects. PARAPIA applies the concept of a reference area around the project area, that is also used to determine leakage effects.	Afforestation and Reforestation
[28] Boer *et al.*, 2007	Assessment of carbon leakage in multiple carbon-sink projects: a case study in Jambi Province, Indonesia.	Use of a logit model to estimate the probability of a land use getting converted into other uses, in order to assess leakage from fictive carbon sink projects in the Jambi Province, Sumatra, Indonesia.	Afforestation and Reforestation projects
[29] Lasco *et al.*, 2007	Analysis of leakage in carbon seq. projects in forestry: a case study of upper magat watershed, Philippines	Analyze the leakage potential of forest conservation, tree plantations, and agroforestry for carbon sequestration. Leakage potential is derived from applying historical technology adoption rates in watershed areas in the Philippines.	Forest conservation and afforestation

SM2. Carbon standards and leakage quantification methods selected for the assessment. Square brackets indicate the reference as presented in the reference list in the article.

Standard name and version	Short description	Methodologies approved as of June 2011	Number of leakage quantification methods assessed	Method references
[40] Clean Development Standard (CDM)	The CDM is one of the project-based mechanisms under the Kyoto Protocol, and involves emission reduction activities in developing countries that also contribute to sustainable development. Afforestation and reforestation (A/R) are the only eligible activities under this standard.	A total of 20 approved A/R methodologies: 13 large scale and 7 small scale ones Six of the large scale methodologies and four of the small scale ones address leakage, while the other methods excluded leakage emissions	6 large scale, 4 small scale and two CDM A/R tools for quantification of leakage emissions = 12 documents	AR-AM0004 AR-AM0005 AR-AM0011 AR-AM0013 AR-AM0014 AR-ACM 0001;AR-AMS 0001 AR-AMS 0002;AR-AMS 0003 AR-AMS 0007 *Tools:* EB 51, Annex 15; EB 39 Annex 11
[41] Climate Action Reserve (CAR) v.3.2	The Forest Protocol is part of the Climate Action Reserve, a national offsets program that establishes regulatory quality standards for the development of emission reduction projects in North America	The program does not approve individual project-based methods but provides regulatory frameworks in the form of protocols for different sectors, which provide project development, verification and monitoring guidelines. One Forest Protocol exists.	1 document	CAR Forest Protocol v 3.2
[42] Verified Carbon Standard (VCS) v.3.1	Accounting standard for carbon projects in the voluntary market, founded in 2005. It includes a comprehensive standard for the land-use sector, allowing activities in agriculture, A/R, forest management and REDD [VCS 2011].	9 approved methodologies: 4 REDD and 5 IFM. One of the REDD methodologies (VM0007) consists of methodological modules, four of which address leakage quantification	9 approved methodologies, of which one contains 4 methodological leakage modules. Thus; the basis of our assessment is a total of 12 documents.	VM0003 VM0004 VM0005 VM0006 VM0007 - VMD 0009 - VMD0010 - VMD0011 - VMD0012 VM0009 VM0010 VM0011 VM0012
[43] Carbon Fix Standard (CFS) v.3.1	A/R standard developed 2007 by a non-profit group of forestry experts. The CFS provides accounting guidelines for afforestation and reforestation projects, which are allowed to also include a forest conservation component	Similar to CAR, the CFS does not require project developers to submit their own methodologies. Instead, CFS has one methodological document containing the standard and all equations to be applied	Our assessment covers the main standard document	CarbonFix Standard v3.1

SM3. The individual leakage accounting methods by carbon standard or literature source, grouped into the different methodological approaches. Square brackets indicate the reference as presented in the reference list in the article.

Methodological approaches	**CDM**	**VCS**	**CAR**	**CFS**	**Scientific methods**
PLA 1		VM0003 VM0004 VM0010 VM0011 VM0012 VMD009			
PLA 2	AR-AM0005 AR-AM0011 AR-AM0013 AR-CM0001 and CDM Leakage Tool for Agriculture				Ewers and Rodrigues [26]
PLA 3	CDM Leakage tool for non-renewable biomass	VMD0012			
PLA 4	CDM AR-AM0004	VM0006 and VMD0010		Carbon Fix	Dutschke *et al.* [27]
PLA 5	AR-AMS 0001 AR-AMS 0002 AR-AMS 0003 AR-AM0014		CAR Forest Protocol		
PLA 6		VM0009			Boer *et al.* [28] Lasco *et al.*[29]
SLA 1		VM0003 VM0004 VM0005 VM0010 VM0011 VM0012 VMD0011	CAR Forest Protocol		
SLA 2		VM0012			
SLA 3					Gan and McCarl [18] Sun and Sohngen [23] Sohngen and Brown [24] Murray *et al.* [25]