AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

HWWA HAMBURG

DISCUSSION PAPER

The Role of Forestry Sinks in the CDM - Analysing the Effects of Policy Decisions on the Carbon Market

Martina Jung

HWWA DISCUSSION PAPER

241

Hamburgisches Welt-Wirtschafts-Archiv (HWWA)
Hamburg Institute of International Economics
2003
ISSN 1616-4814

Hamburgisches Welt-Wirtschafts-Archiv (HWWA)
Hamburg Institute of International Economics
Neuer Jungfernstieg 21 - 20347 Hamburg, Germany
Telefon: 040/428 34 355
Telefax: 040/428 34 451
e-mail: hwwa@hwwa.de
Internet: http://www.hwwa.de

The HWWA is a member of:

- Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (WGL)
- Arbeitsgemeinschaft deutscher wirtschaftswissenschaftlicher Forschungsinstitute (ARGE)
- Association d'Instituts Européens de Conjoncture Economique (AIECE)

HWWA Discussion Paper

The Role of Forestry Sinks in the CDM - Analysing the Effects of Policy Decisions on the Carbon Market

Martina Jung

HWWA Discussion Paper 241
http://www.hwwa.de

Hamburg Institute of International Economics (HWWA)
Neuer Jungfernstieg 21 - 20347 Hamburg, Germany
e-mail: hwwa@hwwa.de

This paper has been prepared within the research programme
International Climate Policy

Edited by the Department World Economy
Head: PD Dr. Carsten Hefeker

HWWA DISCUSSION PAPER 241
August 2003

The Role of Forestry Sinks in the CDM - Analysing the Effects of Policy Decisions on the Carbon Market

ABSTRACT

The details on rules and modalities for the inclusion of forestry projects in the Clean Development Mechanism (CDM) are one of the last non resolved implementation issues of the Kyoto Protocol. We examine in detail the implications of different policy decisions concerning the inclusion of CDM forestry sink enhancement projects in the first commitment period of the climate regime (2008-2012). Our analysis is based on the development of marginal forestry cost curves which are implemented into the carbon market model CERT. The latter is a partial equilibrium model of the international market for emissions permits under the Kyoto Protocol. The scenario analysis sheds light on the role of CDM forestry sinks in the climate regime, the effect of different policy scenarios on the carbon market price as well as the distribution of benefits and losses between countries. The results suggest, that the role of forestry projects in CDM in the first commitment period will be rather small. The countries mainly benefiting from the introduction of forestry in the CDM are the Annex B and the Latin American and African countries while China and the hot air holding countries will lose as compared to a purely energy based CDM.

JEL-Classificiation:
Keywords: Clean Development Mechanism, Forestry, CERT, LULUCF, marginal cost curves

Martina Jung
HWWA Hamburg Institute of International Economics
Research Programme International Climate Policy
Neuer Jungfernstieg 21
20347 Hamburg
e-mail: martina.jung@hwwa.de
Tel.: 040 42834-434
Fax: 040 42834-451

Introduction

The Kyoto Protocol of the United Nations Framework Convention on Climate Change imposes a reduction of greenhouse gas (GHG) emissions of 5.2% of their 1990 levels on Annex B countries (most OECD countries and countries in transition) for the first commitment period (2008-2012). For the fulfillment of these reduction obligations, the Protocol offers three flexible mechanisms, namely Emissions Trading, Joint Implementation (JI) and the Clean Development Mechanism (CDM). The latter two are project-based mechanisms, allowing Annex B Parties to implement emissions reduction and carbon sequestration projects in other countries and to count the achieved emissions reduction towards their own emissions account. JI projects are those project activities taking place in an Annex B country, while CDM projects are the ones located in developing countries (Non-Annex B) countries. Although, the Kyoto Protocol focuses mainly on emissions reductions, the option to reduce the concentration of greenhouse gases in the atmosphere through the enhancement of terrestrial carbon sinks was debated ever since the Kyoto conference in 1997, where the subject entered into the negotiations as the Land use, Land-use change and Forestry (LULUCF) issue. The very controversial debate in the following negotiations finally led to an limited inclusion of LULUCF activities. In the first commitment period, under Article 3.3 Annex B countries have to account for afforestation, reforestation and deforestation activities in their emissions inventories.[1] Article 3.4 lists other LULUCF activities which might be included voluntarily in the inventories.[2] The activities of Articles 3.3 and 3.4 are also eligible project activities in the frame of JI, while LULUCF activities in the CDM - which are the focus of this paper - are restricted to afforestation and reforestation only. [3] Forestry sinks in the CDM are subject to a demand side cap, limiting the use of greenhouse gas removals from such projects to 1% of a Party´s baseline year emissions for each year of the commitment period. The development of rules and modalities for the inclusion of afforestation and reforestation projects under the CDM in the first commitment period are one of the last open issues of the Kyoto Protocol. Issues which still have to be addressed under are: the definitions for forest, afforestation and reforestation, stringency of project baselines, the base year for deforestation, leakage, impermanence and socio-economic and environmental impacts. The

[1] For the Kyoto definitions of the relevant terms forest, afforestation and reforestation, see Appendix A. The document FCCC/CP/2001/13/Add.1 contains the decisions on LULUCF taken in Bonn (COP 6 II).

[2] Debits under Article 3.3 may be compensated by Forest Management under Art. 3.4 up to 9 MtC per year and an additional amount specified for each country in Appendix Z, while the other Article 3.4 activities cropland management, grazing land management and revegetation can be accounted for without any restrictions.

[3] Although LULUCF projects in the CDM are limited to forestry projects only, we use the term LULUCF when refering to the CDM forestry activities.

final decisions on these implementation issues are supposed to be taken on COP 9 in December 2003. The definitions of forest, afforestation and deforestation adopted for Art. 3 are probably going to be applied to the CDM as well. But it remains unclear if additional decisions are going to be taken to explicitly exclude certain project types, like monocultural plantations or agroforestry projects. If the Kyoto definitions, which rely solely on three quantitative thresholds (minimum land area, minimum crown cover and minimum height of trees), will not be modified, all project types, including plantations and agroforestry projects will be eligible CDM projects.

Decisions to be taken on these issues will determine the potential of LULUCF in the CDM and therefore, the role LULUCF might play in the first commitment period of the climate regime. In this paper, we use a quantitative approach to estimate effects of different policy decisions concerning LULUCF in the CDM on the carbon market, the creation of CDM emissions permits as well as on the distribution of economic benefits between countries.

LULUCF in economic models

Most of the economic models of the international carbon market are mainly based on the marginal abatement cost curves of the energy sector and do not include the sink enhancement activities allowed in the framework of the Kyoto Protocol. Some account for LULUCF activities in a very simple manner by modifying the marginal energy cost curve through the inclusion of one horizontal segment with a constant marginal cost for the amount of carbon sequestration assumed to be available (e.g. (Missfeldt and Haites 2001; Jotzo and Michaelowa 2002), Jotzo, 2002). Others assume zero cost sinks for Annex B by shifting the energy cost curve to the right by the sequestration potential (Kappel, Staub et al. 2002). This negligence of LULUCF in economic models leads to an unsatisfactory representation of the reductions potentials and costs countries encounter in the climate regime.

But what means including LULUCF into a model? What the sinks potentials and costs and, therefore, the carbon sequestration cost curves - look like is mainly determined by policy decisions taken in the frame of the international climate regime, e.g. which sinks enhancement projects are eligible, how the GHG reduction is accounted for and how costly the emissions permits generated through forestry projects will be. Almost all of the models including sinks do not specify at all which LULUCF activities they considered for the calculation the sinks potentials and costs or only focus on one forestry activity, e.g. afforestation.

In this paper, we analyse the implications of different policy decisions in the climate negotiations concerning LULUCF in the CDM[4] on the supply of tradable emissions permits by differentiating four sink enhancement project types. This makes it possible to carry out a scenario analysis, varying the assumptions on policy decisions like project eligibility in the framework of the CDM and carbon accounting. Therefore, marginal carbon sequestration cost curves[5] for Non-Annex-B regions will be developed and implemented into the carbon market model CERT.

Carbon sequestration costs in the literature

The research on carbon sequestration is relatively young. Starting in the late 80s, mainly US-American researchers began studying potentials and costs of afforestation activities to sequester carbon. Several studies on the construction of bottom-up (marginal) carbon sequestration cost curves have been conducted.[6] Bottom-up approaches focus on individual processes of abatement technologies or sequestration options.[7] Different methods for constructing bottom-up marginal carbon sequestration cost curves can be used. The simplest and mostly used method is to order the cumulative sequestration potentials of different LULUCF activities from the lowest to the highest cost option. Other methods apply sector or sub-sector models, e.g. timber market models, cost-benefit approaches and econometric techniques.

Table 1 gives a broad overview on the existing studies on LULUCF costs and potentials and the respective marginal cost curves developed. Most of the studies concentrate on the US or its regions. Some global studies exist, mainly looking at the carbon sequestration potentials and costs differentiated by continents or climatic zones. Studies which focus on the potentials and costs of forestry carbon sequestration in developing countries, especially the tropics just started in the mid-nineties. The estimates of potentials of comparable geographic zones vary widely between studies. The same applies to the cost estimates. The existing cost studies do

---

[4] LULUCF activities in Annex B countries will, of course, also have an effect on the demand and supply of emissions certificates. Here we are only focussing only on LULUCF in the CDM. For an analysis of different scenarios of eligible sinks categories under Art. 3.3 and Art. 3.4 see Missfeldt and Haites (2001).

[5] The term carbon sequestration cost curve is misleading when refering to conservation of forest or avoiding/slowing deforestation, since these lead to emission reductions. However, it will use here for all marginal cost curves of forestry projects.

[6] For a detailed analysis of past studies see Richards and Stokes 2003

[7] Of course, there is also the option of constructing marginal sequestration cost curves by a top-town approach. In our study we are just looking at bottom-up cost curves, since the development of top down costs curves for LULUCF is still in its infancy.

not allow for a comprehensive analysis on the main factors which influence the differences in costs.[8]

Table 1: Bottom-up estimates of forestry carbon sequestration potentials and costs

Author	*Country/region*	*Project types covered*	*Potentials (land/ carbon)*	*Costs*	*Marginal cost curve*
Global/Non-Annex B					
Benìtez (2003)	South America	Plantations	x	x	x
Dixon, Schroeder, Winjum (1991)	Boreal, temperate, tropical	Natural regeneration, afforestation, reforestation, agroforestry, forest management	x	x	x
Dixon et al. (1994)	South America, Africa, South Asia, North America	Agroforestry	x		
Deying (2001)	China	Plantations, regeneration, agroforestry, conservation	x	x	
Fearnside (1995)	Brazil	Reduced deforestation, plantations, sustainable timber management	x	x	
Fearnside (2001)	Brazil	Silvicultural plantations, forest management, avoided deforestation	x		
Houghton et al. (1993, 2001)	Latin America, Africa, Asia	Plantations, Agroforestry, Forest Management	x		
IPCC (2000)	Global	Plantations, regeneration, agroforestry, protection, forest management	x	x	x
Ismail (1995)	Malaysia	Forest protection, plantations, forest management	x	x	
de Jong, Tipper and Montoya-Gomez (2000)	Mexico	Forest Management, agroforestry	x	x	x
Kerr, Pfaff and Sanchez (2001)	Costa Rica	Forest management	x	x	
Makundi, Okitingati (1995)	Tanzania	Conservation, agroforestry	x	x	
Masera, Bellon, Segura (1995)	Mexico	Conservation/protection, forest management, plantations, agroforestry	x	x	
Niles et al. (2002)	48 developing countries	Forest restoration, , avoided deforestation	x		
Nordhaus (1991)	Global	Plantations	x	x	
Ravindranath, Sudha and Sandhya Rao (2001)	India	Forest protection, plantations, regeneration	x	x	
Ravindranath and Somashekhar (1995)	India	Natural regeneration, agroforestry, community forestry	x	x	
Sathaye et al. (1995)	China, Brazil, Indonesia, India, Mexico, Philippines	Forest, Protection, Forest Management, Plantations, regeneration, agroforestry	x	x	x
Sedjo (1999)	Argentina	Plantations	x	x	
Sedjo and Solomon (1989)	Global	Plantations		x	x
Sedjo, Sohngen and Mendelsohn (2001)	Global	50 different timber and forest management types	x	x	x
Trexler and Haugen (1995)	Tropics	Slowed Deforestation, regeneration, agroforestry, plantations	x		
Wangwacharakul,V. Bowonwiwat, R. (1995)	Thailand	Forest protection, plantations, agroforestry	x	x	x
Winjum and Schroeder (1997)	Global	Plantations	x		
Xu (1995)	China	Plantations, agroforestry, forest management	x	x	x
Xu, Zhang and Shi (2001)	China	Forest protection, plantations, regeneration, agroforestry	x	x	
Annex B					
Adams et al. (1993)	USA	Plantations	x	x	x
Adams et al (1999)	USA	Plantations	x	x	x
Alig et al. (1997)	USA	Plantations	x	x	
Barson and Gifford (1990)	Australia	Plantations	x		
Callaway and McCarl (1996)	USA	Plantations	x	x	x
Cannel(2003)	Europe, UK	Art. 3.3/Art.3.4 activities and biomass	x		
Dudek and LeBlanc(1990)	USA	Plantations	x	x	
Golub (2000)	Russia	Forest management, plantations and regeneration	x	x	x

[8] For some first approaches on factors influencing the cost of carbon sequestration see Newell and Stavins 2000, Richard and Stokes 2002 and Richards 2002.

Gurney and Neff (2000)	Canada, Russia, USA	Art. 3.4 activities	x	x	
van Kooten et al. (1992)	Canada	Forest management, plantations	x	x	x
van Kooten et al. (2000)	British Columbia, Alberta (Canada)	Plantations	x	x	
Lewis, Turner and Winjum (1996)	USA	Plantations	x	x	
Moulton and Richards (1990)	USA	Forest management, plantations	x	x	x
Newell and Stavins (2000)	Delta States	Plantations	x	x	x
New York State (1991)	New York State	Forest management, plantations	x	x	
Parks and Hardie (1995)	USA	Plantations	x	x	x
Petroula (2002)	Europe	Art. 3.3/3.4 activities	x		
Plantinga et al. (1999)	Maine, South Carolina, Wisconsin	Plantations	x	x	x
Plantinga and Mauldin (2000)	Maine, South Carolina, Wisconsin	Plantations	x	x	
Richards (1997)	USA	Plantations	x	x	
Richards, Moulton and Birdsey (1993)	USA	Plantations	x	x	x
Slangen and van Kooten (1996)	Netherlands	Plantations	x	x	
Sohngen, Mendelsohn and Sedjo (1998)	North America, Europe, subtropical	Plantations	x		
Stavins (1999)	USA	Plantations	x	x	x

Most of the studies neglect a substantial part of costs (e.g. land costs, monitorig costs) as well as the benefits[9] generated by the projects (Kauppi, Sedjo et al. 2001). This, of course, will change the cost estimates dramatically and result in a distorted structure of estimates when comparing different project types. Fast growing plantations, e.g. may have higher implementation costs than avoided deforestation projects, but they also generate marketable benefits which can make them even profitable. Other factors influencing the carbon sequestration cost will be the discount rate used for the costs as well as the carbon benefits, the carbon accounting method applied, the model used to estimate the opportunity cost of land, the baseline assumed, the physical characteristic of the project area, the biomass pools included, the silvicultural species used etc..

Due to the inconsistencies in the use of different geographic scopes, terms, underlying assumptions and methods, the existing studies on carbon sequestration costs are not comparable (Kauppi, Sedjo et al. 2001; Richards and Stokes 2002). This makes it impossible to take marginal forestry sequestration cost curves for the implementation into a global carbon market model from the existing literature. Therefore, for this study, we relied on a simple method to develop consistent marginal carbon sequestration cost curves, which can be implemented into a global carbon market model.

Development of marginal carbon sequestration cost curves

The purpose of this paper is to analyse in detail possible policy scenarios concerning forestry in the CDM. Therefore, it is necessary to define what activities we consider to be eligible sink

[9] Here we are referring only to the direct, marketable benefits.

enhancement activities. The four categories of sink enhancement project types included in our study are plantations, regeneration, agroforesty and avoided deforestation. The first three are "direct human-induced conversion of non-forest to forested land through planting, seeding and/or the human induced promotion of natural seed sources", meeting the Kyoto definition of forest (Sussman and Leining 2002). The term "Regeneration"[10] as used here, includes the rehabilitation of degraded lands to secondary forests, while the category "Plantations" covers fast-growing commerical plantations. "Agroforestry" refers to all kinds of natural resource management systems integrating trees in farmland and rangeland. Projects falling under "Avoided deforestation" result in the conservation of forest which otherwise would have been deforestated.

Necessary data for the development of our cost curves is data on land availability potentials for each project type in hectares per year, carbon uptake factors in tCO2/ha and year and costs for possible forestry activities in $/tCO2.[11] By multiplying the land availability and carbon uptake factors one receives the carbon sequestration and storage potential for each project type and country.[12] However, the use of the word "potential" in the literature on carbon sequestration is often unclear and misleading. Cannel (2003) distinguishes between three different interpretations of the term potential, first the "theoretical potential capacity" (physical potential without consideration of practical, e.g. institutional or financial constraints), second the "realistic potential capacity" (physical potential with consideration of most constraints, but optimistic assumptions) and finally the "conservative, achievable capacity" (cautious prognosis, based on current trends, with few optimistic assumptions).

We base our land availability potentials on the data from Trexler and Haugen (1995), who added qualitative constraints[13] to their physical potential estimates in 52 tropical countries[14] to achieve more realistic land availability potentials for the above four project types. For our

---

[10]Regeneration under the Kyoto Protocol falls under the term "Reforestation", which for the first commitement period will be equal to "Afforestation", since it is limited to reforestation occurring on those lands that did not contain forest on 31 December 1989. Some Parties are pushing for a change the deforestation base year for the use of the definition in the CDM, though.

[11] Although we are often using the term carbon, the measurement unit used is always carbon dioxide (CO2). This makes sense, because in the frame of the IPCC, carbon dioxide (CO2) was chosen as the reference gas to for the Global Warming Potentials. However, many studies and models and especially the literature in the US employ carbon (C) as the main measurment unit.

[12] For obtaining potentials for the first commitment period, the annual values are multiplied by five.

[13] Variables considered are: existing land use and projected land-use change, population growth rates and urbanization trends, institutional and economic sources of deforestation, governmental and non-governmental forestry experience and infrastructures, current foresry-concession, agricultural and energy policies, land-tenure systems and land-titling requirements, political and economic structures and stability, infrastructural development plans and potential environmental, economic or social crisis facing the country.

[14] These 52 countries, plus China and Chile, which we included additionally, cover the most important countries for forestry projects under the CDM. Estimates for China are taken from Deying, Zhang and Shi 2000. For a country list see Appendix C

land availability potentials, we further consider that the implementation of LULUCF projects in the CDM will not start before 2005. Although CDM projects in the first commitment period may accumulate credits starting from 2000, basic implementation issues will not be solved by policy until the end of 2003, which makes implementation of projects before the year 2005 unlikely. In spite of these additional restrictions, the Trexler and Haugen data might be optimistic in the sense, that the estimates of regrowth project potentials do not exclude land having been deforested after December 1989.[15] This land is not eligible for LULUCF projects in the CDM because policy makers wanted to prevent deforestation occurring to clear land for afforestation projects under the CDM. According to Cannel´s categorization, we consider our land availability estimates to represent a conservative, achievable potential capacity, since it is considering most of the constraints and few optimistic assumptions.

Carbon uptake factors are estimated on the basis of the IPCC Special Report on Land use, Land-use change and Forestry (Cerri, Erda et al. 2001) weighted by the percentage of the forest area type in each region from the Global Forest Resources Assessment 2000 (FAO 2001). In our study, the amount of carbon from LULUCF projects on the market does not represent the real carbon uptake, but the one accounted for by the carbon accounting scheme used for forestry projects in the CDM. Due to the given uncertainties on this carbon accounting scheme[16], we considered two different sets of carbon uptake factors, one with low and one with high estimates, representing a conservative and a less conservative carbon accounting respectively. For plantations the carbon uptake factors vary between 5.5 and 22 tCO2/ha and year, for agroforestry between 1.8 and 4.2 tCO2/ha and for regeneration between 1.8 and 14.7 tCO2/ha, without considering belowground biomass and carbon storage in wood products.[17] The carbon emissions saved through avoided deforestation were calculated on the basis of data from Trexler and Haugen (1995) and the FRA 2000 (FAO 2001) on the standing biomass per hectare, assuming an immediate loss of 80% of the carbon stored in the biomass to the atmosphere. Additionally, 10% of carbon was subtracted from the biomass estimates. This is supposed to account for revegetation occurring in the baseline after forest clearing, which reduces the amount of carbon credits that can be generated by the project. On the basis of the described land availability estimates and carbon uptake factors, we calculate the

[15] The most probable base year for deforestation is 1989, as stated in Article 3 of the Kyoto Protocol. But, as mentioned earlier, the base year for deforestation might still change, since some countries are trying to push through a later base year in the negotiations.

[16] The carbon accounting schemes under discussion vary by the length of project lifetimes, crediting period as well as the way they consider impermanence of carbon sequestration.

[17] The exclusion of soil carbon can be justified by the uncertainties in soil carbon measurement as well as the high costs that will prevent most of the project developers from including soil carbon uptake in their carbon

potential carbon sequestration and storage for the different project types as summarised in Table 2. The potentials for each country are listed in Appendix B.

Table 2: Estimates of global potential for carbon uptake/storage in tCO2 per year

	Low uptake	**High uptake**
Plantations	3,936,000	6,316,700
Plantations and Regeneration	6,953,500	13,386,200
Plantations, Regeneration and Agroforestry	7,324,853	14,240,311
Only avoided deforestation	93,215,250	159,367,750
All LULUCF	100,540,103	173,608,061

As explained above, the cost estimates vary widely and are not comparable neither between activities nor between countries. Therefore, based on the literature review, we assume a certain order of net cost estimates with plantations being the cheapest of the regrowth project types. In this order of costs, agroforestry follows as the second cheapest project type. High implementation costs of these two projects are often assumed to be almost compensated by income generated through marketable benefits. Consequently, regeneration projects involve higher net costs, since less marketable benefits accrue and regrowth is slower.

The literature is divided over the costs of avoided deforestation. While many studies find it to be the most cost-efficient sinks project type (e.g. Newell and Stavins 2000) others studies argue that costs are higher than in other project types because opportunity costs of alternative use of the forested land have to be taken into account (e.g. Sathaye et al. 2001). For this study, two cost scenarios are constructed, one with avoided deforestation being the cheapest and the other one with it being the most expensive of the four project types.

Cost differences of regrowth projects between countries are calculated considering differences in GDP/capita and the carbon uptake factors[18], while costs for avoided deforestation are assumed to be determined by scarcity of arable land and the carbon uptake factors of the project activity in the respective country.[19] Our cost estimates range rather in the lower bound of the ones given in the literature, but do not include negative costs which are often found in bottom-up studies. The latter can be justified by the recent decision of the CDM Executive Board on the additionality of projects, which suggests that no-regret projects are unlikely to

---

accounting. For details on this see Ellis 2000. Procedures for the accounting of carbon sequestration in wood products are in development, but will probably not be applicable for the first commitment period.

[18] Cost ($/tCO2) = D * X/C, with D= default value of 0.0005 for plantations, 0.0002 for agroforestry and 0.0009 for regeneration, X= GDP/capita in PPP in current international 2000 US$, C= carbon uptake factor for respective project type.

be accepted.[20] The cost estimates used for the development of the marginal sequestration cost curves are presented in Appendix D. The bottom-up marginal sink cost curves are developed by ordering the cumulative carbon sequestration/storage potentials starting with the lowest cost option to the highest cost option. Then, steady marginal cost curves are obtained through an OLS regression .

Scenario analysis with CERT

For the analysis of the different LULUCF policy scenarios, we use the CERT model[21], which is a partial equilibrium model of the international GHG trading market. It is based on energy sector marginal abatement cost curves (MACs) and Business As Usual (BAU) data from the equilibrium models EPPA and GTEM.[22] The CERT model comprises 6 Annex B (USA, Japan, EU15, remaining OECD, Eastern Europe and the FSU) and 6 Non-Annex B regions (Energy Exporting Countries, China, India, Dynamic Asian Economies, Brazil, Rest of the world).[23] In our study, we use the GTEM MACs and BAU paths and only consider CO2. LULUCF options for Annex B Parties are included by deducting the Appendix Z sinks agreed upon at Marrakech from reduction requirement, thus lowering demand of emissions certificates by this amount. Transaction costs associated with the generation of emissions certificates are set to 0.55 $/tCO2 for CDM and 0.27 $/tCO2 for Annex B. In the standard model run, the United States participate to some small extent (reduction of 25% of Kyoto goal) in the international carbon market, which –despite the repudiation of Kyoto Protocol on the national level- seems likely when looking at the interest from the state and company level. But with the withdrawal of the US, even when assuming some partial participation in the carbon market, the biggest buyer of emissions permits leaves the market, which will dramatically reduce the demand for emissions permits. On a perfect market and with zero participation of the US, this would drive the price of emissions permits to zero. For the hot air suppliers Russia and the eastern european countries this would mean a loss of the revenue from the sale of their surplus emissions permits. Therefore, it is probable that the hot air supplying countries will exert market power to maximize their revenue from permit sales

[19] Cost ($/tCO2) = D * 1/(0.07*C*L) , with D = default value (0.14 for cheap and 6 for expensive avoided deforestation scenario), C= carbon uptake factor for respective project type, L = ha of arable land per capita in 1999.

[20] In equilibrium models, anyways, no negative costs (no-regrets) exist by assumption. Bottom-up cost curves, often including negative costs, would then have to be scaled up, so the cost curve starts at the interception of the x and y axis.

[21] CERT 1.3.1 is a publicly available spreadsheet model from Grütter Consulting, financed by the World Bank for the use in National Strategy Studies. The model can be downloaded at: www.ghgmarket.info.

[22] EPPA stands for MIT´s "Emissions Prediction and Policy Analysis model, and GTEM for "Global Trade and Environment Model" of ABARE Australia.

[23] For the countries contained in each group, see Appendix C

(Böhringer and Löschel 2001; Löschel and Zhang 2002). Consequently, we assume, Russia and eastern European countries to restrict supply of emissions permits by banking an amount of 722.3 MtCO2. This amounts to 55.6 % of the total hot air available.

Five policy scenarios reflecting different policy decisions on LULUCF in the CDM are constructed for our analysis. Table 3 summarises the underlying assumptions of each scenario. The five basic scenarios are determined by the variation in the forestry project types being eligible as LULUCF projects under the CDM. Then, for each basic scenario, the assumptions on the cost of avoided deforestation (if applicable), the two carbon uptake factors representing the conservativeness of the carbon accounting scheme and the consideration of the 1% cap for rCERs[24] are varied.

Table 3 : Policy scenarios

No.	Scenario	Activities included	Cost of avoided deforestation	Carbon uptake factor	1% cap
0	No Sinks*	--	--	--	--
All project types					
1A	Expensive AD	P, AF, R, AD	High	High	No
1B	Expensive AD	P, AF, R, AD	High	Low	No
1C	Expensive AD	P, AF, R, AD	High	High	Yes
1D	Expensive AD	P, AF, R, AD	High	Low	Yes
2A	Cheap AD	AD, P, AF, R	Low	High	No
2B	Cheap AD	AD, P, AF, R	Low	Low	No
2C	Cheap AD	AD, P, AF, R	Low	High	Yes
2D	Cheap AD	AD, P, AF, R	Low	Low	Yes
Without avoided deforestation					
3A	Regrowth all	P, AF, R	n.a.	High	**
3B	Regrowth all	P, AF, R	n.a	Low	**
4A	Regrowth I	P, R	n.a	High	**
4B	Regrowth I	P, R	n.a	Low	**
5A	Regrowth II	AF, R	n.a.	High	**
5B	Regrowth II	AF, R	n.a	Low	**

* CDM implementation rate 100 %, participation rate USA 25 %, transaction costs CDM 0.55 $/tCO2, transaction cost Annex B 0.27 $/tCO2, 722.3 MtCO2 hot air banked
* * 1% cap not binding,
n.a = not applicable
P : Plantations, AF: Agroforestry, R: Regeneration, AD: Avoided Deforestation

[24] CER stands for "Certified Emissions Reduction" and represents emissions permits created under the CDM. rCERs are the removal CERs, which we use here for all the emissions credits being created by LULUCF under the CDM.

The first two scenarios (1A-2D) include avoided deforestation as an eligible project activity, thus representing only a hypothetical policy development, since avoided deforestation has already been excluded from the CDM. In spite of this, we decided to include it in our analysis.[25] In the negotiation process, some were pointing out the multiple benefits of avoiding deforestation in the first place instead of having to incur time and effort for afforestion or reforestion, and others brought up the argument the inclusion of avoided deforestation would lead to a flooding of the carbon market and thus the crowding out of emissions reduction projects in the energy sector. By including avoided deforestation, we are able to examine if the latter concern is justified or not. Furthermore, this argument is based on the claim that avoided deforestation is relatively cheap as compared to any other sinks and non-sinks projects. To account for the mentioned uncertainties concerning the real costs for avoided deforestation, the respective scenarios look at two cases, one with avoided deforestation being the cheapest and one with it being the most expensive project type.

Additionally, we examine the sensitivity of our results to the conservativeness of the carbon accounting scheme by applying one high and one low set of carbon uptake factors. When considering the existing 1% cap on the use of rCERs, we assumed the maximum amount of available rCERs to be equal to the maximum allowed amount (479.1 million tCO2 or 95.8 million tCO2 per year) of the 1% cap.[26] This is only applicable to scenarios, where the carbon sequestration/storage potential is greater than the one defined by the 1 % cap, which is only valid for the scenarios including avoided deforestation.

The policy scenarios 3 to 5 encompass the regrowth policy options still under discussion. In the following, we are therefore referring to these scenarios as the “realistic policy scenarios”. They all exclude avoided deforestation and vary the eligibility of the three regrowth project types as well as the carbon uptake factors applied in the development of the cost curve. Scenarios 3A and 3B represent a policy decision on project eligibility based only on the quantitative definition of forest, afforestation and reforestation as used under Article 3, without the explicit exclusion of certain regrowth project types. The other two scenarios additionally exclude agroforestry projects (scenario 4) or plantations (scenario 5).[27]

---

[25] The importance of addressing deforestation is widely recognized, because it is contributing to around 20 % of the world wide CO2 emissions from human activities.

[26] Forner and Jotzo (2002) point out that a binding cap on demand might create a parallel market for rCER with different permit prices, because – contrary to our assumption here – an excess supply would drive rCER prices down.

[27] This has been proposed by some Parties in the recent negotiations process.

In the realistic policy options (scenarios 3 to 5), the potential of rCERs will not exceed 300.4 MtCO2 (scenario 3A), which represents 18.6 % of the total reduction requirements.[28] If policy should decide to exlude agroforestry practices from the CDM, the maximum amount of rCERs will be between 91.4 and 283.6 MtCO2, 5.7 % to 17.5 % of the total reduction requirements, respectively.

Table 4: Potential rCERs generated and market price for carbon for each scenario

All activities										
	Scenario	**0**	**1A**	**1B**	**1C**	**1D**	**2A**	**2B**	**2C**	**2D**
Potential forestry CERs	*Million tCO2*	--	3605.5	1996.3	479.1	479.1	3605.5	1996.3	479.1	479.1
	*% of reduction requirements**	--	223.0	123.5	29.6	29.6	223.0	123.5	29.6	29.6
Permit price	*$/tCO2*	**3.08**	**1.94**	**2.54**	**2.73**	**2.86**	**0.95**	**1.55**	**0.98**	**1.09**

Without avoided deforestation								
	Scenario	**0**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**
Potential forestry CERs	*Million tCO2*	--	300.4	158.8	283.6	91.4	155.0	66.9
	*% of reduction requirements**	--	18.6	9.8	17.5	5.7	9.6	4.1
Permit price	*$/tCO2*	**3.08**	**2.51**	**2.92**	**2.54**	**2.89**	**2.7**	**3.03**

* Assumed reduction of USA is included in calculation of reduction requirements, although it is not based on Kyoto target. Due to the hot air, FSU and Eastern Europe are not considered to have reduction requirements.

Should plantations be excluded (5A and 5B) a maximum of 66.9-155 MtCO2 CERs (4.1 % to 9.6 % of total reduction requirements) could be offered on the market. In the scenarios including avoided deforestation, the potential to create rCERs could reach 1996.3 to 3605.5 million tCO2 (123.5 % to 223 % of reduction requirements). At these levels, the 1% cap gets binding, which would limit the amount of rCERs bought on the market during the first commitment period to 479.1 million tCO2, representing almost 30 % of total reduction requirements.

The market price of emissions permits under our standard scenario “No Sinks” which does not include LULUCF in the CDM is 3.08 US$/tCO2. In the realistic policy scenarios 3A and 3B, the effect of including forestry sinks in the CDM will lead to a slighly reduced price of 2.51-2.92 $/tCO2 - depending on the carbon uptake factors considered - as compared to 3.08$/tCO2 in the standard scenario. When additionally excluding certain project types, as e.g. agroforestry in the 4A and 4B, the carbon price reaches 2.54 to 2.89 $/tCO2, and thus does not differ very much from scenario 3. The scenario with the exclusion of plantations, leads to a negligible reduction in the permit price of 0.05 to 0.38 $/tCO2 as compared to the

[28] The assumed reduction of USA is included in calculation of reduction requirements, although it is not based on Kyoto target. Therefore, the percentage values of the LULUCF potentials of purely Kyoto based reduction requirements will be slightly bigger. Due to the hot air, FSU and Eastern Europe are not considered to have reduction requirements.

"No Sinks" scenario. Therefore, we can conclude, that in any of the cases which are still open policy options (scenarios 3 to 5), the effect of the inclusion of forestry sinks in the CDM on the carbon price will be rather small, at least for the first commitment period. The withdrawal of the US from the Kyoto Protocol and the amount of hot air offered on the market remain the main factors which determine the market price, while the role of rCERs will be of minor importance

The price reduction of the most optimistic avoided deforestation scenario 2A leads to a permit price of 0.95 $/tCO2. When assuming avoided deforestation to be the most expensive of the four forest project types and considering the 1% cap (scenarios 1C and D) , the effect on the market price will be in the range of the ones without deforestation (price 2.73 – 2.86 $/tCO2). In the case of avoided deforestation as the cheapest activity and including the 1% cap (scenarios 2C and D), the price will be decreased to 0.98 – 1.09 $/tCO2. This suggests, that the inclusion of avoided deforestation has a potential to exert a significant effects on the carbon price if the assumption holds, that it will very cheap. Although this effect is considerable compared to the realistic scenarios 3 to 5, it is a relatively small effect as compared to the ones exerted by the US withdrawal and the hot air in the market. In the probable case of avoided deforestation being more expensive than widely thought, its inclusion would not have a significant effect on the carbon price, especially when considering the 1% cap (scenarios 2C and 2D).

In spite of this, one of the main concerns for the exclusion of avoided deforestation, namely its potential to crowd out the energy projects if it had been included as an eligible option in the Kyoto Protocol is confirmed by our analysis. As shown in Table 5, in the scenarios 1A and B as well as 2 A and B, all the reduction requirements not fulfilled by hot air or domestic abatement, can be fulfilled only by sinks CERs, thus crowding out the non-sinks projects.[29] While hot air covers around 30 % of reduction requirements, between 46.6 % and 60.9 % could have been fulfilled by rCERs if avoided deforestation would have been included and no cap on sinks credits would apply. Due to the cheap supply of hot air, the amount of the potential rCERs supply is considerably higher than the actually demanded ones in these scenarios, though (compare column 2 and 3 of Table 5). However, the 1% cap considered in the C and D scenarios reduces the amount of reduction requirements fulfilled by rCERs to around 30 % (479.1 MtCO2), thus leaving some space for non-sink CDM projects.[30]

---

[29] This holds only for our simplifying assumptions made for the construction of our marginal costs curves, for which all sinks projects are more cost-efficient than all energy projects.

[30] Considering that the calculation of the 1% cap includes the hot air countries, which will not be demanding rCERs, this estimate is probably too high.

Table 5 : Role of LULUCF in the CDM

	Million tCO2	% of reduction requirements*					
Scenario	Potential rCERs (2008-2012)	Potential rCER (2008-2012)	Actual rCERs sold	Others (non-sinks CERs)	Hot air**	Domestic abatement ***	1 % cap binding
0	0	0	0	43.0	30.2	26.8	--
All activities							
1A	3,605.5	223.0	51.4	0.00	30.2	18.4	--
1B	1,996.3	123.5	46.6	0.00	30.2	23.2	--.
1C	479.1	29.6	29.6	15.7	30.2	24.5	Yes
1D	479.1	29.6	29.6	14.8	30.2	25.4	Yes
2A	3,605.5	223.0	60.9	0.00	30.2	8.9	--
2B	1,996.3	123.5	54.8	0.00	30.2	15.0	--
2C	479.1	29.6	29.6	31.1	30.2	9.1	Yes
2D	479.1	29.6	29.6	29.8	30.2	10.4	Yes
Without avoided deforestation							
3A	300.4	18.6	18.6	28.3	30.2	22.9	No
3B	158.8	9.8	9.8	34.4	30.2	25.6	No
4A	283.6	17.5	17.5	29.4	30.2	22.9	No
4B	91.4	5.7	5.7	38.5	30.2	25.6	No
5A	155.0	9.6	9.6	35.9	30.2	24.3	No
5B	66.9	4.1	4.1	39.2	30.2	26.5	No

* USA included, although its reduction is not based on Kyoto target.
** Based on our assumptions of banking 55.6 % of available hot air by Russia and Eastern Europe
*** includes JI
-- = 1 % cap not considered/applicable

In the realistic policy scenarios, the percentage of reduction requirements covered by rCERs is considerably lower and reaches values between 4.1 % and 18.6 %. In these scenarios, Annex B countries meet their reduction requirements to at least 28.3 % with non-sink CERs and abate around one forth domestically. Therefore, in the realistic scenarios rCERs play some, but no dominant role in the carbon market of the first commitment period. Non-sinks projects and domestic abatement will still have a considerably higher share in the fulfillment of reduction requirements. When worrying about the environmental credibility of the climate regime, hot air is certainly the bigger issue. It has to be emphasised though, that this is only true because of the policy restrictions put opon LULUCF in the CDM. When looking at the policy unrestricted LULUCF scenarios including avoided deforestation (scenarios 1A, 1B and 2A, 2B) the role of LULUCF could outweight the one of hot air by far.

Distributional aspects

The CDM is supposed to provide the opportunity for Non-Annex B countries to participate in the first commitment period of the climate regime by attracting sustainble climate projects.

For the Annex B countries, the CDM broadens the chances to reduce emissions where they are cheapest and offers the opportunity to decrease compliance costs. Therefore, policy decisions on forestry sinks always have implications for the distribution of costs and benefits between different countries. As shown in Table 6, Annex B countries incur a total of 2353 million $ to fulfill their Kyoto obligations in the scenario without forestry in the CDM, with Eastern Europe and FSU making a profit from hot air sales of 417 million $ and 2136 million $, respectively.

For Non-Annex B countries, the CDM without forestry projects gives the opportunity to gain 708.6 million $, with China getting the biggest (506.5 million $) and Brazil the smallest slice (4.9 million $) of the cake.

In general, the more and the cheaper forestry offsets are offered on the market, the more FSU and Eastern Europe lose their benefits from hot air trading. In spite of this, Annex B as a whole is gaining from the introduction of LULUCF in the CDM, because the overall compliance costs decrease. With 62 %, the maximum potential reduction in compliance cost is reached in scenario 2A. In the scenarios considering the 1 % cap, the decrease in compliance cost reaches a maximum of 8.8 % in the case of expensive avoided deforestation (scenario 1C) and 61.4 % in the case of cheap avoided deforestation (scenario 2C). Thus, in the case of cheap avoided deforestation, the reduction in compliance cost for Annex B Parties will be considerable, even when considering the 1 % cap.

For the realistic policy scenarios, the reduction in total compliance costs due to the introduction of LULUCF in the CDM range between 1.3 % in scenario 5B and 14.2 % in scenario 1A. The exclusion of avoided deforestation limits the redistribution of benefits from Non-Annex B towards Annex B and thus maintains some of Non-Annex B profits from the standard scenario. All Non-annex B countries except China export a greater or at least the same amount of CERs in all the scenarios.[31] Although the amount of CERs exported from Non-Annex B rises, the Non-Annex B Parties still lose as a whole compared to the standard scenario because this quantity effect is overcompensated by the price effect induced by the shrinking permit price. However, this loss is smaller the more expensive or the more restricted the sinks options are, meaning, the the more expensive or the less sinks CERs can be created. Again compared to the case of a purely energy based CDM, all forestry sinks scenarios results in a redistribtion of CDM potentials from all other Non-Annex B countries towards Latin America and Africa, the two regions mainly represented in the ROW group. This is due to the

[31] Except in two cases (scenario 1B and 2D), in which also India´s exports are reduced. For the export of permits see Appendix E.

relatively low non-sink CDM and the high forestry CDM potential of most Latin American and African countries.

Table 6 : Distribution of benefits and losses due to the inclusion of LULUCF in the CDM

Scenario	**USA**	**Japan**	**Europe**	**Other OECD**	**Eastern Europe**	**FSU**	**Total Annex B**
0	costs in million $						
	1552	463	1927	963	-417	-2136	2353
Annex B: Profits (- = Losses) compared to scenario 0 in %							
All project types							
1A	36.8	37.1	37.1	36.8	-43.9	-42.7	**30.4**
1B	17.3	17.5	17.4	17.2	-21.6	-20.8	**13.5**
1C	11.5	11.7	11.6	11.4	-14.4	-14.0	**8.8**
1D	7.3	7.3	7.3	7.3	-9.4	-8.9	**5.5**
2A	68.4	68.7	68.7	68.4	-75.5	-74.3	**62.0**
2B	49.2	49.5	49.5	49.2	-57.1	-55.8	**42.2**
2C	67.8	68.0	68.1	67.8	-74.8	-73.8	**61.4**
2D	64.0	64.4	64.3	64.1	-71.5	-70.3	**57.3**
Without Avoided Deforestation							
3A	18.2	18.4	19.7	18.2	-22.5	-21.8	**14.2**
3B	5.9	5.8	5.9	5.8	-7.4	-7.2	**4.4**
4A	17.9	18.1	18.1	17.9	-22.3	-21.5	**14.0**
4B	6.0	6.0	6.1	6.0	-7.7	-7.4	**4.5**
5A	11.9	12.1	12.0	11.9	-15.1	-14.5	**9.2**
5B	1.8	1.9	1.8	1.8	-2.4	-2.2	**1.3**
Non-Annex B							
Scenario	**EEX**	**China**	**India**	**DAE**	**Brazil**	**ROW**	**Total Non-Annex B**
0	costs in million $						
	56,1	506,5	56,4	25	4,9	59,6	**708,6**
Profits (- = Losses) compared to scenario 0 in %							
All project types							
1A	-26.4	-68.0	-18.6	-14.8	1932.7	61.1	**-34.2**
1B	-4.8	-36.5	-27.1	-4.0	1449.0	51.3	**-14.4**
1C	-6.8	-22.4	11.7	-0.8	483.7	29.9	**-9.8**
1D	-1.8	-15.5	-8.5	-1.2	612.2	22.5	**-5.8**
2A	-53.5	-96.9	-51.6	-65.2	340.8	41.6	**-74.1**
2B	0.0	-83.3	-43.1	-32.0	718.4	119.3	**-49.1**
2C	-61.1	-97.0	-57.6	-52.0	987.8	14.3	**-72.6**
2D	-55.6	-95.1	-85.6	-56.4	1804.1	11.1	**-67.8**
Without Avoided Deforestation							
3A	-7.1	-30.4	44.7	-16.4	226.5	30.5	**-15.2**
3B	1.4	-10.9	25.7	-4.8	95.9	3.9	**-4.8**
4A	-4.6	-31.4	49.1	-13.2	261.2	31.5	**-14.9**
4B	3.0	-11.8	29.8	-3.6	112.2	3.4	**-4.9**
5A	29.9	-24.0	-12.2	-7.6	216.3	52.5	**-10.2**
5B	-2.9	-3.9	0.4	2.8	75.5	12.9	**-1.3**

In the realistic policy scnearios, additionally India is joining the group which is profiting from an introduction of LULUCF in the CDM, especially in the cases where plantations are not excluded project activities. In spite of China´s big LULUCF potential, it encounters the biggest loss of all countries due to this redistribution. The explanation for this is, that its huge CDM potential from substitution of coal based electricity generation has still greater dimensions than its forestry potential.

This redistribution pattern, can explain most of the country positions in the climate negotiations concerning the introduction of LULUCF in the CDM. It might be the reason for the division of Non-Annex B countries represented in the G77/China group over the question whether to include LULUCF in the CDM at all, with most of the Latin American countries having been in favour and most of the Asian countries having been against them (Anderson, Grant et al. 2001). Africa was in favor of LULUCF in the CDM, because its potential to participate in a purely energy based CDM is relatively small. Especially China, but also India have been the greatest opponents of the inclusion of LULUCF in the CDM. While the position of China derives from the big losses from any kind of introduction of LULULCF in the CDM, the situation of India is more complex. In our analysis, India loses in the most of the scenarios including avoided deforestation, but gains in most of the realistic policy scenarios.[32] Russia was opposing LULUCF in the CDM, but at the same time, it managed to negotiate a maximum amount of LULUCF for Appendix Z under Art. 3.4 in the climate negotiations (Michaelowa, Greiner et al. 2001). This, at first view, contradicting position is explicable, because on the one hand, Russia has a considerable domestic LULUCF potential which can be used to further increase amount of Russian hot air. On the other hand, Russia encounters a devaluation of its hot air through the introduction of LULUCF in the CDM. Astonishing, from an economic point of view, is that Brazil has been rejecting avoided deforestation in the CDM. In all our scenarios with avoided deforestation, Brazil profits like no other country from its introduction into the CDM. This position and the active role Brazil took in the negotiations to prevent avoided deforestation from being included may be explained by non-economic reasons, like the strong position of Brazil in the G77 group as well as sovereignty concerns about the amount of foreign investment in the Amazon region (Fearnside 2001; Michaelowa, Greiner et al. 2001).

[32] The contrary can be found in scenario 1C and 5A. Also for EEX and DAE, the direction of the results is not the same for all scenarios, which can be explained by the interaction of the market price, costs and rCERs potential of the respective country.

Uncertainties and limits of the analysis

The basis of our analysis is the construction of the LULUCF supply curves, which are subject to uncertainties about the potentials and costs they are based on. Especially the costs estimates are contributing to this uncertainty because they are often neglecting certain elements influencing the costs of forestry projects, like land costs, monitoring costs or marketable benefits. Furthermore, the techniques employed for the estimation of carbon sequestration costs mostly do not consider transaction costs which have to be incurred before and during the project activities. However, transaction cost can make up a relatively big share of project costs ranging from search cost for finding appropriate project land, costs for negotiating contracts up to investments in programs and institutions giving incentives to farmers to plant trees on non-forested lands. (Kooten van, Shaikh et al. 2002). An additional optimistic element to our already low cost estimates is that the consideration of transaction costs in the model probably does not cover the full amount of transaction costs related to LULUCF projects. Therefore, our cost estimates will result in rather optimistic cost curves.[33] When taking this into account, the inclusion of carbon sequestration projects in the CDM will probably have an even smaller effect on the carbon market of the first commitment period than it is already suggested by our study. Additionally, the calculation of demand for emissions permits in the CERT model does not consider political preferences toward non-CDM and non-sinks permits. The European Union, with the exception of some individual countries[34], rejects rCERs for the fulfillment of its own compliance and might include barriers for the introduction of rCERs in the European Emissions Trading Scheme (Commission of the European Communities 2003).[35] The remaining buyer countries Canada, Japan, New Zealand, Norway and Switzerland may put emphasis on domestic sinks under Art. 3 of the Kyoto Protocol. Therefore, the countries actually demanding rCERs will be limited to Japan, Austria, Denmark, The Netherlands and Canada (Bernoux, Eschenbrenner et al. 2002). Consequently, due to political preferences the demand for rCERs might be smaller than assumed by the model, which additionally decreases the role LULUCF in the CDM might play in the first commitment period. On the other hand, the total demand for emissions permits in the CERT model might be underestimated, because it is assumed that Annex B countries will use all of the emissions permits they own or buy to fulfill their obligations in

[33] Another important aspect to address under our assumptions of very low costs is, that transaction costs will make up the biggest part of costs and will in some cases be almost as high as the permit price. Therefore, transaction costs become a really important subject, because they could get the decisive factor for which projects will be implemented in which countries. Though, little is known on transaction costs of CDM projects still.

[34] The Netherlands, Austria and Denmark

[35] This position might change though, if the EU should run into problems fulfilling its reduction requirement with domestic action or non-sinks emissions permits.

the first commitment period. The CERT model is a static partial equilibrium model considering the first commitment period only and is not able to account for banking of emissions permits. From our analysis above we know, that the permit price in the first commitment period will probably be very low. One strategy Annex B countries might follow is the banking of (bankable) emissions permit while using a greater amount of sinks CERs for complying with their first commitment period target, since all other emissions permits are bankable[36], while rCERs are not. This way, they could take advantage of the relatively cheap emissions reductions in the first commitment period and carry some of them over to the second commitment period. Such behavior might lead to some increase in permits demand. However, this will not change our results concerning the importance of sinks CERS on the market substantially, since the potential of the eligible forestry projects (scenario 3 to 5) is the limiting factor for the forestry projects in the CDM.

Conclusion

The rules and modalities for the implementation of LULUCF projects in the CDM are one of the last open issues of the Kyoto Protocol, on which final decisions are supposed to be taken at COP 9 in December 2003. We analyse the implications of different policy decisions concerning this subject on the supply of tradable emissions permits, the carbon market price and the distribution of costs and benefits between countries and regions.

The literature on forestry carbon sequestration does not offer a guideline on costs and potentials of forestry projects, since the range of estimates is huge and no factors influencing the costs of projects can be clearly identified. Furthermore, studies on carbon sequestration cost curves are not comparable due to different methods, terms and assumptions used. Therefore, we construct our own marginal cost curves for Non-Annex B Parties, representing the forestry carbon sequestration and storage options in the CDM. Contrary to most of the other studies on carbon sequestration cost curves, we differentiate four different forestry project types which makes it possible analyse policy decisions on LULUCF project eligibility in the CDM. For the scenario analysis, we implement our LULUCF cost curves into the carbon market model CERT.

The compliance cost of Annex B countries decline, the broader the eligibility of projects for the introduction of LULUCF in the CDM is defined. Avoided deforestation, which has already been excluded as an eligible project type, has the greatest potential to lower the market price (from 3.08 $/tCO2 to maximum 0.95 $/tCO2) and thus, the compliance costs of Annex B Parties (at most 62 % cost reduction). If one considers the 1% cap on the use of

[36] With the exeption of RMUs, which are the LULUCF credits created in the frame of Joint Implementation.

rCERs, then this price reduction turns out to be smaller. In general, the effects of an inclusion of avoided deforestation in the CDM on the market price are relatively small when comparing them to the implications of hot air or of the withdrawal of the US from the Kyoto Protocol.

When looking at the LULUCF policy options which are still under discussion for the CDM, our results suggest a rather small reduction of the permit price between 0.05 and 0.57 $/tCO2, which is almost negligible. In the most optimistic of our realistic forestry scenarios, 18.6 % of the permit demand will be covered by forestry CERs. With around 30 % of the reduction requirements being covered by hot air, this leaves a space of around 28.3 % to non-sinks CDM projects and 22.9 % to domestic abatement. In the most restrictive sink scenario 5B, the percentage of reduction requirement being met by forestry CERs is considerably lower and reaches only 4.1 %. This leaves a space of around 39 % of the reduction requirements to be covered by non-sinks projects. Based on these results, LULUCF in the CDM will play some, but no dominant role. When pointing to problems concerning the environmental credibility of the Kyoto Protocol, not LULUCF in the CDM but hot air is certainly the bigger issue. However, the latter is only true because the use of LULUCF in the CDM is limited by policy. For the hypothetical policy unrestricted cases, energy projects in the CDM are crowded out by LULUCF projects and the amount of rCERs traded on the market is considerably higher than the one of hot air.

Three lines of redistribution have to be looked at when analysing the distributional aspects of an introduction of LULUCF in the CDM. One is between Annex B and non-Annex B countries, one inside the group of Annex B and one inside the group of non-Annex B Parties. With the option of creation of rCERs, non-Annex B Parties as a whole lose, while Annex B countries win due to the reduction in permit price. This leads to a redistribution of benefits to Annex B and away from Non-Annex B countries. In the realistic scenarios (3 to 5), this gain is reflected by a reduction in compliance costs between 1.3 % and 14.2 %. The potential for reduction in compliance costs due to LULUCF might be as high as 62 %, which is however not realistic because avoided deforestation has already been excluded as an eligible project activity for the first commitment period. The losers of an introduction of LULUCF in the CDM inside the Annex B group are the FSU and Eastern Europe, because the decreased permit price leads to a devaluation of their hot air. Inside the group of Non-Annex B, Latin America and Africa increases profits while China loses its dominant share. To a great extent, this pattern of redistribution between Parties is able to explain the position they have taken towards LULUCF in the CDM in the climate negotiations.

Our results suggest that the role CDM forestry sinks in the first commitment period might play will to be rather limited. This is reinforced by the consideration of uncertainties in the cost estimates used for the construction of the marginal cost curves. Several aspects lead to the conclusion, that our cost curves are rather optimistic upper bound estimates of the forestry CDM potential and, thus lead to an overestimation of the already suggested small role of forestry CERs.

This rather small role of LULUCF in the first commitment period does not say anything about the role LULUCF might play after the year 2012. However, the LULUCF potentials, especially for avoided deforestation, suggest that they might turn into an important element in the negotiation of reduction targets of future commitment periods. Furthermore, the practical experience, the progress in reducing uncertainties in carbon measurement and the credibility of forestry projects implemented in the first commitment period will be decisive for decisions to be taken on the inclusion of LULUCF beyond 2012.

Appendix A

Definitions for Art. 3.3 and 3.4 (FCCC/CP/2001/13/Add.1)

Forest: is a minimum area of land of 0.05 to 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 percent with trees with the potential to reach a minimum height of 2-5 meters at maturity in situ.

Afforestation: is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources

Reforestation: is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestatioon occurring on those lands what did not contain forest on 31 December 1989.

Appendix B: LULUCF potentials of considered Non-Annex B countries – first commitment period (in tCO2)

Project type	**Plantations**		**Avoided deforestation**		**Agroforestry**		**Regeneration**		**Total carbon**	
Uptake factors	low	high	low	high	low	high	low	high	low	high
EEX	**9,900,000**	**14,850,000**	**247,500,000**	**392,333,333**	**48,125**	**110,689**	**1,191,667**	**2,383,333**	**258,639,792**	**409,677,356**
Indonesia	9,166,667	13,750,000	165,000,000	297,000,000	45,833	105,417	275,000	550,000	174,487,500	311,405,417
Venezuela	733,333	1,100,000	82,500,000	95,333,333	2,292	5,273	916,667	1,833,333	84,152,292	98,271,939
CHN	**46,530,000**	**76,774,500**	**10,807,500**	**16,211,250**	**4,766,667**	**10,963,333**	**10,500,417**	**31,501,250**	**72,604,583**	**135,450,333**
IND	**18,333**	**27,500**	**24,750,000**	**41,250,000**	**22,917**	**52,708**	**916,667**	**1,833,333**	**25,707,917**	**43,163,542**
DAE	**1,549,167**	**2,328,333**	**49,500,000**	**86,625,000**	**128,333**	**295,167**	**2,429,167**	**4,904,167**	**53,606,667**	**94,152,667**
Malaysia	55,000	82,500	0	0	9,167	21,083	550,000	1,100,000	614,167	1,203,583
Philippines	1,466,667	2,200,000	30,937,500	55,687,500	114,583	263,542	1,833,333	3,666,667	34,352,083	61,817,708
Thailand	27,500	45,833	18,562,500	30,937,500	4,583	10,542	45,833	137,500	18,640,417	31,131,375
BRA	**9,166,667**	**13,750,000**	**464,062,500**	**773,437,500**	**45,833**	**105,417**	**13,750,000**	**27,500,000**	**487,025,000**	**814,792,917**
ROW	**4,995,833**	**8,075,833**	**912,326,250**	**1,611,885,000**	**1,796,256**	**4,131,384**	**26,532,917**	**61,485,417**	**945,651,256**	**1,685,577,634**
Bolivia	27,500	45,833	18,562,500	30,937,500	4,583	10,542	45,833	137,500	18,640,417	31,131,375
Chile	275,000	550,000	0	0	1,833	4,217	18,333	55,000	295,167	609,217
Colombia	183,333	275,000	222,750,000	371,250,000	45,833	105,417	1,833,333	3,666,667	224,812,500	375,297,083
Costa Rica	110,000	165,000	6,187,500	12,375,000	22,917	52,708	183,333	366,667	6,503,750	12,959,375
Ecuador	82,500	137,500	148,500,000	247,500,000	45,833	105,417	458,333	1,375,000	149,086,667	249,117,917
Guatemala	73,333	110,000	16,706,250	27,843,750	45,833	105,417	458,333	916,667	17,283,750	28,975,833
Guyana	0	0	0	0	0	0	183,333	366,667	183,333	366,667
Honduras	18,333	27,500	24,750,000	41,250,000	22,917	52,708	916,667	1,833,333	25,707,917	43,163,542
Mexico	550,000	825,000	57,750,000	123,750,000	458,333	1,054,167	9,166,667	18,333,333	67,925,000	143,962,500
Nicaragua	55,000	82,500	0	0	9,167	21,083	550,000	1,100,000	614,167	1,203,583
Panama	18,333	27,500	33,000,000	49,500,000	18,333	42,167	183,333	366,667	33,220,000	49,936,333
Paraguay	82,500	137,500	23,100,000	49,500,000	32,083	73,792	183,333	550,000	23,397,917	50,261,292
Peru	137,500	229,167	0	0	22,917	52,708	916,667	2,750,000	1,077,083	3,031,875
Suriname	0	0	0	0	48	106	146,667	293,333	146,714	293,440
ROW, Latin America	*1,613,333*	*2,612,500*	*551,306,250*	*953,906,250*	*730,631*	*1,680,448*	*15,244,167*	*32,110,833*	*568,894,381*	*990,310,031*
Bangladesh	366,667	550,000	0	0	114,583	263,542	0	0	481,250	813,542
Myanmar	366,667	550,000	0	0	22,917	52,708	2,200,000	4,400,000	2,589,583	5,002,708
Lao	275,000	412,500	0	0	0	0	458,333	916,667	733,333	1,329,167

Project type	**Plantations**		**Avoided deforestation**		**Agroforestry**		**Regeneration**		**Total carbon**	
Uptake factors	low	high	low	high	low	high	low	high	low	high
Papua New Guinea	36,667	55,000	0	0	9,167	21,083	1,833,333	3,666,667	1,879,167	3,742,750
Vietnam	275,000	412,500	0	0	0	0	458,333	916,667	733,333	1,329,167
ROW, Asia	*1,320,000*	*1,980,000*	*0*	*0*	*146,667*	*337,333*	*4,950,000*	*9,900,000*	*6,416,667*	*12,217,333*
Angola	137,500	229,167	0	0	4,583	10,542	183,333	550,000	325,417	789,708
Benin	27,500	45,833	7,218,750	15,468,750	11,458	26,356	183,333	550,000	7,441,042	16,090,939
Botswana	0	0	3,465,000	7,425,000	9,167	21,083	22,917	68,750	3,497,083	7,514,833
Burkina Faso	68,750	114,583	4,331,250	6,187,500	45,833	105,417	458,333	1,375,000	4,904,167	7,782,500
Cameroon	27,500	45,833	41,250,000	74,250,000	114,583	263,542	275,000	825,000	41,667,083	75,384,375
Central African R.	13,750	22,917	11,343,750	20,418,750	34,375	79,064	18,333	55,000	11,410,208	20,575,731
Chad	13,750	22,917	4,620,000	6,600,000	13,750	31,625	18,333	55,000	4,665,833	6,709,542
Congo	137,500	229,167	0	0	4,583	10,542	183,333	550,000	325,417	789,708
Congo D. Rep	68,750	114,583	0	0	45,833	105,417	916,667	2,750,000	1,031,250	2,970,000
Cote d´Ivoire	137,500	229,167	103,125,000	185,625,000	45,833	105,417	458,333	1,375,000	103,766,667	187,334,583
Ethiopia	412,500	687,500	618,750	1,031,250	91,667	210,833	183,333	550,000	1,306,250	2,479,583
Gabon	55,000	91,667	0	0	0	0	0	0	55,000	91,667
Ghana	55,000	91,667	0	0	11,458	26,356	91,667	275,000	158,125	393,023
Guinea	68,750	114,583	10,395,000	22,275,000	22,917	52,708	183,333	550,000	10,670,000	22,992,292
Kenya	137,500	229,167	0	0	68,750	158,125	0	0	206,250	387,292
Madagascar	27,500	45,833	24,750,000	41,250,000	2,292	5,273	91,667	275,000	24,871,458	41,576,106
Mali	13,750	22,917	0	0	9,167	21,083	45,833	137,500	68,750	181,500
Mozambique	55,000	91,667	0	0	11,458	26,356	550,000	1,650,000	616,458	1,768,023
Niger	27,500	45,833	3,465,000	4,950,000	22,917	52,708	45,833	137,500	3,561,250	5,186,042
Nigeria	412,500	687,500	24,750,000	41,250,000	68,750	158,125	91,667	275,000	25,322,917	42,370,625
Senegal	27,500	45,833	11,550,000	24,750,000	91,667	210,833	229,167	687,500	11,898,333	25,694,167
Somalia	27,500	45,833	2,887,500	6,187,500	22,917	52,708	137,500	412,500	3,075,417	6,698,542
Sudan	137,500	229,167	46,200,000	99,000,000	22,917	52,708	916,667	2,750,000	47,277,083	102,031,875
Tanzania	82,500	137,500	33,000,000	66,000,000	68,750	158,125	916,667	2,750,000	34,067,917	69,045,625
Uganda	82,500	137,500	14,850,000	24,750,000	45,833	105,417	91,667	275,000	15,070,000	25,267,917
Zambia	27,500	45,833	6,600,000	6,893,333	4,583	10,542	45,833	137,500	6,677,917	7,087,208
Zimbabwe	55,000	91,667	6,600,000	3,666,667	22,917	52,708	458,333	1,375,000	7,136,250	5,186,042
Africa	*2,337,500*	*3,895,833*	*361,020,000*	*657,978,750*	*918,958*	*2,113,606*	*6,797,083*	*20,391,250*	*371,073,542*	*684,379,439*

Appendix C Country groupings of the CERT model

Annex B Parties

GTEM name	Countries in GTEM
USA	United States of America
JPN	Japan
EEC	15 EU members: includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK
OOE	Rest OECD; Includes: Australia, Canada, Iceland, New Zealand, Norway, Switzerland
EET	Economies in Transition of Eastern Europe; Includes: Bulgaria, Croatia, Czech Rep., Hungary, Poland, Romania, Slovakia, Slovenia
FSU	Soviet Union; Includes: Estonia, Latvia, Lithuania, Russia, Ukraine

Non-Annex B Parties

	GTEM	LULUCF cost curves
EEX	Energy Exporting Countries; Includes: Algeria, Bahrain, Botswana, Swaziland, Egypt, Indonesia, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Lesotho, Libya, Namibia, Oman, Qatar, Saudi Arabia, Syria, South Africa, Tunisia, United Arab Emirates, Venezuela, Yemen.	Indonesia, Venezuela
CHN	Includes China and Chinese Taipei	China
IND	India	India
DAE	Dynamic Asian Economies; Includes: Philippines, Malaysia, Singapore, South Korea, Thailand	Malaysia, Philippines, Thailand
BRA	Brazil	Brazil
ROW	Rest of the World (all other Non-Annex B countries)	Bolivia, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, , Paraguay, Peru, Suriname, Bangladesh, Mayanmar, Lao, Papua New Guinea, Vietnam, Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, Congo D. Rep., Cote d´Ivoire, Ethiopia, Gabon, Ghana, Guinea, Kenya, Madagascar, Mali, Mozambique, Niger, Senegal, Somalia, Sudan, Tanzania, Uganda, Zambia, Zimbabwe

Appendix D: Average cost estimates in $/tCO2 for each project type and country/region

Costs ($/tCO2)	EEX*	China	India	DAE*	Brazil	ROW*
Low uptake factors						
Plantations	0.11	0.27	0.08	0.19	0.26	0.15
Agroforestry	0.35	0.43	0.26	0.62	0.83	0.34
Regeneration	0.40	1.95	0.29	0.70	0.94	0.73
Avoided deforestation (cheap)	0.05	0.12	0.07	0.06	0.02	0.07
Avoided deforestation (expensive)	2.39	5.24	3.20	2.54	1.10	3.08
high uptake factors						
Plantations	0.07	0.16	0.05	0.13	0.17	0.09
Agroforestry	0.15	0.19	0.11	0.27	0.36	0.15
Regeneration	0.20	0.65	0.14	0.35	0.47	0.28
Avoided deforestation (cheap)	0.03	0.08	0.02	0.03	0.02	0.04
Avoided deforestation (expensive)	1.38	3.50	0.92	1.37	0.66	1.79

*For the country grouping used, see Appendix C. The potentials for which these average costs are estimated are shown in Appendix B.

Appendix E: CER sales of Non-Annex B countries (million tCO2)

Scenario	EEX	China	India	DAE	Brazil	ROW	Total Non-Annex B
0	44.7	391.2	44.7	20.2	4.0	47.3	**551.8**
All project activities							
1A	61.6	236.1	68.6	31.9	148.9	143.4	**690.1**
1B	54.6	320.5	41.8	24.6	78.5	92.4	**612.3**
1C	48.8	357.1	59.0	23.5	27.1	72.2	**587.8**
1D	48.4	365.6	45.1	21.6	31.2	64.2	**576.0**
2A	136.8	82.1	143.0	45.5	112.9	442.2	**962.5**
2B	116.6	173.1	66.7	35.6	83.6	272.1	**1322.6**
2C	108.9	75.9	119.5	60.1	266.2	340.6	**970.6**
2D	97.2	95.0	31.5	42.2	364.1	258.1	**888.1**
Without avoided deforestation							
3A	54.3	357.5	85.1	21.6	16.9	81.0	**616.0**
3B	49.1	378.0	61.2	20.5	8.4	53.2	**570.2**
4A	55.4	350.5	87.3	22.4	18.3	81.0	**614.9**
4B	49.9	374.7	63.4	20.9	9.2	53.2	**570.9**
5A	68.9	352.0	46.6	21.6	14.7	85.8	**589.6**
5B	44.4	385.4	46.2	20.9	7.0	54.6	**558.8**

References

Adams, D., R. Alig, et al. (1999). "Minimum Cost Strategies for Sequestering Carbon in Forests." Land Economics **75**(3): 360-374.

Adams, R., D. Adams, et al. (1993). "Sequestering Carbon on Agricultural Land: Social Cost and Impacts on Timber Markets." Contemporary Policy Issues **XI**(1): 76-87.

Alig, R., D. Adams, et al. (1997). "Assessing Effects of Mitigation Strategies for Global Climate Change with an Intertemporal Model of the U.S. Forest and Agriculture." Environmental and Resource Economics **9**: 259-274.

Anderson, D., R. Grant, et al. (2001). Taking Credit - Canada and the role of sinks in international climate negotiations. Vancouver, David Suzuki Foundation**:** 87.

Barson, M. and R. Gifford (1990). Carbon dioxide sinks: the potential role of tree planting in Australia. Greenhouse and Energy. D. Swaine. Australia, CSIRO**:** 433-443.

Benitez Ponce, P. (2003). The Economics of including Carbon Sinks in Climate Change Policy - Evaluating the carbon supply-curve though afforestation in Latin America. Amsterdam, ECN.

Bernoux, M., V. Eschenbrenner, et al. (2002). "LULUCF-based CDM: too much ado for... a small carbon market." Climate Policy **2**(2002): 379-385.

Böhringer, C. and A. Löschel (2001). Market Power in International Emissions Trading: The Impacts of U.S. Withdrawal from the Kyoto Protocol. Mannheim, Germany, Centre for European Economic Research (ZEW).

Burniaux, J.-M. (2002). Incorporating carbon sequestration into CGE models: a prototype GTAP model with land uses.

Callaway, J. and B. A. McCarl (1996). "The Economic Consequences of Substituting Carbon Payments for Crop Subsidies in U.S. Agriculture." Environmental and Resource Economics **7**: 15-43.

Cannel, M. (2003). "Carbon sequestration and biomass energy offset: theoretical, potential and achievable capacities globally, in Europe and the UK." Biomass and Bioenergy **24**(2003): 97-116.

Cerri, C., L. Erda, et al. (2001). Additional Human-Induced Activities-Article 3.4. Land Use, Land-Use Change and Foresty - IPCC Special Report. R. Watson, I. R. Noble, B. Bolinet al. Cambridge, Cambridge University Press**:** 181-282.

Commission of the European Communities (2003). Proposal for a Directive of the European Parliament and of the Council amending the Directive establishing a scheme for greenhouse gas emission allowance trading with the Community, in respect of the Kyoto Protocol´s project mechanisms. COM(2003) 403 final. Brussels.

Deying, X., X. Zhang, et al. (2001). "Mitigation Potential for Carbon Sequestration through Forestry Activities in Southern and Eastern China." Mitigation and Adaptation Strategies for Global Change **6**: 213-232.

Dixon, Schroeder, et al. (1991). Assessment of Promising Forest Management Practices and Techniques for Enhancing the Conservation and Sequestration of Atmospheric Carbon and their Cost at Site Level. Washington D.C., EPA.

Dixon, R., J. K. Winjum, et al. (1994). "Integrated Land-Use Systems: Assessment of Promising Agroforestry and Alternative Land-Use Practices to Enhance Carbon Conservation and Sequestration." Climatic Change **30**: 1-23.

Dudek, D. and A. LeBlanc (1990). "Offsetting New CO2 Emissions: A Rational First Greenhouse Policy Step." Contemporary Policy Issues **8**: 29-42.

Ellis, J. (2002). Developing Monitoring Guidance for Greenhouse Gas Mitigation Projects, OECD and IEA.

FAO (2001). Global Forest Resources Assessment 2000. Rome, FAO.

Fearnside, P. M. (1995). "Global Warming Response Options in Brazil´s Forest Sector: Comparision of Project-Level Costs and Benefits." Biomass and Bioenergy **8**(5): 309-322.

Fearnside, P. M. (2001). "The potential of Brazil´s Forest Sector for Mitigating Global Warming under the Kyoto Protocol." Mitigation and Adaptation Strategies for Global Change **6**(2001): 355-372.

Forner, C. and F. Jotzo (2002). "Future restrictions for sinks in the CDM - How about a cap on supply?" Climate Policy **2002**(2): 353-365.

Golub, A. (2000). Russian Forests for Climate Change Mitigation - An Economic Analysis. Cambridge, Mass., Harvard Forest, Harvard University.

Gurney, K. and J. Neff (2000). Carbon sequestration potential in Canada, Russia and the United States under Art. 3.4 of the Kyoto Protocol, World Wildlife Fund. **July 2000**.

Houghton, R. A. (2002). "Magnitude, distribution and causes of terrestrial carbon sinks and some policy implications." Climate Policy **2**(2002): 71-88.

Houghton, R. A., J. L. Hackler, et al. (2001). Carbon flux to the atmosphere from land-use changes:1850-1990, U.S. Department of Energy.

Houghton, R. A., J. Unruh, et al. (1993). "Current Land Cover in the Tropics and its Potential for Sequestering Carbon." Global Biogeochemical Cycles **7**(2): 305-320.

Ismail, R. (995). "An economic evaluation of carbon emission and carbon sequestration for the forestry sector in Malaysia." Biomass and Bioenergy **8**((5)): 281-292.

Jong de, T. R. and G. Montoya-Gómez (2000). "An economic analysis of the potential for carbon sequestration by forests: Evidence from Southern Mexico." Ecological Economics **33**(2000): 313-327.

Jotzo, F. and A. Michaelowa (2002). "Estimating the CDM market under the Marrakech accords." Climate Policy(2): 179-196.

Kappel, R., P. Staub, et al. (2002). User Guide CERT version 1.3. Andwil, Switzerland, Grütter Consullting.

Kauppi, P., R. Sedjo, et al. (2001). Technological and Economic Potential of Optons to Enhance, Maintain, and Manage Biological Carbon Reservoirs ad Geo-engineering. Climate Change 2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. B. Metz, O. Davidson, J. Pan and R. Swart. Cambridge, Cambridge University Press**:** 301-343.

Kerr, S., A. Pfaff, et al. (2001). The Dynamics of Deforestation and the Supply of Carbon Sequestration: Illustrative Results from Costa Rica. Central America Project, Environment: Conservation and Competitiveness. T. Panayoutou, Harvard Institute for International Development.

Kooten van, G., L. Arthur, et al. (1992). "Potential to Sequester Carbon in Canadian Forests: Some Economic Considerations." Canadian Public Policy **XVIII**(2): 127-138.

Kooten van, G., S. L. Shaikh, et al. (2002). "Mitigating Climate Change by Planting Trees: The Transaction Cost Trap." Land Economics **78**(4): 559-572.

Kooten van, G., B. Stennes, et al. (2000). "Economics of Afforestation for Carbon Sequestration in Western Canada." The Forestry Chronicle **76**(1): 165-172.

Lewis, D. K., D. P. Turner, et al. (1996). "An inventory based procedure to estimate economic costs of forest management on a regional scale to conserve and sequester atmospheric carbon on the global scale." Ecological Economics **16**: 35-49.

Löschel, A. and X. Zhang (2002). The Economic and Environmental Implications of the US Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrkesh. Venice, FEEM.

Makundi, R. and A. O. Ati (1995). "Carbon flows and economic evaluation of mitigation options in Tanzania´s forest sector." Biomass and Bioenergy **8**((5)): 381-393.

Masera, O. R., M. R. Bellon, et al. (1995). "Forest Management Options for Sequestering Carbon in Mexico." Biomass and Bioenergy **8**((5)): 357-367.

Michaelowa, A., S. Greiner, et al. (2001). Position von Ländern und waldpolitisch engagierten Organisationen zur Einbeziehung von Aufforstung und Walderhalt in CDM und Joint Implementation sowie in die nationalen Treibhausgasinventare.

Missfeldt, F. and E. Haites (2001). "The potential contribution of sinks to meeting the Kyoto Protocol commitments." Environmental Science & Policy **4**(2001): 269-292.

Moulton, R. and K. R. Richards (1990). Costs of Sequestering Carbon through Tree Planting and Forest Management in the United States. Washington D.C., U.S. Department of Agriculture.

Newell, R. and R. Stavins (2000). "Climate Change and Forest Sinks: Factors Affecting the Costs of Carbon Sequestration." Journal of Environmental Economics and Management **40**(3): 211-235.

Niles, J. O., S. Brown, et al. (2002). "Potential carbon mitigation and income in developing countries from changes in land use and management of agricultural and forest lands." Philosophical Transactions **360**(2002): 1621-1639.

Nordhaus, W. (1991). "The Cost of Slowing Climate Change: A Survey." The Energy Journal **12**(1): 37-65.

Parks, P. J. and I. W. Hardie (1995). "Least-Cost Forest Carbon Reserves: Cost-Effective Subsidies to Convert Marginal Agricultural Land to Forest." Land Economics **71**(1): 122-136.

Petroula, T. (2002). Sinks as an option to meet CO2 emission reduction targets in Europe. Bilthoven, RIVM.

Plantinga, A. J. and T. Mauldin (2000). A Method for Estimating the Cost of CO2 Mitigation through Afforestation.

Plantinga, A. J., T. Mauldin, et al. (1999). "An Econometric Analysis of the Costs of Sequestering Carbon in Forests." American Journal of Agricultural Economics **81**(4): 812-824.

Ravindranath, N. H. and B. S. Somashekhar (1995). "Potential and Economics of Forestry Options for Carbon Sequestration in India." Biomass and Bioenergy **8**((5)): 323-336.

Ravindranath, N. H., P. Sudha, et al. (2001). "Forestry for sustainable biomass production and carbon sequestration in India." Mitigation and Adaptation Strategies for Global Change **6**(2001): 233-256.

Richards, K. R. (1997). Estimating Costs of Carbon Sequestration for a United States Greenhouse Gas Policy.

Richards, K. R., R. Moulton, et al. (1993). "Costs of Creating Carbon Sinks in the U.S." Energy Conservation and Management **34**(9-11): 905-912.

Richards, K. R. and C. Stokes (2002). A review of forest carbon sequestration cost studies: a dozen years of research.

Sathaye, J. A., W. R. Makundi, et al. (2001). "Carbon mitigation potential and costs of forestry options in Brazil, China, India, Indonesia, Mexico, The Philippines and Tanzania." Mitigation and Adaptation Strategies for Global Change **6**(2001): 185.211.

Sedjo, R. (1999). Potential for carbon forest plantations in marginal timber forests: the case of Patagonia, Argentina, RFF.

Sedjo, R., B. Sohngen, et al. (2001). Estimating Carbon Supply Curves for Global Forests and Other Land Uses. Washington, Resources for the Future. **Discussion Paper 01-19**.

Sedjo, R. and A. Solomon (1989). Greenhouse Warming:Abatement and Adaptation. RFF Proceedings. P. Crosson, J. Darmstadter, W. Easterling and N. Rosenberg. Washington D.C.**:** 110-119.

Slangen, L. and G. Kooten van (1996). Economics of Carbon Sequestration in Forests on Agricultural Land in the Netherlands.

Sohngen, B., R. Mendelsohn, et al. (1998). The Effectiveness of Forest Carbon Sequestration Strategies with System-wide Adjustements.

Stavins, R. (1999). "The Cost of Carbon Sequestration: A Revealed-Preference Approach." American Economic Review **89**: 994-1009.

Sussman, F. and C. Leining (2002). Priority Rules, Modalities and Guidelines for Land Use, Land-Use Change and Forestry Projects in the Clean Development Mechanism - Key Considerations for Negotiators Post-Marrakech. Washington D.C., Center for Clean Air Policy (CCAP).

Trexler, M. C. and C. Haugen, Eds. (1995). Keeping it green: opportunities for mitigating climate change. Washington D.C., World Resources Institute.

Wangwacharakul, V. and R. Bowonwiwat (1995). "Economic evaluation of CO2 response optionns in the forestry sector: the case of Thailand." Biomass and Bioenergy **8**((5)): 293-307.

Winjum, J. K. and P. E. Schroeder (1997). "Forest plantations of the world: their extent, ecological attributes and carbon storage." Agricultural and Forest Meteorology **84**(1997): 153-167.

Xu, D. (1995). "The Potential for Reducing Atmospheric Carbon by Large-Scale Afforestation in China and Related Cost/Benefit Analysis." Biomass and Bioenergy **8**((5)): 337-344.

Xu, D., X.-Q. Zhang, et al. (2001). "Mitigation potential for carbon sequestration through forestry activities in southern and eastern China." Mitigation and Adaptation Strategies for Global Change **6**(2001): 213-232.

Anonymous, (1991). Analysis of Carbon Reduction in New York State. New York, New York State Energy Office, in consultation with NYS Department of Environmental Conservation and NYS Department of Public Service.