Climate Change

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16. Kurzfassung

Einige Entwicklungsländer (Papua Neuguinea, Costa Rica und andere) haben vorgeschlagen, Emissionsminderungen durch verringerte Entwaldung in ein Klimaregime nach 2012 einzubeziehen. Dieser Vorschlag hat breite Unterstützung im Rahmen der UN Klimaverhandlungen gefunden. Dieser Bericht analysiert die Implikationen und notwendigen Regelungen eines Mechanismus, der verringerte Entwaldung in Entwicklungsländern kompensiert. Die Analyse beinhaltet eine Analyse der Datenverfügbarkeit über Entwaldung von Waldflächenänderungen und den damit verbundenen Biomasseverlusten und Treibhausgasemissionen, einen Versuch den Zusammenhang zwischen den Antriebskräften für Entwaldung und Entwaldungsraten zu quantifizieren, eine detaillierte Diskussion der Optionen Referenzniveaus für Entwaldung festzulegen, Anrechnungsmodalitäten für einen Kompensationsmechanismus, eine Schätzung der potentiellen Höhe von Emissionsgutschriften aus vermiedener Entwaldung und eine Diskussion von Optionen für einen Kompensationsmechanismus.

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16. Abstract

Some developing countries (Papua New Guinea, Costa Rica and others) proposed to include emission reductions from reduced deforestation in a post-2012 climate regime. This proposal has gained broad support under the UNFCCC negotiations. This report aims at assessing the implications and implementation needs of a future international regime that provides compensation for reducing emissions from deforestation in developing countries. This assessment includes an analysis of data availability for deforestation and forest area changes and related losses of biomass and GHG emissions, an attempt to quantify the relationship between deforestation drivers and deforestation rates; a detailed discussion of options related to the establishment of reference emission levels and accounting issues for reducing deforestation; an approximation of the possible magnitude of credits from a RED mechanism and a discussion of approaches to implement a compensation scheme for reducing emissions in a post-2012 climate regime.

17. Keywords

Climate Change, Deforestation, Forest degradation, Tropics, drivers of deforestation, land-use, land-use

change and forestry, Kyoto Protocol, RED mechanism, reference level.		
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Abbreviations

ACCA	Asociación para la Conservación de la Cuenca Amazónica (Association for the Conservation of the Amazonian Basin)
AFOLU	Agriculture, Forestry and Land use
AGB	Aboveground biomass
AIDER	Asociación para la Investigación y el Desarrollo Integral (Association for the Investigation and Integral Development)
ALI	Advanced Land Imager
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AWiFs	Advanced Wide Field Sensor
BAU	Business As Usual
CBERS	China-Brazil Earth Resources Satellite or Satélite Sino-Brasileiro de Recursos Terrestres
CCAP	Center for Clean Air Policy
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CIFOR	Center for International Forestry Research
COMIFAC	Commission des Ministres en charge des Forêts d'Afrique Centrale (Commission of Ministers in charge of Central African Forests)
COP	Conference of the Parties
CPCA	Commitment Period Annual Conversion Area
CPF	Carbon Preserving Factor
CPI	Corruption Perception Index
CR	Compensated Reduction
CWD	Coarse woody debris
DBH	Diameter at breast height
EF	Emission Factor
EMBRPA	Empresa Brasileira de Pesquisa Agropecuária
ETM+	Enhanced Thematic Mapper Plus
FAO	UN Food and Agriculture Organisation
FEMA	Federal Emergency Management Agency
FRA	Forest Resources Assessment

GCB	Global Conversion Rate during Baseline Period
GDP	Gross Dmoestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GLC	Global Land Cover
GLOBCARBON	Project by ESA (European Space Agency)
GNI	Gross National Income
GPG	Good Practice Guidance
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit – German Association for Technological Cooperation
GWP	Global Warming Potential
HCA	Historic Annual Conversion Area
HDI	Human Development Index
HPI	Human Poverty Index
HRC	High-Resolution Camera
ICRAF	International Centre for Research in Agroforestry
IGBP	International Geosphere-Biosphere Programme
IKONOS	Commercial earth observation satellite with high-resolution imagery at 1- and 4-meter resolution. It offers multispectral (MS) and panchromatic (PAN) imagery.
IMF	International Monetary Fund
INPE	Instituto Nacional de Pesquisas da Amazônia, National Institute For Space Research
INRENA	Instituto Nacional de Recursos Naturales
IPB	Institut Pertanian Bogor at Bogor Argicultural University, Indonesia
IPCC	Intergovernmental Panel on Climate Change
JAXA	Japanese Space Agency
JERS	Japanese Earcth Resources Satellite
JRC	Joint Research Center
LAC	Local Area Coverage
LBA	Large Scale Biosphere-Atmosphere Experiment in Amazonia
LCCS	Land cover classification system
LDCF	Least Developed Countries Fund
LISS	Linear Imaging and Self Scanning sensor

LULUCF	Land-use, land use change and forestry
MDGLS	Mid-decadal Global Land Survey
MODIS	Moderate Resolution Imaging Spectroradiometer
MPI	Max-Planck Institut for Biogeochemistry
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NCB	National Conversion Rate during Baseline Period
NCC	National Conversion Rate during Commitment Period
NEAP	National Environment Action Plan
NFI	National forest inventory
NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NWFP	Non-wood Forest Products
ODA	Official Development Assistance
PNG	Papua New Guinea
PRODES	Programa de Cálculo do Desflorestamento da Amazônia (Monitoring project of the Brazilian Amazon forest by satellite)
PSP	Permanent sample plot
RAINFOR	Red Amazónica de Inventarios Forestales
RCA	Reduced Annual Conversion Area
RCR	Reduced Conversion Rate
RED	Reducing emissions from deforestation
REDD	Reducing emissions from deforestation and degradaion
REED	Reduction from reduced deforestation
RFC	Rain Forest Coalition
RS-GIS	Remote Sensing-Geographic Information System
SALVIAS	Synthesis and Analysis of Local Vegetation Inventories Across Scales
SAR	Synthetic Aperture Radar
SBSTA	Subsidiary Body for Scientific and Technological Advice
SCCF	Special Climate Change Fund
SD-PAM	Sustainabale Development Policies and Measures
SLC	Scan Line Corrector
SPOT	Satellite Pour Observation de la Terre, Satellite for Earth Observation

SPSS	Statistical Product and Service Solutions
TM	Thematic Mapper
TREES	Tropical ecosystem Environment and Ecosystem observation by Satellite
UBA	Umweltbundesamt
UNALM	Universidad Nacional Agraria La Molina
UNDP	United National Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNTAD	Tadulako University (UNTAD), Indonesia
USGS	United States Geological Survey
WB	World Bank
WHO	World Health Organization
WRI	World Resource Institute

1 Zusammenfassung

Dieser Bericht analysiert die Implikationen und Voraussetzungen für die Umsetzung einer zukünftigen Klimaschutzvereinbarung, die Anreize oder Kompensationsmechanismen für die Reduzierung von Entwaldung in Entwicklungsländern gibt. Diese Untersuchung beinhaltet:

- Die Analyse der Datenverfügbarkeit über Waldflächenänderungen und den damit verbundenen Biomasseverlusten sowie Treibhausgasemissionen für ausgewählte Schwerpunktländer und auf globaler Ebene;
- Einen Überblick der Waldflächenänderungen, Biomasseverluste und Kohlenstoffemissionen für die Schwerpunktländer und auf globaler Ebene, einschließlich einer Diskussionen der Unsicherheiten und der Variabilität der Emissionen aus Entwaldung;
- Den Versuch, den Zusammenhang zwischen Ursachen und Antriebskräften der Entwaldung und Entwaldungsraten zu quantifizieren;
- Eine Schätzung der möglichen Größenordnung von Gutschriften im Rahmen eines RED Mechanismus verglichen mit den notwendigen globalen Emissionsreduktionen;
- Eine detaillierte Diskussion der Optionen für die Erstellung von sogenannten Referenzniveaus und für Anrechnungsmodalitäten für einen Kompensationsmechanismus für reduzierte Entwaldung.

1.1 Waldflächenänderungen und damit verbundene Treibhausgasemissionen

1.1.1 Datenverfügbarkeit und Unsicherheiten

Waldflächenänderungen

Für das Monitoring und die Anrechnungen von reduzierter Entwaldung werden verlässliche Daten der Waldflächen für alle teilnehmenden Länder benötigt. Die wichtigste globale Datenquelle mit Daten für alle Länder sind die Forstdaten der FAO, insbesondere die globalen Waldressourcen-Schätzung. Die FAO-Daten basieren für einige Länder auf ziemlich alten und wenigen nationalen Quellen, insbesondere für die afrikanischen Länder und haben daher teilweise hohe Unsicherheiten. FRA 2005 stellt Daten für die Jahre 1990 und 2000 zur Verfügung, während Daten für das Jahr 2005 extrapoliert sind. Die nächste Schätzung wird FRA 2010 sein, bei der eine erste globale Fernerkundungserhebung die nationalen Daten ergänzen wird (Ridder 2007).

Seit dem Start der Erderkundungssatelliten in den 70er Jahren, haben Satellitenaufnahmen die traditionelle Schätzung der Waldflächen durch Kartierungen und Luftaufnahmen ergänzt. Viele Studien für einzelne Länder oder Regionen haben die Nützlichkeit von Satellitendaten für die Überwachung von Landnutzung und Entwaldung gezeigt. Die am häufigsten genutzten Satellitendaten für Studien zu tropischen Wäldern sind die Landsat Satellitenbilder. Verschiedene Faktoren trugen zu einer ausgedehnten Nutzung der Landsat-Daten in jüngster Zeit bei: die kostenlose oder kostengünstige Nutzung, zentralisierte Online-Suche und Download über das Internet und eine räumliche Auflösung (30 m), welche es erlaubt, Veränderungen der Beschirmung oder die Landnutzung um Waldflächen herum zu bestimmen.

Die globalen Landsat-Daten sind mehr oder weniger durch Wolken und Nebel sowie durch Jahreszeiten beeinflusst. Für einige Gebiete liefert der Sensor manchmal weniger als ein nutzbares Bild (mit weniger als 20% Wolkenbedeckung) pro Szene und Jahr (Ridder 2007, Fuller 2006). Das bedeutet, dass geringe zeitliche Abdeckung über wolkenreichen tropischen Gebieten den Prozess des Waldflächenmonitorings erschweren kann (Fuller 2006).

In der Vergangenheit lag der Schwerpunkt der Verbesserung der Satellitendaten bei der Verbesserung der Genauigkeit und verbesserter globaler Abdeckung. Für das Monitoring und die Anrechnung von reduzierter Entwaldung ist es von besonderer Bedeutung, dass Flächenänderungen über die Zeit mit denselben Methoden gemessen wurden. FAO FRA 2010 wird der erste globale Ansatz sein, der eine konsistente Zeitreihe von 1975 bis 2005 erhebt. Die Verbesserungen in Technologien und Methoden werden sich fortsetzen, aber neue Daten und Methoden können oft nicht in die Vergangenheit extrapoliert werden. Daher wird es in Zukunft eine Herausforderung bleiben, bei einem sich schnell entwickelnden Forschungsgebiet konsistente Zeitreihen zu gewährleisten.

Viele tropische Länder haben noch keine konsistente Zeitreihe mit Veränderungen der Waldflächen in den letzten 10 bis 20 Jahren erstellt. Brasilien und Indien sind Ausnahmen mit jährlichen (Brasilien) oder zweijährlichen (Indien) Datenerhebungen auf der Basis von Satellitendaten. Für die meisten anderen Staaten müssten konsistente Zeitreihen der vergangenen Waldflächenänderungen für einen RED Mechanismus erst noch erarbeitet werden. Während in einzelnen Ländern funktionierende Monitoringsysteme implementiert sind, welche den Anforderungen eines RED-Mechanismus genügen, wäre es eine erhebliche zusätzliche Anstrengung, dies in allen relevanten Staaten umzusetzen. Hierzu müssten beachtliche zusätzliche Kapazitäten gebildet werden, sowie ein institutioneller Rahmen entwickelt und finanzielle Ressourcen bereitgestellt werden.

Es ist außerdem notwendig, weitere methodische Richtlinien und gute Praxis für die Schätzung von Waldflächenänderungen unter verschiedenen nationalen Voraussetzungen zu entwickeln (z.B. vollständige Erhebung oder Zahl der Stichproben beim Stichprobenahmeansatz, minimale Abholzungsfläche, die identifiziert werden sollte, Monitoring-Intervalle, harmonisierte Klassifizierungssysteme).

Ein stärkerer Schwerpunkt sollte auf die Erstellung von konsistenten Zeitreihen auf Basis von Routineanwendungen von Fernerkundungsdaten für einen RED-Mechanismus gelegt werden. Hochauflösende Daten stehen möglicherweise nicht für alle Regionen mit hoher Wolkenbedeckung zur Verfügung. Für längere Zeitreihen müssen möglicherweise verschiedene Satellitendaten miteinander kombiniert werden. Es gibt wenige Richtlinien, wie in solchen Fällen konsistente Zeitreihen sichergestellt werden sollen.

Es ist wichtig, dass klare, harmonisierte und eindeutige Definitionen für Landnutzungsbedeckung und den Wald entwickelt werden, um zu gewährleisten, dass solche Definitionen über die Zeit konsistent angewandt werden.

Analyse von Kohlenstoffvorräten

Nur wenige tropische Länder führen regelmäßig Waldinventuren durch, und viele dieser Inventare sind unvollständig und veraltet (Ridder 2007). Daher sind Waldinventuren in den Ländern, wo sie durchgeführt wurden eine sehr nützliche Informationsquelle, sie sind jedoch nicht als Standardmethode in tropischen Ländern etabliert, um regelmäßig die Waldbedeckung zu evaluieren. Derzeit rührt ein hoher Anteil der Datenunsicherheit in der Bestimmung der C Vorräte und den Emissionen von aggregierten Daten auf regionaler Ebene her, die keine vernünftige Anwendung auf nationaler Ebene zulassen. Außerdem besteht eine große Variation in der Datenstruktur, Qualität und der Verfügbarkeit von Forstinventuren unter den untersuchten tropischen Ländern. Es wäre wünschenswert, diese Daten zusammenzufassen und sie öffentlich verfügbar zu machen. Erste Schritte hierzu wurden bereits gemacht, wie beispielsweise die Online-Datenbank der Holzdichten (von ICRAF gepflegt) oder die über neotropische Regenwaldinventare (SALVIAS, ATDN), die für diese Studie nützliche Quellen waren. Trotz der erheblichen Bemühungen in vielen tropischen Ländern, besteht weiterhin ein deutlicher Datenmangel, um die C-Verluste durch Entwaldung zu berechnen. Es fehlen insbesondere Daten in den folgenden Bereichen:

- Die Aufteilung der nationalen Waldflächen in unterschiedliche Waldtypen mit ausreichend homogener Struktur als Ausgangsbasis für die Bewertung der Biomasse und C-Vorräte;
- Waldinventuren, die jeden Waldtyp mit einer ausreichend großen Anzahl an Wiederholungsflächen repräsentieren;
- Allometrische Gleichungen für die Umrechung der in den Waldinventuren gemessenen Baumparameter in Biomasse- und Kohlenstoffvorräte. In dieser Untersuchung wurden lediglich für Tieflandswälder in Lateinamerika und Südost-Asien geeignete Allometrien gefunden und weitere Forschungsbemühungen zur Erarbeitung von allometrischen Daten sind notwendig;
- Daten zur Holzdichte, um Holzerträge in Biomassedaten umzurechnen. Verbesserte Daten zur Holzdichte haben das höchste Potential die Berechnungen der überirdischen Biomasse zu verbessern, da die Variation der Holzdichte zwischen Kontinenten, Regionen und Waldtypen deutlich variiert (Chave et al. 2005, 2006; Nogueira et al. 2006, 2007).

Treibhausgasemissionen

Veränderungen in C-Vorräten durch Entwaldung können leicht in CO_2-Emissionen umgerechnet werden. Die exakte Berechnung der Emissionen aus Entwaldung benötigt jedoch außerdem Daten über die Art der Entwaldung, insbesondere ob die Waldflächen abgebrannt oder auf andere Weise gerodet wurden. Nicht-CO_2- Treibhausgase wie CH_4 und N_2O entstehen vor allem durch das Verbrennen von Biomasse, d.h. wenn Wälder abgebrannt werden, oder die verbleibende Biomasse nach dem Einschlag verbrannt wird. Obwohl solche Daten auf regionaler Ebene geschätzt werden (FAO 2006), gab es Daten zur Häufigkeit des Brennens auf nationaler Ebene in den Schwerpunktländern nicht. Daher wurden zwei verschiedene Szenarien berechnet (eines mit und eines ohne Brennen), und es bestehen hohe Unsicherheiten bezüglich des tatsächlichen Einflusses des Brennens auf die Nicht-CO_2 Emissionen aus der Entwaldung.

1.1.2 Ergebnisse für die Schwerpunktländer

Waldflächen

Die folgenden sechs Schwerpunktländer wurden für diese Studie ausgewählt, da sie eine breite Spannbreite aus Regionen, Waldbedingungen und Datenverfügbarkeit bilden:

Lateinamerika:	Brasilien, Peru
Afrika:	Madagaskar, Republik Kongo (Kongo-Brazzaville)

Asien/ Ozeanien: Papua-Neuguinea, Indonesien

Diese Schwerpunktländer wurden als Testgebiete genutzt, um verbessere Schätzungen der Waldflächenänderungen, Biomassevorräte und Entwaldungstrends zu erhalten. Tabelle 1 und Tabelle 2 zeigen die Waldflächenänderungen für die Schwerpunktländer dieser Untersuchung. Für zwei der Länder (Republik Kongo und Papua-Neuguinea) wurde eine Analyse von Satellitendaten für diese Studie durchgeführt, während für andere Schwerpunktländer nur Literaturdaten ausgewertet wurden, um die Flächenangaben in diesen Tabellen abzuleiten.

Tabelle 1 Historische Waldflächen der Schwerpunktländer dieser Studie

Waldflächen	**Sources**	**1980**	**1990**	**2000**	**2005**
			[1000 ha]		
Kongo-Brazzaville*	MPI-BGC, e.S.		22 100	22 250	22 350
Brasilien**	INPE		520 027	493 213	477 698
Indonesien	FAO		116 567	97 852	88 495
Madagaskar	FAO		21 148	13 023	12 838
Papua-Neuguinea	MPI-BGC, e.S.	33 000	30 195	27 390	26 300
Peru	FAO		70 156	69 213	68 742

*Anmerkungen: * Nur tropische Feuchtwälder*

*** Nur Amazonasgebiet*

Quelle: MPI-BGC, e.S.= MPI-BGC, eigene Abschätzung

Tabelle 2 Historische Waldflächenänderungen in den Schwerpunktländern

Waldflächenänderung		**1980-1990**	**1990-2000**	**2000-2005**
			[1000 Hektar]	
Kongo-Brazzaville*	MPI-BGC, e.S.		+ 150	+ 100
Brasilien**	INPE		- 26 814	- 15 515
Indonesien	FAO		- 1 8715	- 9 357
Madagaskar	FAO		- 8125	- 185
Papua-Neuguinea	MPI-BGC, e.S.	- 2 805	- 2805	- 1 090
Peru	FAO		- 943	- 471
Peru	Oliveira (2007)			- 315
			[%/Jahr]	
Kongo-Brazzaville*			+ 0.1	+ 0.1
Brasilien**			- 0.5	- 0.3
Indonesien			- 1.6	- 1.0
Madagaskar			- 3.8	- 0.1
Papua-Neuguinea		- 0.9	- 0.9	- 0.4
Peru			- 0.1	- 0.1

*Anmerkungen: * Nur tropische Feuchtwälder*

*** Nur Amazonasgebiet*

Quelle: MPI-BGC, e.S.= MPI-BGC, eigene Abschätzung

Die Waldfläche in der **Republik Kongo** (Kongo-Brazzaville) hat unbedeutend – weniger als 1% der Waldflächen – zugenommen. Fast die gesamte Entwaldung war im Grenzgebiet zu Kamerun konzentriert. Die Analyse in dieser Studie hat nicht die Verluste durch Walddegradation abgeschätzt, aber als Expertenschätzung kann angenommen werden, dass seit 1990 mehr als 10% des kongolesischen Waldes degradiert wurde. Ein kürzlich veröffentlichter Artikel (Laporte et al. 2007) beschreibt die Ausdehnung des industriellen Holzeinschlages im nördlichen Kongo, wo die Entwaldungsrate durch den Wege- und Straßenbau von 156 km Jahr^{-1} für die Periode 1976-1990 auf über 660 km Jahr^{-1} nach 2000 anstieg. Das bedeutet, dass historisch und gegenwärtig Walddegradation der wesentliche Prozess ist, der zu Treibhausgasemissionen führt. Das Bestehen eines gut ausgebauten Wegenetzes kann in Kongo zu einer raschen Entwaldung in der nahen Zukunft führen, ähnlich wie dies derzeit schon an der Grenze zu Kamerun geschieht.

Brasilien verzeichnete in der Vergangenheit hohe Entwaldungsraten durch die Umwandlung von Waldflächen in landwirtschaftliche Flächen. Die brasilianischen Daten zeigen jedoch auch eine hohe Variabilität der Entwaldung für die einzelnen Jahre, mit einem Entwaldungsminimum von 11 030 km^2 in 1991 und einem Maximum von 29 059 km^2 im Jahr 1995. Der Gipfel in 1995 korrespondiert mit einer Landreform in Amazonien, wo Land an ca. 150 000 Familien vergeben wurde. Dieser neue Faktor war laut Berichten für 40% der Entwaldung in diesem Jahr verantwortlich. Die zweite Entwaldungsspitze im Jahr 2004, fand am Ende von zwei anderen Jahren mit hoher Entwaldung statt, die mit der letzten Finanzkrise des Landes korrespondierte und mit vielen Landnutzungskonflikten in den ländlichen Gebieten. Für 2007 haben vorläufige Daten der Regierung zunächst eine geringere Entwaldung angegeben, während jüngste Presseberichte von einem erneuten starken Anstieg der Entwaldung in 2007 berichteten, die auf einem ähnlichen Niveau wie in 2003-2004 liegen soll (BBC 2008). In Brasilien kann ca. ein Drittel der jüngsten Entwaldung mit der sogenannten „shifting cultivation“ verbunden werden. Ein großer Anteil der Entwaldung geht auf die Umwandlung in Weide- und landwirtschaftliche Flächen durch kommerzielle und spekulative Interessen, fehlgeleitete Regierungspolitiken und die kommerzielle Ausbeutung der Waldressourcen zurück. Es scheint wahrscheinlich, dass die Entwaldung in Brasilien auch künftig fortgesetzt wird, aber sie wird sich wahrscheinlich etwas verlangsamen.

Indonesien hat in den vergangenen Jahren mehr als 20% seiner Wälder verloren. Während der 90er Jahre waren die Jahre 1997 und 1998 die Jahre mit den höchsten Entwaldungsraten auch diejenigen mit starken Klimaanomalien (El Niňo, la Niňa), wodurch menschliche Eingriffe zur Waldumwandlung vorangetrieben wurden. In jedem dieser Jahre gingen ca. 18 000 km^2 Wald verloren, ein großer Teil durch Feuer. Nach dieser Periode ging die Entwaldung zurück, stieg aber in 2004 und 2005 mit ca. 8 000 und 11 000 km^2 pro Jahr wieder stark an. In Indonesien korrespondieren wie in Brasilien die Entwaldungsspitzen mit der Finanzkrise des Landes. Es sind keine Daten zur Walddegradierung verfügbar, aber Degradierung findet in allen Waldregionen statt und ist möglicherweise im Ausmaß in ähnlicher Höhe wie die Entwaldung oder übersteigt diese sogar. In Indonesien wurden große Waldgebiete in Plantagen umgewandelt und für ca. 60 % des verbleibenden Waldes sind Einschlagskonzessionen vergeben. Heute zählen die indonesischen Waldgebiete mit zu den am stärksten gefährdeten auf der Welt. Die indonesischen Wälder werden durch Holzeinschlag, Bergbau, große landwirtschaftliche Plantagen, Kolonisierung und Subsistenzlandwirtschaft und dem Sammeln von Feuerholz reduziert. Die Waldbedeckung ging seit den 60er Jahren stetig zurück. Legaler Holzeinschlag findet auf 700 000-850 000 Hektar im Jahr statt, aber illegaler Einschlag ist weit verbreitet und bringt die eingeschlagene Fläche auf mindestens 1.2-1.4 Millionen Hektar und möglicherweise höher. In Indonesien treten praktisch alle Ursachen für Entwaldung kombiniert auf, daher ist es auch wahrscheinlich, dass die Entwaldung in der Zukunft fortgesetzt wird.

Madagaskar verlor zwischen den Jahren 2000 und 2005 ungefähr 37 Hektar Wald pro Jahr nach den Angaben der Vereinten Nationen. Das bedeutet einen Rückgang der Waldflächen um 42% seit 1990. Trotz beachtlicher internationaler Walderhaltungsbemühungen waren die Gesamteffekte hinsichtlich der Entwaldung gering (Harezga 2007). Die Einhaltung von schützenden Gesetzen wird nicht verfolgt und Umwelteinrichtungen kooperieren nicht ausreichend miteinander (Gezon, 1997). Dieses Scheitern der globalen Schutzbemühungen in Madagaskar kann vor allem auf sozio-ökonomische Faktoren zurückgeführt werden (Harzega 2007). Die Finanzhilfe führte nicht zu einer Verbesserung der ökonomischen Situation der allgemeinen Bevölkerung. Schlechte sozioökonomische Bedingungen schufen eine Situation, wo die ländliche Bevölkerung in direktem Konflikt zu den Schutzbemühungen steht (Ferraro, 2002). Durch die ungelösten sozio-ökonomischen Probleme kann erwartet werden, dass die Entwaldung in Madagaskar in Zukunft ebenfalls fortgesetzt wird. Die ökonomische Entwicklung einer wachsenden Bevölkerung wird die Entwaldungsrate stark beeinflussen.

In **Papua-Neuguinea** (PNG) fand in der Vergangenheit ebenfalls eine starke Entwaldung und Walddegradation statt, die jedoch eine regional stark unterschiedliche Ausprägung zeigt. Die Ursachen sind regional ebenfalls sehr unterschiedlich. Im Neubritannien fand eine starke Umwandlung von Wald in Ölpalmplantagen statt. In Küstengebieten der Papua Insel fand Entwaldung durch nicht nachhaltige Feueranwendung statt und Entwaldung durch Holzeinschlag konzentrierte sich auf die Tieflandwälder in den Golf- und westlichen Provinzen. Die hohen Waldverluste sind erst ein junger Prozess, der in den 80er Jahren startete und ein Maximum in den 90er Jahren erreichte, wo jährlich ca. 0.5-0.9% der Waldfläche umgewandelt wurde. Die beiden kritischsten Jahre waren 1997 und 1998, als viele Feuer auftraten, die durch Klimaanomalien (El Niňo, la Niňa) zusätzlich befördert wurden. Seit 2000 nehmen die Entwaldungsraten konstant ab und lagen immer unter 0.5%. Die Fläche, auf der Walddegradation auftritt, war in der Periode 1990 bis 2000 zur Entwaldungsfläche äquivalent und in der Periode 2000 bis 2005 höher als die Entwaldungsfläche. Es ist sehr schwierig, den zukünftigen Trend der Entwaldung für PNG anzugeben. Die Unsicherheiten hängen mit der einzigartigen sozialen Struktur des Landes zusammen, wo Landrechte von Stämmen gehalten werden und wo traditionelle Verhaltensweisen die staatliche Organisation dominieren. Nach 2000 verlangsamte sich die Entwaldung, es gibt dafür aber keine klaren Erklärungen. Einerseits gab es keine ökonomischen Anreize zum Walderhalt und andererseits ist die staatliche Kontrolle der Waldflächen weiterhin sehr schwach.

Für **Peru** zeigen jüngste Daten (Oliveira et al. 2007), dass die Entwaldung etwas geringer ist als in den Daten, die von der peruanischen Regierung an die FAO berichtet wurden (Tabelle 2). Olivirea et al. (2007) gibt für Entwaldung in Peru zudem eine hohe jährliche Variabilität zwischen 192 bis zu 1174 km^2 Entwaldungsfläche pro Jahr an. Das jüngste Jahr, für das Daten zur Verfügung stehen, ist das Jahr von 2004 auf 2005 mit der höchsten Entwaldung in der Zeitreihe und mit einem Maximum an Walddegradation auf 1070 km^2. Zur Verifikation offizieller Daten baut Peru derzeit mit der brasilianischen Organisation INPE ein nationales Waldmonitoringsystem auf. Dieses System wird den Ansatz aus dem brasilianischen Prodes-Projekt übernehmen. Oliveira et al.. (2007) folgerten, dass die Landnutzungspolitik in Peru stark zur Waldzerstörung und –degradierung beitrug. Infolge der Ausweisung von kommerziellen Holzkonzessionen für große neue Gebiete und die Verbesserung der Zufahrtswege, wird erwartet, dass die Entwaldung in Peru in der Zukunft fortgesetzt wird und Raten erreicht, die denen der jüngsten Vergangenheit (Oliveira et al. 2007) entsprechen.

Biomasse und C-Vorräte

Für einige der Schwerpunktländer wurden neue Biomassewerte in dieser Studie erarbeitet, vor allem für die wichtigsten Waldtypen. Tabelle 3 zeigt die C-Vorräte pro Hektar in oberirdischer Biomasse für die Schwerpunktländer aus unterschiedlichen Quellen.

Tabelle 3 Übersicht der C-Vorräte pro Hektar in oberirdischer Biomasse aus unterschiedlichen Quellen. Die Anwendung eines arithmetischen Mittels über alle Waldtypen pro Kontinent wird mit einem gewichteten Mittel über die Waldtypen entsprechend ihrer Anteile an der nationalen Waldfläche verglichen.

	Kohlenstoffvorräte in oberirdischer Biomasse (Mg ha^{-1})												
	Marklund & Schöne (2006) Regionaler Durchschnitt	FAO (2006) Durchschnitt aller Wälder	Arithmetischer Mittelwert (MW) von IPCC Defaultwerten aller relevanten tropischen und subtropischen Waldtypen (je Kontinent)			Gewichteter Mittelwert von IPCC Defaultwerten aller relevanten Waldtypen			Anzahl Waldtypen		Abweichung gewichteter IPCC MW von arithemetischem IPCC MW aller Waldtypen (%)		
			MW	Min.	Max.	MW	Min.	Max.	berichtet	verwendet	MW	Min.	Max.
Brasilien*	110	105	94	29	170	81	36	129	5	5	-14	23	-24
Peru	110	123	94	29	170	141	86	182	16-39	7	51	193	7
Kongo	155	107	94	35	152	155	65	255	1	1	65	84	68
Madagaskar	64	97	48	35	60	92	69	134	2	2	93	96	122
Indonesien	77	68	106	34	171	167	129	252	0	2	57	275	48
PNG	55	29	106	34	171	132	79	219	9	7	24	131	28

*Anmerkungen: * Für den Ansatz mit dem gewichteten Mittel wurden die C-Vorräte nicht von den IPCC-Daten, sondern vom Ministry of Science and Technology (2006) abgeleitet.*

Nur die Bedeckung mit Naturwäldern wurde berücksichtigt, und Plantagen ausgeschlossen.

Quelle: Berechnungen MPI-BGC, J. Dietz

Diese Tabelle zeigt, dass der gewichtete Mittelwert der C-Vorräte in der oberirdischen Biomasse aus nationalen Quellen für Brasilien niedriger ist als der FAO-Durchschnittswert und als die Daten von Marklund & Schöne. Die gewichteten Mittelwerte der in dieser Studie erarbeiteten C-Vorräte für Peru, Kongo-Brazzaville, Indonesien und PNG sind höher als die FAO-Durchschnittswerte. Die größten Unterschiede treten für Indonesien auf (167 Mg ha^{-1} aus dieser Studie verglichen mit 68 Mg ha^{-1} in den Daten des FAO FRA 2005) und für PNG (219 Mg ha^{-1} in dieser Studie verglichen mit 29 Mg ha^{-1} aus dem FAO FRA 2005 und 55 Mg ha^{-1} von Marklund und Schöne 2006).

Table 3 zeigt die Unterschiede in den Werten der C-Verluste durch Entwaldung für oberirdische Biomasse und alle Pools zwischen 1990 und 2005 für die Schwerpunktländer, wobei für die Berechnungen die unterschiedlichen C-Vorratsdaten aus der vorangegangenen Tabelle genutzt wurden. Für oberirdische Biomasse ist der C-Verlust mit den Daten, die im Rahmen dieser Studie für PNG gesammelt wurden, 4.5 Mal höher als mit den FAO-Daten. Der Verlust ist 2.5 Mal höher für Indonesien mit den Daten dieser Studie als die Werte der FAO. Für Brasilien ergibt sich das umgekehrte Ergebnis, hier liegen die C-Verluste auf Basis der nationalen Daten 23% unter den Werten auf Basis der FAO-Mittelwerte.

Tabelle 4 *Kohlenstoffverluste aus der oberirdischen Biomasse und allen Pools (Gesamt) zwischen 1990 und 2005 durch Entwaldung, die mit unterschiedlichen C-Vorratswerten berechnet wurden. Die Anwendung des arithmetischen Mittelwerts wird mit dem gewichteten Mittelwert aus verschiedenen Waldtypen verglichen.*

		Kohlenstoffverlust aus Entwaldung 1990 - 2005 (Tg)											
		FAO (2006) Durch-schnitt aller	Arithmetischer Mittelwert (MW) von IPCC Defaultwerten aller relevanten tropischen und subtropischen Waldtypen (je			Gewichteter Mittelwert von IPCC Defaultwerten aller relevanten Waldtypen			Anzahl Waldtypen		Abweichung gewichteter IPCC MW von arithemetischem IPCC MW aller Waldtypen		
			MW	Min.	Max.	MW	Min.	Max.	berichtet	verwendet	MW	.	Max.
Brasilien	Oberird.B	4805	4311	1352	7819	3706	1668	5912	5	5	-14	23	-24
	Total*	*n.d.*	6107	2590	10271	5261	2903	7810			-14	12	-24
Peru	Oberird.B	252	193	61	350	291	177	374	16-39	7	51	193	7
	Total*	*n.d.*	276	119	462	381	249	477			38	109	3
Kongo	Oberird.B	29	26	10	41	42	18	70	1	1	65	84	68
	Total*	*n.d.*	38	19	57	56	28	88			48	47	54
Madagaskar	Oberird.B	91	45	33	57	86	65	125	2	2	93	96	122
	Total*	*n.d.*	71	56	85	116	91	161			64	62	90
Indonesien	Oberird.B	2255	3527	1138	5656	5523	4262	8358	0	2	57	275	48
	Total*	*n.d.*	5108	2268	7636	7176	5726	10391			40	152	36
PNG	Oberird.B	66	243	78	390	303	181	499	9	7	24	131	28
	Total*	*n.d.*	358	155	545	418	269	656			17	74	20

*Anmerkungen: * Für den Ansatz mit dem gewichteten Mittel wurden die C-Vorräte nicht von den IPCC-Daten, sondern vom Ministry of Science and Technology (2006) abgeleitet.*

Nur die Bedeckung mit Naturwäldern wurde berücksichtigt, und Plantagen ausgeschlossen.

** Kombiniert den Verlust von 100% oberirdischer Biomasse, 80% unterirdischer Biomasse, 100% Streu, 100% Totholz und 40% des organischen C m Boden.*

Quelle: Berechnungen MPI-BGC, J. Dietz

Treibhausgas-Emissionen

Für die Berechnung der THG-Emissionen aus der Entwaldung wurden für die Schwerpunktländer zwei verschiedene Szenarien berechnet, die auf verschiedenen Annahmen zur Rolle des Abbrennens basieren:

1. Das erste Szenario nimmt an, dass die Wälder nicht gebrannt werden. Entwaldung resultiert nur aus der Umwandlung der C Vorräte in CO_2 und aus einigen CH_4-Emissionen aus dem Abbau von Streu und Totholz (niedriges THG-Szenario).
2. Das zweite Szenario nimmt an, dass die gesamte Entwaldung mit Feuer durchgeführt wird. Neben CO_2 entstehen CH_4 und N_2O-Emissionen durch die Waldbrände.

Diese beiden Szenarien sollen die Spannbreite der THG-Emissionen aufzeigen, die durch den Einschluss der Nicht-CO_2-Emissionen auftreten können.

Tabelle 5 *Vergleich der Treibhausgase in CO_2eq die in der Periode 1990 – 2005 unter dem hohen und niedrigen THG-Szenario entstehen*

		Treibhasgasemissionen (THG) aus Waldverlusten im Zeitraum 1990 - 2005 (Tg)								
		Hohes THG-Szenario			Niedriges THG-Szenario			Zusätzliche THG-Emissionen im Falle vollständigen Verlustes		
		MW[a]	Min.[b]	Max.[c]	MW	Min.	Max.	MW	Min.	Max.
Brasilien	oberird.B[d]	15123	6302	25370	13588	6118	21679	1535	184	3691
	Total[e]	23164	11849	36492	19292	10646	28635	3873	1203	7857
Peru	oberird.B[d]	1189	670	1604	1068	651	1370	121	20	233
	Total[e]	1646	1020	2190	1397	915	1747	249	105	442
Kongo	oberird.B[d]	172	67	298	155	65	255	18	2	43
	Total[e]	243	113	404	206	103	322	37	11	83
Madagaskar	oberird.B[d]	353	245	538	317	238	460	36	7	78
	Total[e]	500	373	737	426	334	589	74	38	148
Indonesien	oberird.B[d]	22537	16099	35867	20249	15628	30648	2288	471	5219
	Total[e]	31010	23498	47879	26313	20997	38102	4697	2502	9777
PNG	oberird.B[d]	1235	685	2142	1109	665	1830	125	20	312
	Total[e]	1799	1094	3018	1532	986	2405	267	108	613

Anmerkungen: Nur Naturwälder, keine Plantagen berücksichtigt.

[a] berechnet mit 51 % Verlusten an Gesamt-C durch Feuer (Kauffman et al. 1995).

[b] berechnet mit 42 % Verlusten an Gesamt-C durch Feuer (Fearnside et al. 1999, 2007).

[c] berechnet mit 29 % Verlusten an Gesamt-C durch Feuer (Fearnside et al. 2001).

[d] Vollständiger Verlust durch Feuer nach dem hoen Spurengasszenario von Fearnside (2000).

[e] Kombiniert den Verlust von 100 % oberirdischer Biomasse durch Verbrennen, 80 % der unterirdischen Biomasse durch Abbau, 100 % der Streu durch Schwelbrände, 100 % des Totholzes durch Schwelbrände, 40 % des Bodenkohlenstoffs durch Abbau (Fearnside 2000).

1.1.3 Ergebnisse auf globaler Ebene

Der erste Versuch globale Emissionen aus der Entwaldung zu berechnen stammt von Houghton und Kollegen (Houghton et al., 1983, 1985; Houghton, 1999, 2003). Sie stellten Daten der Landbedeckung aus Forstinventaren zusammen und schätzten die globalen C-Emissionen in den 90er Jahren auf 2.2 PG C, a^{-1}. Laut Houghton (2005) wurden in den 90er Jahren durch globale Entwaldung (sowohl die dauerhafte Umwandlung von Wäldern in Acker- und Grünland als auch die temporäre Umwandlung im Rahmen des Wanderfeldbaus und Einzelstammnutzung) CO_2-Emissionen in der Größenordnung von 1-2 Pg C pro Jahr (15-35% der jährlichen Emissionen aus der Verbrennung von fossilen Brennstoffen) freigesetzt. Schätzungen der globalen Emissionen aus Entwaldung für diese Periode aus verschiedenen Quellen variieren um mehr als den Faktor 2 (Tabelle 6), hauptsächlich durch unterschiedliche Schätzungen der Entwaldungsraten (DeFries & Achard 2002). Diese verschiedenen Studien sind jedoch nicht direkt vergleichbar. Sie haben unterschiedliche geographische Abdeckungen und Zeitperioden, haben unterschiedliche Landbedeckungsänderungen einbezogen, haben unterschiedliche Annahmen zu den historischen Veränderungen getroffen und haben unterschiedliche Kohlenstoffkreislaufmodelle genutzt.

Tabelle 6 Durchschnittliche jährliche Entwaldung (in Mio. ha pro Jahr) in tropischen Gebieten in den 90er Jahren

	Durchschnittliche jährliche Entwaldung in tropischen Regionen		
Regions	**FAO (2001)**	**DeFries et al (2002)**	**Achard et al. (2004)**
	$[\mathrm{Mha\ a^{-1}}]$		
Amerika	5.2	3.982	4.41
Asien	5.9	2.742	2.84
Afrika	5.6	1.325	2.35
Gesamt	16.4	8.049	9.60

Anmerkung: Alle Quellen beziehen sich auf Bruttoraten an Waldverlusten FAO Daten basieren auf nationalen Erhebungen, Forstinventuren, Expertenschätzungen und Fernerkundungsdaten. Die Schätzungen von DeFries und Archard basieren auf Fernerkundungsdaten.

Quelle: Houghton 2005

Neben Abweichungen hinsichtlich der zugrundeliegenden Walddefinitionen führt auch der Ein- oder Ausschluss von Plantagenflächen zu unterschiedlichen globalen Werten für einzelne Länder. Die Genauigkeit der Schätzungen ist beeinträchtigt durch das Fehlen von verlässlichen und konsistenten Zeitreihen, variierende Standards der Wald- und Nicht-Waldklassifizierung, unzureichende Verifizierung der Satellitendaten mit Kartierungen und institutionelle Schwächen der Forstbehörden in manchen Ländern (Fuller 2006).

Die Schätzungen der C-Verluste durch Entwaldung auf globaler Ebene in dieser Untersuchung erforderten einige allgemeine Annahmen. Die Waldflächenverluste wurden dem FAO FRA 2005 (FAO 2006, Table 2.4) entnommen und für C-Vorräte wurde der einfachere und im allgemeinen niedrigere arithmetische Mittelwert der IPCC Kennzahlen sowie der regionale Mittelwert der FAO-Daten genommen. Zusätzlich wurde ein gewichteter Mittelwert aus den IPCC Kennzahlen für die Regionen berechnet. Dies erforderte die Annahme, dass die Anteile der einzelnen Waldtypen, wie sie in FRA 2000 (FAO 2001) dokumentiert sind, über die gesamte Periode konstant blieb. Tabelle 7 zeigt die globalen C-Verluste auf regionaler Ebene. Diese Schätzung ist wahrscheinlich eine erhebliche Unterschätzung der tatsächlichen Emissionen aus der Entwaldung, weil 1) nur die oberirdische Biomasse berücksichtigt wurde und 2) sich bei der Einzelbetrachtung der Länder in dieser Studie herausgestellt hat, dass die globalen Daten deutlich niedriger als differenzierte nationale Daten lagen.

Tabelle 7 *C-Verluste aus oberirdischer Biomasse durch Entwaldung in den Tropen auf regionaler Ebene zwischen 1990 und 2005, die mit zwei unterschiedlichen Ansätzen für C-Vorräte berechnet wurden.*

	Kohlenstoffverlust in oberirdischer Biomasse aus Entwaldung 1990 - 2005 (Tg)						
	FAO (2006) Durchschnitt aller Wälder	Arithmetischer Mittelwert (MW) von IPCC Defaultwerten aller relevanten tropischen und subtropischen Waldtypen (je			Gewichteter Mittelwert von IPCC Defaultwerten aller relevanten Waldtypen		
		MW	Min.	Max.	MW	Min.	Max.
Karibik	-79	-120	-40	-155	-164	-93	-218
Süd- & Mittelamerika	12913	12137	3845	20922	14254	9665	21534
Nordafrika	359	1328	1056	1598	1863	1863	1863
West- & Zentralafrika	3822	4199	1581	6806	5330	2869	8430
Ost- & Südafrika	2167	3247	1817	4672	3874	2755	5858
Süd- & Südostasien	6768	8380	3505	12975	9686	5738	12774
Ozeanien	1174	1282	414	2056	1902	1477	2812
Tropische Länder, Gesamt	27124	30453	12177	48875	36746	24274	53052

Quelle: Berechnungen durch MPI-BGC, J. Dietz

Derzeit versuchen viele Projekte wie beispielsweise JRC TREES 3, FAO FRA2010 oder NASA Landsat Pathfinder Humid Tropic deforestation Project neue Informationen und Schätzungen der Emissionen aus der tropischen Entwaldung zu erhalten. Neue Daten über die globalen Emissionen werden voraussichtlich aber erst um 2010 herum vorhanden sein.

Da es große Unsicherheiten der THG-Emissionen der vergangenen und gegenwärtigen Entwaldung gibt, sind die Unsicherheiten von Projektionen der zukünftigen Emissionen aus Entwaldung noch wesentlich unsicherer und es gibt nicht viele Quellen, die die zukünftigen Emissionen abgeschätzt haben.

Wenn die derzeitigen Entwaldungsraten fortgesetzt werden, schätzten Houghton et al (2005), dass zusätzlich 87 bis 130 Pg C in den nächsten 100 Jahren emittiert werden und dass die jährlichen C Emissionen aus der tropischen Entwaldung bis 2012 auf einem Niveau von 2.1 PG C/Jahr bleiben. Die größten Waldverluste in dieser langfristigen Vorhersage resultieren aus der fast vollständigen Entwaldung in einigen Ländern Asiens (Myanmar, Indonesien und Malaysia), Lateinamerika (Peru), und Afrika (Benin, Elfenbeinküste, Nigeria und Sambia).

Ein andere Schätzung der globalen Entwaldung wurde von IIASA (Kindermann et al. 2006) publiziert. Das Referenzszenario von IIASA zeigt einen Waldflächenverlust von 200 Mio. ha oder von ca. 5% der aktuellen Waldfläche bis 2025, der zu zusätzlichen Emissionen von 17.5 PG C führt. Innerhalb der nächsten 100 Jahre, sinkt die Waldfläche um 500 Mio. ha, was 1/8 der aktuellen Waldbedeckung entspricht. Die akkumulierte C-Freisetzung während der nächsten 100 Jahre beläuft sich auf 45 Pg C, was 15% des Gesamtkohlenstoffes entspricht, der gegenwärtig in Wäldern gespeichert wird. D.h. die IIASA-Schätzung beträgt nur ca. die Hälfte der Schätzung von Houghton's niedrigerem Wert, was wiederum die hohen Unsicherheiten solcher Schätzungen aufzeigt. Aber selbst die niedrigeren Schätzungen zeigen, dass dringender Handlungsbedarf besteht, diese zusätzlichen Emissionen in der Zukunft zu vermeiden.

1.2 Zusammenhang zwischen Entwaldungsursachen und Entwaldungsraten

Jedes Klimaregime, das Anreize zur Reduzierung von Entwaldung geben möchte, muss berücksichtigen, dass es eine Vielzahl von Ursachen und Treibergrößen für die Entwaldung gibt. Direkte Ursachen können in natürliche und anthropogene unterteilt werden. Geist und Lambin (2002) schlussfolgerten in einer Studie über Entwaldungsursachen, dass *„der Rückgang an Tropenwald von unterschiedlichen Kombinationen von verschiedenen unmittelbaren Gründen und darunterliegenden Antriebsfaktoren in sich verändernden geographischen und historischen Kontexten bestimmt wird.“* Vor allem Antriebsfaktoren wie nationale oder globale ökonomische Möglichkeiten und Politiken reagieren häufig in Kombination mit anderen Faktoren und hängen von verschiedenen Faktoren ab und sind deshalb schwer vorauszusagen. Bezüglich der quantitativen Zusammenhänge zwischen Entwaldungsraten und Antriebskräften haben Kaimowith und Angelsen (1998) die verschiedenen Modelle zur Entwaldung analysiert und gefolgert, *dass „die meisten Forscher stimmen darin überein, dass mehr Straßen, höhere landwirtschaftliche Preise, geringere Löhne und zu wenig Arbeitsplätze außerhalb der Landwirtschaft im allgemeinen zu mehr Entwaldung führen, aber gleichzeitig bleiben die Effekte der Preise für landwirtschaftliche Inputmaterialien, das Haushaltseinkommen, die Sicherheit des Landeigentums, die Reduzierung von Armut, das Nationaleinkommen, ökonomisches Wachstum und Auslandsverschuldung unklar.“* Sie verweisen außerdem auf die Schwierigkeit globale Regressionsmodelle zu nutzen, da die begrenzte Datenverfügbarkeit und schlechte Qualität es sehr schwer machen zwischen Korrelation und ursächlichem Zusammenhang zu unterscheiden. Selbst wenn statistische Zusammenhänge gefunden werden, müssen diese nicht notwendigerweise tatsächlich den Entwaldungsursachen zugeordnet werden. Korrelationen müssen sorgfältig in Feldstudien für die einzelnen Länder getestet werden. Vanclay (2005) verweist darauf, dass eine statistische Analyse der Entwaldung schwierig ist, da die Verlässlichkeit der Entwaldungsdaten für die einzelnen Länder sehr unterschiedlich ist. Keine der für diesen Bericht analysierten Studien konnte eindeutige Zusammenhänge zwischen Antriebskräften für Entwaldung und zukünftigen Waldflächenänderungen finden.

Trotz dieser Datenprobleme und –unsicherheiten, wurden in diesem Bericht statistische Zusammenhänge zwischen nationalen Entwaldungsraten in den Tropen und biophysikalischen / sozioökonomischen als auch mit der Regierungsführung zusammenhängende Ursachen erarbeitet, um Kriterien für die Vorhersage von Entwaldungstrends zu entwickeln. Für die Periode 2000-2005, wurden für alle tropischen Länder signifikante univariate Korrelationen zwischen der Waldflächenänderungen und den Variablen „Bevölkerungswachstum“, „Fruchtbarkeitsrate“ und „Öffentliche Ausgaben für Bildung“ gefunden. Diese Variablen zeigten jedoch nur jeweils eine Erklärungskraft von weniger als 15% und relativ geringe Korrelationskoeffizienten. Für 1990-2000 zeigten nur zwei Variablen signifikante Korrelationen, nämlich der „menschliche Armutsindex“ und der „Analphabetismus unter Erwachsenen“, wobei letzterer nur ein R2 von 0.082 als erklärende Variable bei einer schrittweisen Regression erreichte.

Die Ergebnisse der Regressionsanalyse für alle tropischen Länder zeigten, dass die individuellen nationalen Umstände oft zu unterschiedlich sind, um für verschiedene Länder klare Korrelationen zu finden. Die Ergebnisse zeigen jedoch, dass mit der Bevölkerung zusammenhängende Parameter eine wichtige Rolle bei den Ursachen spielen. Daneben war auch für beide Perioden die Rolle der Bildung klar sichtbar. Daneben kann auch die Sicherheit der Eigentumsrechte als positiver Faktor für die ökonomische Leistungsfähigkeit eines Staates gesehen werden. Eine Regierung ohne Mechanismen und Eigentumsrechte durchzusetzen, lässt Raum für zahlreiche illegale Aktivitäten in Bezug auf die Waldnutzung. Die rechtliche Struktur und die Sicherung der Eigentumsrechte bringt einen substantiellen Beitrag zum Erhalt und nachhaltigen Bewirtschaftung der natürlichen Ressourcen.

1.3 Schätzung der möglichen Größenordnung der Emissionsreduktionen durch einen RED Mechanismus

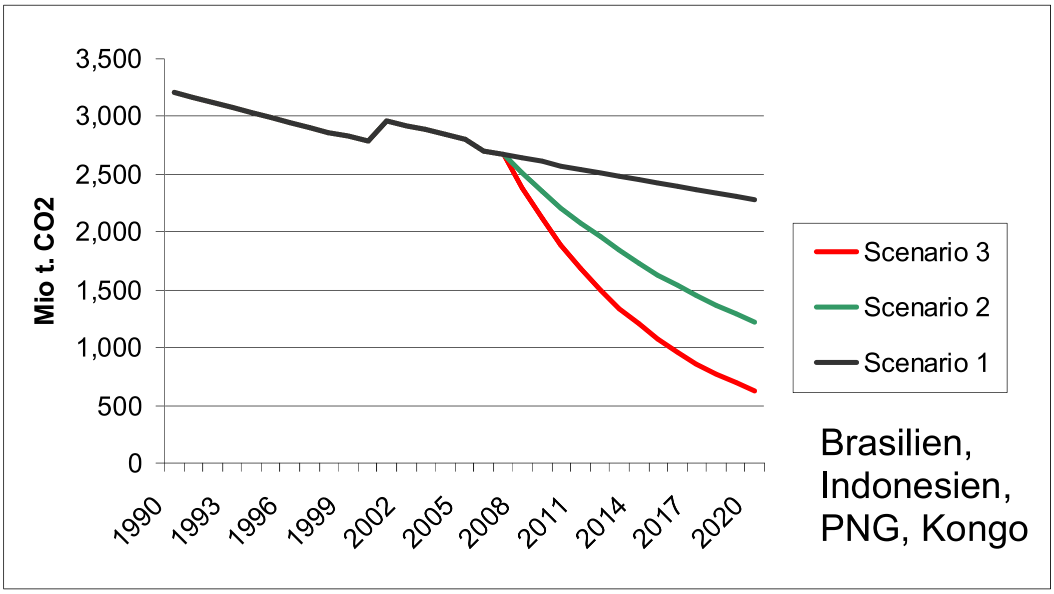
Für eine grobe Annäherung der potentiellen Größenordnung der Emissionsreduktionen durch einen RED Mechanismus wurden drei Szenarien berechnet:

- **Szenario 1**: Entwaldungsrate aus dem Zeitraum 2000-2005 bleibt konstant
- **Szenario 2**: Entwaldungsrate geht nach 2008 um jährlich 5% zurück (Entwaldungsrate wird in 10 Jahren um 50% reduziert)
- **Szenario 3**: die Entwaldungsrate geht nach 2008 um jährlich 10% zurück (Entwaldungsrate wird in 5 Jahren um 50% reduziert)

Das erste Szenario könnte als Business-as-Usual-Szenario angesehen werden mit unveränderter Entwaldung nach dem Jahr 2000. In solch einem Szenario entstehen jedoch weniger Emissionen aus Entwaldung als in der Vergangenheit, da sich die konstante Entwaldungsrate auf eine kontinuierlich sinkende Waldfläche bezieht. Staaten könnten daher in diesem Szenario ihre Emissionen reduzieren, ohne dass sich die Entwaldungsrate ändert.

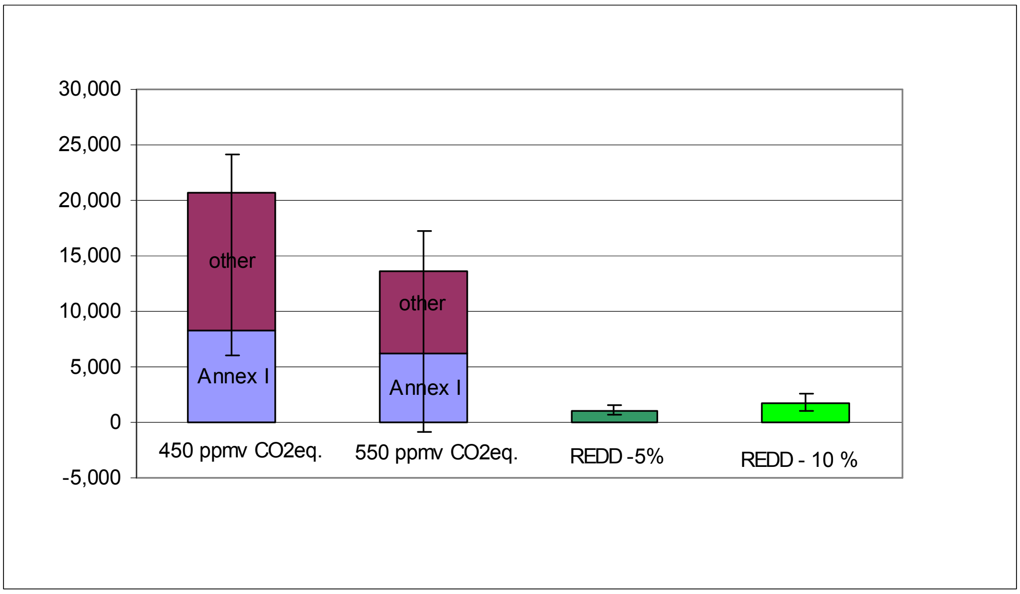
Abbildung 1 stellt die Ergebnisse der drei Szenarien für Brasilien, Papua-Neuguinea und die Demokratische Republik Kongo dar (berechnet mit durchschnittlichen Biomasse-Werten). Die Emissionen aus Entwaldung würden in 2020 von 2 278 Mt CO_2 auf 1 217 Mt CO_2 oder 620 Mt CO_2 sinken, wenn die Entwaldung um 5% (Szenario 2) oder 10% (Szenario 3) gesenkt würde. Dies entspricht einer Emissionsreduktion von 1 061 Mt CO_2 (5% Reduktion) und 1 658 Mt CO_2 (10% Reduktion) in 2020 im Vergleich zum BAU-Szenario (Szenario 1). Diese Emissionsreduktionen durch vermiedene Entwaldung in den vier betrachteten Ländern (1 061 Mt CO_2 – 1 658 Mt CO_2) entsprechen 25-40% der Emissionen der EU-15 in 2005 oder 15-23% der gesamten Emissionen der USA in 2005.

Abbildung 1 Die summierten CO_2-Emissionen aus Entwaldung in den Ländern Brasilien, Indonesien, Papua-Neuguinea und Republik Kongo in den drei Szenarien
Szenario 1 = konstante Entwaldungsperiode im Vgl zur Periode 2000-2005
Szenario 2 = Entwaldungsrate um jährlich 5% reduziert
Szenario 3 = Entwaldungsrate um jährlich 10% reduziert



Quelle: Berechnungen von MPI-BGC and Ecofys

Abbildung 2 Potentielle Emissionsreduktionen aus reduzierter Entwaldung in Brasilien, Indonesien, PNG und Kongo (die beiden rechten Säulen) in 2020 verglichen mit den notwendigen globalen Emissionsreduktionen in anderen Sektoren um die Stabilisierung der CO_2-Konzentration in der Atmosphäre auf einem Niveau von 450 und 550 ppmv CO2eq. zu erreichen (linke Säulen)



Quelle: Berechnungen von Ecofys, Daten für die globalen Reduktionen von Höhne et al. 2007

Abbildung 2 zeigt die potentielle Emissionsreduktion durch verminderte Entwaldung (in Brasilien, Indonesien, PNG und Kongo) verglichen mit den global notwendigen Emissionsminderungen in Annex I- und Nicht-Annex I-Staaten für die 450 ppmv und 550 ppmv Stabilisierungsszenarien. Das angenommene Ziel für Annex I Emissionsreduktionen ist dabei -35% (450 ppmv) und -24% (550 ppmv) bezogen auf die Emissionen in 1990. Wenn die Entwaldungsraten um 5% jährlich gesenkt würden, würde die Emissionsreduktion in Brasilien, Indonesien, PNG und Kongo 5% der global notwendigen Emissionsreduktion umfassen und fast 8% um die Reduktionen des 550 ppmv-Szenarios zu erreichen. Für das Szenario mit jährlich 10% Rückgang der Entwaldungsrate würde durch RED in diesen 4 Ländern 8-12% der globalen Emissionsreduktion erreicht. Die Unsicherheiten dieser quantitativen Angaben sind jedoch sehr hoch und bei der Interpretation müssen die zahlreichen vereinfachenden Annahmen berücksichtigt werden.

Wenn man bedenkt, dass die Potenziale der Emissionsreduktion durch verminderte Entwaldung in dieser Annäherung eher unterschätzt wurden und dass diese Angaben nur vier Länder beinhalten, ergibt sich, dass RED einen beachtlichen Anteil der globalen Emissionsreduktion erreichen kann, der für die Stabilisierung der THG-Konzentration in der Atmosphäre notwendig ist. Falls solche Emissionsreduktionen in handelbare Gutschriften in einem Emissionshandelsmarkt umgewandelt würden, könnte das potentiell hohe Angebot an Gutschriften durch den RED-Mechanismus die Stabilität des C-Marktes gefährden. Die vereinfachenden Berechnungen unterstützen die These, dass unter den gegenwärtigen Bedingungen und den hohen Unsicherheiten ein vollständig marktbasierter Ansatz mit handelbaren RED-Gutschriften wahrscheinlich nicht angemessen ist.

1.4 Festlegung von Referenzniveaus der Emissionen und Anrechnungsmodalitäten für einen Kompensationsmechanismus zur Verminderung von Entwaldung

Für einen RED-Mechanismus in einer globalen Klimavereinbarung nach 2012 ist es notwendig, ein Maß zu finden, mit Hilfe dessen die Leistung eines teilnehmenden Landes gemessen werden kann. Zu diesem Zweck ist es notwendig, ein Referenzniveau festzulegen, mit welchem die Anstrengungen der teilnehmenden Länder verglichen und entsprechend kompensiert werden. Verschiedene Vorschläge für Referenzniveaus wurden in der jüngsten Diskussion zum RED Mechanismus eingebracht und dieser Bericht diskutiert einige der Probleme und Herausforderungen bei der Umsetzung dieser Vorschläge.

Die einfachste Option für ein Referenzniveau ist die Höhe der historischen Entwaldung. Historische Entwaldungsraten als Referenz wurden von vielen Staaten und wissenschaftlichen Institutionen oder NGOs vorgeschlagen. Es gibt jedoch viele Lücken im vorhandenen Wissen über vergangene Entwaldungstrends und für viele Länder gibt es keine konsistenten Zeitreihen der Waldflächenänderungen. Eine zweite Möglichkeit zur Festlegung von Referenzniveaus sind Projektionen der zukünftigen Emissionen aus Entwaldung. Der Datenmangel hinsichtlich aktueller Entwaldungstrends führt automatisch zu hohen Unsicherheiten für die Projektion der künftigen Entwaldung. Außerdem wirken viele Antriebskräfte für Entwaldung gleichzeitig auf komplizierte Weise zusammen, was eine Vorhersage sehr schwierig macht. Daher sind Referenzniveaus auf der Basis von Projektionen mit sehr hohen Unsicherheiten behaftet.

Die Konsistenz der Methoden und Daten über die Zeit ist von herausragender Bedeutung für eine glaubwürdige und verlässliche Schätzung der Emissionsreduktionen. Die Änderungen der Waldflächen und der damit verbundenen C-Vorräte sollten für die Referenzperiode und die Erfüllungsperiode mit den gleichen Methoden berechnet werden. Es kann sein, dass das Kriterium der Zeitreihenkonsistenz einige der jüngeren Entwicklungen der Fernerkundungstechnologien für eine erste Anrechnungsperiode ausschließt, weil nicht mit der gleichen Methode die historischen Daten nachträglich erhoben werden können.

Für die Zwecke der Anrechnung von Emissionsreduktionen muss das Endergebnis für die Referenzniveaus der Emissionen und die Verpflichtungsperiode nicht notwendigerweise sehr genau sein, aber beide Daten sollten konsistent über die Zeit sein und sie sollten eine konservative Abschätzung sein. Konsistent über die Zeit bedeutet, dass die Daten des Referenzniveau und die des aktuellen Trends während der Verpflichtungsperiode auf den gleichen Methoden basieren sollte, um zu vermeiden, dass die Emissionsreduktion lediglich durch eine Veränderung in der Methodik oder Datenerhebung hervorgerufen wird. Konservativ bedeutet, dass die Methodik sicherstellt, dass die Emissionsreduktion, für die ein Land eine Kompensation erhält, auch tatsächlich vermindert wurde während die tatsächlichen Emissionsreduktionen darüber liegen können. Dies ist ein klarer Unterschied zu der Aufgabe, verlässliche globale, regionale oder nationale Emissionen aus Entwaldung zu berechnen.

Die Erstellung von Referenzniveaus für die historische Entwaldung erfordert zusätzliche methodische Leitlinien in den folgenden Bereichen:

- Dem gewählten Monitoringansatz (z.B. vollständige Erfassung eines Lands oder Hochrechnung von Stichproben;
- Walddefinitionen und Bedeckungsgrad, die in der Analyse der Waldflächen durch Fernerkundungsdaten verwendet werden sollen;
- Die Festlegung der erforderlichen Auflösung und der minimalen Flächengröße von Abholzungen, die durch die gewählten Fernerkundungstechnologien detektierbar sein sollten;
- Die Bestimmung der historischen Periode, die für das Referenzniveau verwendet werden soll. Diese Periode sollte vom Vorhandensein von Daten auf Basis konsistenter Methoden gewählt werden. Es wird empfohlen, mit den historischen Daten in 1990 zu beginnen, wo hochauflösende Landsat-Daten zur Verfügung stehen. Das jüngste Jahr, das in die Referenzentwicklung eingeht, muss ebenfalls definiert werden. Dieses Jahr sollte aus dem Zeitraum stammen, wo ein Land noch nicht am RED-Mechanismus teilgenommen hat, um zu vermeiden, dass Referenzniveaus aktiv erhöht werden können, ehe ein Land an einem RED Mechanismus teilnimmt.

Biomasse

In einem zweiten Schritt bei der Festlegung des Referenzniveaus müssen nachgewiesene Waldflächenänderungen in Kohlenstoff-Einsparung umgerechnet werden. Die Kohlenstoffvorräte hängen vom Waldtyp ab, d.h. je nachdem wo eine Entwaldung stattgefunden hätte, würden die dabei freigesetzten Emissionen variieren. Über die Verteilung der Waldbiomasse in den Tropen gibt es nur wenige Daten. Viele Biomasseschätzungen wurden für intakte oder ungestörte Wälder erstellt, aber natürliche Störungen und menschliche Eingriffe Verändern diese Verteilung. Aber auch bei der Bestimmung der Biomasse gilt wieder das Prinzip, dass es für Anrechnungsmodalitäten weniger wichtig ist, dass die Daten zu den C-Vorräten und der räumlichen Verteilung sehr genau sind, sondern dass ein konservativer default-Wert bestimmt wird, wenn Länder keine Daten von hoher Qualität haben. Daneben ist es sowieso unmöglich, genau zu bestimmen, wo eine vermiedene Entwaldung räumlich genau aufgetreten wäre, wenn sie nicht vermieden worden wäre. D.h. die Emissionsreduktionen können nicht eindeutig bestimmten Flächen zugeordnet werden und default Parameter und nationale Referenzwerte müssen für die Anrechnung festgelegt werden. Für Anrechnungszwecke könnte ein Ansatz mit unterschiedlichen Tiers entwickelt werden, je nach Datenlage in den teilnehmenden Ländern, ähnlich wie bei den Methoden zur Emissionsberechnung in THG-Inventaren.

Als einfache Standardmethode, könnte für jedes Land ein gewichteter Mittelwert der oberirdischen Biomasse und C-Vorräte über alle Waldtypen bestimmt werden, die auf IPCC default C-Vorräten und Daten der FAO zur räumlichen Verteilung der verschiedenen Waldtypen beruhen. Um die Berechnung konservativ zu machen, könnte der niedrigere Wert aus der Spannbreite der C-Vorräte für verschiedene Waldtypen genutzt werden.

Höhere methodische Tiers könnten länderspezifische Daten zu C-Vorräten auf unterschiedlichen Niveaus berücksichtigen. Anstelle eines IPCC default-Wertes könnte ein gewichteter landesspezifischer Mittelwert über alle Waldtypen treten. Dieser nationale default-Wert sollte sowohl für die Berechnung der Referenzemissionen als auch während der Verpflichtungsperiode verwendet werden. Eine weitere Annahme müsste zum Anteil der intakten und degradierten Wälder getroffen werden. Ohne nationale Daten zum Zustand der Wälder sollte eher von einem höheren Anteil an degradierten Wäldern ausgegangen werden. Diese Annahme sollte durch nationale Daten zu Degradierung und damit verbundenen C-Verlusten ersetzt werden, falls diese vorhanden sind. Wenn Länder weitgehend intakte Waldgebiete haben, können nationale Biomasseinventare zeigen, dass Walddegradation nicht relevant ist und nicht berücksichtigt werden muss.

In großen Ländern wie beispielsweise Brasilien sollten höhere methodische Tiers für C-Vorräte auf durchschnittlichen regionalen Werten basieren und gewichtete Werte über die regionalen Waldtypen oder Biom-Typen gebildet werden. Das erfordert jedoch, dass die historischen Daten für das Referenzniveau auf Basis der gleichen Gewichtung über die Regionen und Biome berechnet wird.

Dieser Ansatz würde die C-Vorräte in anderen Pools wie die unterirdische Biomasse, Totholz und Bodenkohlenstoff nicht berücksichtigen. Das ist eine vernünftige Vereinfachung für die Anrechnung von vermiedener Entwaldung, weil die Veränderungen der anderen Pools, insbesondere des Bodenkohlenstoffs von der nachfolgenden Landnutzung abhängen. Die Flächen, auf denen die Entwaldung vermieden wurde, können räumlich nicht lokalisiert werden und es kann auch keine nachfolgende Landnutzung für eine hypothetische Abholzung bestimmt werden. Aus diesem Grund sollte die Anrechnungsmethode nur die oberirdische Biomasse einbeziehen. Das gleiche Argument betrifft auch die Nicht-CO_2-Gase. Emissionen der Nicht-CO_2-Gase hängen von der Nutzung des Brennens bei der Entwaldung ab. Es kann nur hypothetisch angenommen werden, auf welche Weise ein Wald, der von der Abholzung gerettet wurde, gerodet worden wäre. Nationale Mittelwerte müssten erarbeitet werden und müssten auch in die Berechnung des Referenzniveaus eingehen.

Im Allgemeinen unterscheiden sich die methodischen Anforderungen an die Anrechnung von C aus reduzierter Entwaldung von der Aufgabe eine genauer Abschätzung der Emissionen aus der Entwaldung zu erstellen und es ist mit einigen konservativen Annahmen möglich, eine Methodik mit unterschiedlichen Tier zu bestimmen. Weitere Diskussionen und Forschungen zu den zu verwendenden default Werte sind vor dem Start eines solchen Mechanismus notwendig.

Für Länder mit niedriger historischer Entwaldung sollte ein anderer Ansatz zur Bestimmung des Referenzniveaus entwickelt werden, weil das Ziel, einen historischen Entwaldungswert zu unterschreiten für diese Länder nicht anwendbar ist. Es wird vorgeschlagen in einem ersten Schritt Kriterien für die Identifizierung der tropischen Länder mit geringer historischer Entwaldung zu entwickeln. Dieser Bericht diskutiert zwei verschiedene Ansätze zur Ermittlung von Referenzniveaus für diese Gruppe von Ländern. Jeder Ansatz zur Berechnung eines Referenzniveaus, der nicht auf einer tatsächlich historisch erfolgten Entwaldung basiert, birgt jedoch das Risiko, dass die Kompensation nicht mehr mit tatsächlichen Anstrengungen zum Walderhalt zusammenhängt und dass die Kompensation nicht für Zwecke des Walderhalts genutzt wird. Um solche Mitnahmeeffekte zu vermeiden, sollten Anreize zum Walderhalt für Länder mit geringer Entwaldung in der Vergangenheit mit der Implementierung von nationalen Walderhaltungsprogrammen verbunden werden. Wenn die Anreize mit solchen Aktivitäten verbunden werden, ist es möglicherweise sinnvoller einen Kompensationsansatz zu entwickeln, der die Kosten des Walderhalts berücksichtigt anstelle der hypothetischen Emissionsreduktion. Ein separater Fonds könnte für diese Gruppe von Ländern eingerichtet werden, der auf den vorgeschlagenen und implementierten Walderhaltungsaktivitäten und deren Monitoring basiert. Solch ein Ansatz könnte nicht nur die nationalen Umstände, sondern auch Biodiversitätsaspekte besser berücksichtigen.

Es wird empfohlen, das Referenzniveau periodisch anzupassen, um Veränderungen über die Zeit wiederzuspiegeln. Nach einiger Zeit könnte sich der festgelegte Wert als zu konservativ oder zu lax herausstellen. Der Zeitpunkt der Revision sollte mit der Länge der Verpflichtungsperiode übereinstimmen, d.h. die Referenzentwicklung sollte nach der ersten Verpflichtungsperiode für die nächste Periode korrigiert werden. Innerhalb einer Verpflichtungsperiode sollte die Referenz unverändert bleiben.

Es wird nicht empfohlen das historische Referenzniveau mit weiteren Faktoren anzupassen, um nationale Eigenheiten, sozio-ökonomische Faktoren oder Antriebskräfte für Entwaldung zu berücksichtigen. Wenn solche Differenzierungen der Verpflichtungen, beispielsweise im Hinblick auf die ökonomischen Potenziale der Länder durchgeführt werden sollen, dann sollte dies besser durch die Festlegung differenzierter Ziele als durch Anpassungen der Referenzentwicklung geschehen. Die Verwendung eines historischen Referenzniveaus bedeutet nicht automatisch, dass alle Emissionsreduktionen unter einem historischen Niveau automatisch kompensiert werden, sondern es können auf dieser Basis unterschiedliche Ziele bestimmt werden, d.h. teilnehmende Länder müssten die Emissionen mindestens um ein bestimmtes Niveau im Vergleich zur historischen Referenz mindern, bevor der Kompensationsmechanismus wirksam wird.

Ein internationaler Mechanismus für finanzielle Kompensation von vermiedener Entwaldung schafft den Bedarf an neuen internationalen Verfahren der Berichterstattung, Überprüfung und Verifikation. Berichterstattungsanforderungen für einen RED Mechanismus müssen festgelegt werden. Solche Anforderungen müssen sowohl die Berichterstattung von Daten und Informationen beinhalten, um die Abschätzungen und Berechnungen nachvollziehen machen. Neben der technischen Information zu den Berechnungen, sollten die Berichtsanforderungen auch die Berichterstattung über nationale Walderhaltungsprogramme und nationale Politiken zum Waldschutz beinhalten. Diese Informationen würden eine transparente

Verbindung zwischen den finanziellen Anreizen und den Waldpolitiken und implementierten Maßnahmen schaffen. Die Berichterstattung würde auch den Austausch über erfolgreiche Praktiken und Maßnahmen fördern.

Die Überprüfung der berichteten Informationen würde analysieren, ob die angegebene Reduktion der Entwaldung tatsächlich stattgefunden hat und ob die Berechnung der damit verbundenen Emissionen den vereinbarten Monitoring- und Berechnungsmethoden entspricht. Solch eine Überprüfung könnte auf ähnliche Weise wie die Überprüfung der Annex I THG-Inventare geschehen, die durch internationale Expertenteams in Besuchen im Land oder in schriftlichen Verfahren durchgeführt werden. Der Zeitverlauf solcher Verfahren wäre jedoch deutlich anders, da ein jährlicher Überprüfungsprozess nicht notwendig wäre. Die Überprüfung der angerechneten Emissionsreduktionen aus reduzierter Entwaldung hätte zwei Teile, erstens die Prüfung ob das Referenzniveau in Einklang mit den vereinbarten Regeln erstellt wurde und zweitens müssten am Ende der Verpflichtungsperiode, die reduzierten Emissionen im Vergleich zur Referenz geprüft werden. Solch eine Überprüfung würde hauptsächlich die technische Emissionsberechnung analysieren.

Für die teilnehmenden Länder erfordert die Erarbeitung der Referenzniveaus für die Anrechnung von verminderter Entwaldung einen erheblichen Aufbau von Kapazitäten und neue institutionelle Arrangements um ein nationales System zu etablieren, das in der Lage ist die Entwaldung kontinuierlich zu verfolgen, da solche Daten derzeit häufig noch nicht kontinuierlich und auf einer systematischen Basis erhoben werden.

2 Executive summary

This report assesses the implications and the implementation needs for a future international agreement to reduce GHG emissions that provides incentives or compensation for reducing emissions from deforestation in developing countries (RED).

This assessment includes

- An analysis of availability of data on forest area changes and related losses of biomass and greenhouse gas (GHG) emissions for selected focus countries and at global level;
- An overview of forest area changes, biomass losses and carbon emissions for the focus countries and at global level, including a discussion of uncertainties and variability of emissions from deforestation;
- An attempt to quantify the relationship between deforestation drivers and deforestation rates;
- An estimation of the possible magnitude of credits from a RED mechanism compared to necessary global GHG emission reductions;
- A detailed discussion of options related to the establishment of reference emission levels and accounting issues for a compensation mechanism for reducing deforestation.

2.1 Forest area changes and related GHG emissions

2.1.1 Data availability and uncertainties

Forest area changes

For the purposes of monitoring and accounting for reduced deforestation, reliable country-level data on forest areas are required. The most important global data source with country-specific information are FAO forestry data, in particular the Global Forest Resources Assessments (FRA). However, for some countries FAO data is sometimes based on rather old and few national sources, in particular for African countries, and thus they are partly connected with high uncertainties. FRA 2005 only provides monitored data for 1990 and 2000 while data for the year 2005 is extrapolated. The next assessment will be FRA 2010 for which a first FAO global Remote Sensing Survey of Forests (RSS) will complement the national reporting. The expected outputs are forest area change data for 1975-1990, 1990-2000 and 2000-2005 (Ridder 2007).

Since the launch of earth-observation satellites in the 1970s, satellite data have complemented the traditional estimation of forest cover from field samples and aerial surveys. Many country-level and regional studies demonstrated the usefulness of satellite data for the monitoring of land-use cover change and deforestation.

Of the different satellite sensors used in studies of tropical forest, the literature suggests that Landsat imagery has been the most commonly applied. Several factors explain the widespread and recent use of Landsat imagery: its free use or moderate cost, centralized online search and download through the internet, and a spatial resolution (30 m) appropriate for the detection of change in canopy condition as well as land use around forested areas.

The global Landsat data sets are more or less impacted by atmospheric conditions like haze and clouds, as well as by seasonality. For some regions in the tropics the sensor often delivers less than one usable image (with less than 20% cloud cover) per scene per year (Ridder 2007, Fuller 2006). Thus, low temporal coverage over cloudy tropical regions can make an annual forest area monitoring process difficult in some regions (Fuller 2006).

In the past the focus for the development of remote sensing technologies has been on improved accuracy or improved global coverage. For the monitoring and accounting of reduced deforestation it is particularly important that area changes are measured over time with the same methods. FAO FRA-2010 will be the first global approach developing a consistent time-series from 1975 to 2005. Further improvements in technologies and methods will continue, but new data and methods often cannot be extrapolated backwards. Therefore it will remain challenging to ensure consistent time-series in a rapidly developing research area.

Many tropical countries have not yet prepared a consistent time series of data of forest area changes over the past 10 to 15 years. Brazil and India are exceptions with annual (Brazil) and (biannual) assessments of forest area changes based on satellite data. For most other tropical countries a consistent time series of past forest area changes would have to be established for a RED mechanism, but is not yet available. While monitoring systems are generally available that would satisfy the needs for reporting and accounting of reduced deforestation in an international RED mechanism, considerable efforts are needed until such monitoring systems will be implemented in all relevant countries. This involves considerable capacity-building activities and the establishment of an institutional framework and related financial resources.

It is also necessary to develop further methodological guidance and best practices for the assessment of forest area changes under different national circumstances (e.g. wall-to-wall approach or sampling size, minimum clearing size to be identified, monitoring intervals, harmonized classification schemes).

A stronger focus on consistent time-series data is necessary for a routine application of remote sensing data as part of a future RED mechanism. High resolution data may not be available for cloudy regions. Datasets from different sensors with different resolution have to be combined to derive a time series covering historic and current years. Few research or guidance is available how time-series consistency can be ensured using different satellites and sensors over time.

It will be essential to develop clear, harmonized and unambiguous definitions for land use cover and forests and it has to be ensured that such definitions are consistently applied over time.

Assessment of carbon stocks

Only few tropical nations regularly conduct national forest inventories, and many are incomplete and out of date (Ridder 2007). Thus, forest inventories are a very useful source of information in the countries where they are available, however they are currently not implemented as a standard method on a regular basis to assess forest cover change in most tropical countries.

Currently, a large proportion of the uncertainty in estimating carbon stocks and emissions is caused by highly generalized and aggregated values on regional levels which do not allow a reasonable application to national situations. There exists a very large variation in data structure, quality and availability from forest inventories between the investigated tropical countries. It would be desirable to compile these data and make them publicly available. First steps have already been undertaken, e.g. online databases on wood density (maintained by ICRAF) or on neotropical rainforest inventories (SALVIAS, ATDN) which have been useful resources for this study. However, despite these efforts for many tropical countries there is a considerable lack of data necessary to estimate carbon losses from deforestation which includes

- the partitioning of the overall national forest area into distinct forest types of sufficiently homogeneous structure as basis for the assessment of biomass and carbon stocks.
- Forest inventories that represent each forest type with a sufficient number of replications.
- Allometric equations for the conversion of measured tree dimensions in forest inventories into biomass and carbon stocks which ideally have been developed from forests in the regions. In this study appropriate allometries were only discovered for some lowland forest types in Latin America and South-East Asia and further research efforts are necessary for the establishment of such allometries.
- Wood density values to convert yield biomass/ timber volumes into mass values of biomass. Improved knowledge on wood density holds the highest potential for refining aboveground biomass estimates since the variation of wood density between continents, regions and forest types varies considerably (Chave et al. 2005, 2006; Nogueira et al. 2006, 2007).

GHG emissions

Changes in C stocks due to deforestation can easily be converted into CO_2 emissions. However, the accurate estimation of GHG emissions from deforestation also requires data on the type of deforestation, precisely whether the deforested areas were burnt or whether they were deforested by other means. Non-CO_2 GHG gases such as CH_4 and N_2O are emitted from deforestation predominantly through the burning of biomass, i.e. when forests are burnt as such or remaining biomass is burnt after slashing or logging. Therefore, knowledge on the extent of burning in tropical forests would be essential for an accurate estimation of greenhouse gas emissions. Although such data are approximated on the regional scale (FAO 2006), no such information was available on a national level for the focus countries. Therefore two scenarios (with and without burning were estimated for the focus countries), but high uncertainties exist with regard to the real impact of burning and the estimation of Non-CO_2 emissions from deforestation.

2.1.2 Results for focus countries

Forest areas

The following six focus countries were selected for this study representing a wide range of regions, forest conditions and data availability:

Latin America:	Brazil, Peru
Africa:	Madagascar, Congo (-Brazzaville)
Asia/ Oceania:	Papua New Guinea, Indonesia

These focus countries were used as test areas for improved national estimates of forest area change, biomass stocks and assessment of deforestation trends.

Table 1 and Table 2 show the forest area changes for the focus countries of this study. For two Congo-Brazzaville and Papua New Guinea (PNG) an analysis of satellite data has been performed for this study, while for the other focus countries only available data in literature have been used to derive the area estimates presented in these tables.

Table 1 Past forest areas in focus countries of this study

Forest area	**Sources**	**1980**	**1990**	**2000**	**2005**
			[1000 ha]		
Congo-Brazzaville*	MPI-BGC, o.a.		22 100	22 250	22 350
Brazil**	INPE		520 027	493 213	477 698
Indonesia	FAO		116 567	97 852	88 495
Madagascar	FAO		21 148	13 023	12 838
Papua New Guinea	MPI-BGC, o.a.	33 000	30 195	27 390	26 300
Peru	FAO		70 156	69 213	68 742

*Notes: * Tropical humid forest only*
*** forest extension related only to Amazon regions*

Source: MPI-BGC, o.a .= MPI-BGC, own assessment

Table 2 Past forest area changes in focus countries

Forest area change	**Sources**	**1980-1990**	**1990-2000**	**2000-2005**
			[1000 ha]	
Congo-Brazzaville*	MPI-BGC, o.a.		+ 150	+ 100
Brazil**	INPE		- 26 814	- 15 515
Indonesia	FAO		- 18 715	- 9 357
Madagascar	FAO		- 8 125	- 185
Papua New Guinea	MPI-BGC, o.a.	- 2 805	- 2 805	- 1 090
Peru	FAO		- 943	- 471
Peru	Oliveira (2007)			- 315
			[%/year]	
Congo-Brazzaville*	MPI-BGC, o.a.		+ 0.1	+ 0.1
Brazil**	INPE		- 0.5	- 0.3
Indonesia	FAO		- 1.6	- 1.0
Madagascar	FAO		- 3.8	- 0.1
Papua New Guinea	MPI-BGC, o.a.	- 0.9	- 0.9	- 0.4
Peru	FAO		- 0.1	- 0.1

Forest area in **Congo-Brazzaville** grew insignificantly by less than 1% of forest area. Almost all the deforestation has been concentrated along the border with Cameroon. The analysis done in Congo did not assess the area changes due to forest degradation, but as an expert judgment it could be estimated that since 1990 more than 10% of the Congo forest have been degraded. A recent paper (Laporte et al. 2007) describes the expansion of industrial logging in Central Africa and reports that the most rapidly changes in forest area was in northern Congo, where the rate of logging road construction increased from 156 km year^{-1} for the period 1976–1990 to over 660 km year^{-1} after 2000. Thus historically and presently forest degradation is the main process which leads to GHG emissions. The existence of a well spread road network may push Congo to fast deforestation processes in the near future, as they are now occurring at the border with Cameroon.

Brazil had a continued high deforestation in the past due to the ongoing transformation of forest in agriculture area. The Brazilian data on deforestation in the Amazon region show a high interannual variability with a minimum deforestation in 1991, 11,030 km^2, and a maximum deforestation in 1995, 29,059 km^2. The 1995 peak is corresponding with a land reform which granted land in the Amazon to roughly 150,000 families. This new factor was reported to be responsible for almost 40% of the deforestation for that year. The other deforestation peak, 2004, took place at the end of two other severe years which are corresponding with the last financial crisis in Brazil and with a high level of land battles in Brazil's countryside. For 2007 preliminary data of the Brazilian government confirmed a decreasing trend in deforestation, however recent press briefings confirmed a strong increase in deforestation for 2007 similar to the levels in 2003-2004 (BBC 2008). In Brazil only about one-third of recent deforestation can be linked to "shifted" cultivators. A large portion of deforestation in Brazil can be attributed to land clearing for pastureland and agricultural land by commercial and speculative interests, misguided government policies, and commercial exploitation of forest resources. It seems likely that deforestation will continue in the Brazil Amazon for the foreseeable future, but deforestation may be slower than in the recent past, if the more recent trend continues.

Indonesia in the last 15 years has lost more than 20 % percent of its forests. During the 90s the more severe years were 1997 and 1998 when large climate anomalies (El Niňo, la Niňa) facilitated human actions to convert forest areas. In each of these years around 18.000 km^2 of forest were lost, much of the forest clearing were done by fires. After these years deforestation declined, but rose again in 2004 and 2005 with circa 8.000 and 11.000 km^2 per year respectively. Also in Indonesia like in Brazil the main deforestation peaks are corresponding with country financial crisis. National data on the extension of forest degradation are not available, but degradation occurs in all forest regions and probably could be equivalent or even larger than deforestation. In Indonesia large forest areas have been converted to plantation and circa 60 % of the remaining forest are under logging concession. Today Indonesia's forests are some of the most threatened on the planet. Indonesia's forests are being degraded and destroyed by logging, mining operations, large-scale agricultural plantations, colonization, and subsistence activities like shifting agriculture and cutting for fuelwood. Rainforest cover has steadily declined since the 1960s. Legal timber harvesting affects 700,000-850,000 hectares of forest per year in Indonesia, but widespread illegal logging boosts the overall logged area to at least 1.2-1.4 million hectares and possibly much higher. Indonesia combines practically all drivers for deforestation act in a combined way, deforestation is expected to continue in the future.

Madagascar lost an average of 37,000 hectares per year between 2000 and 2005 according to the U.N. This represents a 42 percent drop since the 1990s. Despite considerable international conservation efforts, the overall results on deforestation have been small (Harezga 2007). Conservation laws are not enforced and highly structured environmental institutions do not cooperate with each other (Gezon, 1997). The failure of the global conservation efforts on Madagascar can be largely attributed to socioeconomic factors (Harezga 2007). The financial aid did not improve the economic conditions of the general population. Poor socioeconomic conditions created a situation where the local population is in direct conflict with the conservation needs (Ferraro, 2002). Due to the unresolved socio-economic problems, it is expected that deforestation continues in the future in Madagascar. The economic development of the growing population will largely influence the deforestation rates.

Papua Newguinea (PNG) has been affected by large deforestation and forest degradation processes with a high regionalization of the forest change patterns. Drivers which lead to forest area changes are quite different in different geographic regions. In general it could be reported that massive conversion of low land forest in oil palm plantations occurred especially in the New Britain island; large deforestation occurred due to unsustainable use of fire in the mountain and in the costal regions of the Papua island, and that forest degradation due to logging was occurring in the internal region with lowland forests like in the Gulf and West Provinces. The large losses of forest area are a recent process, that has started during 80's and that has reached its maximum during 90's when circa 0.5 - 0.9 % of forest area was converted every year. The most critical years were 1997 and 1998 when many fires occurred which were facilitated by climate anomalies (El Niňo, la Niňa). Since 2000 deforestation rates were constantly decreasing being always below 0.5%. The area affected by forest degradation, was equivalent to deforestation from 1990 to 2000 while between 2000 and 2005 the area of forest degradation was larger than forest area converted to other land use. It is very difficult to predict future deforestation trends for PNG, the uncertainties are mainly related to the unique social structure system of this country where land tenure rights are hold by tribes (in PNG there are more than one thousand tribes) and where often traditional conducts prevail over state organization. In recent years, after 2000, the country experienced a slow down of the deforestation processes, but there are no clear explanations for that. On the one hand there are no economic incentives to keep forests and on the other hand the State control of land is very weak.

For **Peru** recent data (Oliveira, et al., 2007) shows that deforestation is lower than the data reported by the Peruvian Government to FAO (see Table 1 and 2). According to Oliviera et al. (2007) deforestation in Peru also shows a very large inter-annual variability with a range from 192 to 1174 km^2 of deforested area per year. The last year for which data is available is the year from 2004 to 2005, with a maximum of deforestation area of 1174 km^2, and a maximum of degraded forest of 1070 km^2. For verification of official data Peru, through cooperation with the Brazilian organisation INPE, is establishing a national forest monitoring system. This system will adopt the Brazilian Prodes project methods and techniques. Oliveira at al (2007) concluded that land-use policies in Peru have been key to tempering rain forest degradation and destruction. Due to the designation of commercial timber concessions to large new areas and the improvement of road infrastructure to forests, deforestation in Peru is expected to continue in the future with rates that may be similar as those analysed by Oliveira et al (2007) in the recent past.

Biomass and C stocks

For some countries new biomass values were established for this study - especially for the most dominant forest types. Table 3 shows the carbon stocks per hectare in aboveground biomass for the focus countries from different sources.

Table 3 *Overview of carbon stocks per hectare in above-ground biomass from different sources*

	Carbon in above-ground biomass (Mg ha^{-1})												
	Marklund & Schöne (2006) regional average	FAO (2006) average of all forest	Arithmetic mean of IPCC default values for all relevant tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types			Number of forest types		Deviation of IPCC weighted mean from IPCC all forest average (%)		
			mean	min	max	mean	min	max	reported	used	mean	min	max
Brazil*	110	105	94	29	170	81	36	129	5	5	-14	23	-24
Peru	110	123	94	29	170	141	86	182	16-39	7	51	193	7
Congo	155	107	94	35	152	155	65	255	1	1	65	84	68
Madagascar	64	97	48	35	60	92	69	134	2	2	93	96	122
Indonesia	77	68	106	34	171	167	129	252	0	2	57	275	48
Papua New Guinea	55	29	106	34	171	132	79	219	9	7	24	131	28

Notes: ** For the weighted approach, carbon stock values were derived from Ministry of Science and Technology (2006) and not from IPCC (2006.)*
Only natural forest cover considered, excluding plantations
The application of an arithmetic mean across all forest types per continent is compared relative to a weighted average across forest types and their proportion in the national forest area

Source: calculations MPI-BGC, J. Dietz

This table shows that the weighted mean of C stocks in aboveground biomass from national data for Brazil is lower than the FAO average and data from Marklund & Schöne for Brazil. The weighted average C stocks elaborated in this study for Peru, Congo-Brazzaville, Indonesia and Papua New Guinea are higher than the FAO average. The largest differences occur for Indonesia (167 Mg ha^{-1} from this study compared to 68 Mg ha^{-1} from FAO FRA 2005) and for PNG (219 Mg ha^{-1} from this study compared to 29 Mg ha^{-1} from FAO FRA 2005 and 55 Mg ha^{-1} from Marklund and Schöne 2006).

Table 4 shows the differences in estimates for total C losses lost from above-ground biomass (AGB) and all pools (Total) between 1990 and 2005 from deforestation for the focus countries estimated using the carbon stock values elaborated in this study and using FAO data. For aboveground biomass the C loss is 4.5 times higher for PNG using the C stock data elaborated as part of this study than with the FAO data. The loss is 2.5 times higher for Indonesia than the values calculated with the FAO average. For Brazil, the opposite situation occurs and the C loss is only 77% of the amount using the FAO average C stocks.

Table 4 *Carbon lost from above-ground biomass (AGB) and all pools (Total) between 1990 and 2005 through deforestation estimated using different carbon stock values*

		Carbon lost to deforestation 1990 - 2005 (Tg)											
		FAO (2006) average of all forest	Arithmetic mean of IPCC default values for all relevant tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types			Number of forest types		Deviation of IPCC weighted mean from IPCC all forest average (%)		
			mean	min	max	mean	min	max	reported	used	mean	min	max
Brazil	AGB	4805	4311	1352	7819	3706	1668	5912	5	5	-14	23	-24
	Total*	*n.d.*	6107	2590	10271	5261	2903	7810			-14	12	-24
Peru	AGB	252	193	61	350	291	177	374	16-39	7	51	193	7
	Total*	*n.d.*	276	119	462	381	249	477			38	109	3
Congo	AGB	29	26	10	41	42	18	70	1	1	65	84	68
	Total*	*n.d.*	38	19	57	56	28	88			48	47	54
Madagascar	AGB	91	45	33	57	86	65	125	2	2	93	96	122
	Total*	*n.d.*	71	56	85	116	91	161			64	62	90
Indonesia	AGB	2255	3527	1138	5656	5523	4262	8358	0	2	57	275	48
	Total*	*n.d.*	5108	2268	7636	7176	5726	10391			40	152	36
Papua New Guinea	AGB	66	243	78	390	303	181	499	9	7	24	131	28
	Total*	*n.d.*	358	155	545	418	269	656			17	74	20

Notes: *Only natural forest cover considered, excluding plantations.*
** Combines the loss of 100% above-ground biomass, 80% below-ground biomass, 100% litter, 100% dead wood, 40% soil organic carbon.*
The application of an arithmetic mean over all possible forest types per continent is compared relative to a weighted mean over various forest types. For periods 1990 - 2000 and 2000 - 2005 see annex 4.

Source: calculations MPI-BGC, J. Dietz

GHG emissions

For the estimation of GHG emissions from deforestation for the focus countries two different scenarios were calculated based on different assumptions related to the role of burning in deforestation:

1. One scenario assumes no burning activities. Deforestation converts forest carbon stocks to CO_2 and some CH_4 emissions from decay of litter and dead wood arise (low GHG emission scenario).

2. The second scenario assumes that all deforestation occurs through burning. Besides CO_2, N_2O and CH_4 emissions arise from forest fires (high GHG emission scenario).

These two scenarios should indicate the range in greenhouse gas emissions if non-CO_2 emissions from forest fires are taken into account. Table 5 compares both scenarios on the basis of CO_2 equivalents. This shows that clearing all deforested areas through burning could lead to an increase of greenhouse gas emissions from above-ground biomass alone by 11 % (3 – 17 %) and considering all carbon pools this increase is enhanced to 17 % (11 – 25 %).

Table 5 *Comparison of greenhouse gases as CO_2 equivalents released in the period 1990 – 2005 under the high and low greenhouse gas scenarios*

		Greenhouse gases released from all forest lost in the period 1990 - 2005 (Tg CO_2 equivalents)								
		High GHG scenario			Low GHG scenario			Additional GHG emissions in the case of total loss due to burning		
		mean[a]	min[b]	max[c]	mean	min	max	mean	min	max
Brazil	AGB[d]	15123	6302	25370	13588	6118	21679	1535	184	3691
	Total[e]	23164	11849	36492	19292	10646	28635	3873	1203	7857
Peru	AGB[d]	1189	670	1604	1068	651	1370	121	20	233
	Total[e]	1646	1020	2190	1397	915	1747	249	105	442
Congo	AGB[d]	172	67	298	155	65	255	18	2	43
	Total[e]	243	113	404	206	103	322	37	11	83
Madagascar	AGB[d]	353	245	538	317	238	460	36	7	78
	Total[e]	500	373	737	426	334	589	74	38	148
Indonesia	AGB[d]	22537	16099	35867	20249	15628	30648	2288	471	5219
	Total[e]	31010	23498	47879	26313	20997	38102	4697	2502	9777
Papua New Guinea	AGB[d]	1235	685	2142	1109	665	1830	125	20	312
	Total[e]	1799	1094	3018	1532	986	2405	267	108	613

Notes: *Only natural forest cover considered, excluding plantations.*
[a] calculated with 51 % of all carbon lost through fire (Kauffman et al. 1995).
[b] calculated with 42 % of all carbon lost through fire (Fearnside et al. 1999, 2007).
[c] calculated with 29 % of all carbon lost through fire (Fearnside et al. 2001).
[d] Loss completely through fires using the high trace gas scenario of Fearnside (2000).
[e] Combines the loss of 100 % above-ground biomass through flaming combustion, 80 % below-ground biomass through decay, 100 % litter through smoldering combustion, 100 % dead wood through smoldering combustion, 40 % soil organic carbon through decay (Fearnside 2000).

2.1.3 Results at global level

The first attempt to assess emissions from global deforestation has been performed by Houghton and colleagues (Houghton et al., 1983, 1985; Houghton, 1999, 2003). They have compiled land-cover change information from forest inventories and estimated global carbon emissions of 2.2 PgC yr^{-1} in the 1990s (compared with 6.4 PgC yr^{-1} from fossil-fuel emissions) and a total release of 156 PgC over the 1850–2000 period (Achard et al. 2007). Recently, several new estimates of carbon emissions from deforestation have emerged. Fearnside (2000) estimated that tropical land-cover changes resulted in a net emission of 2.4 PgC yr^{-1} during the 1981–1990 period. More recently, DeFries et al. (2002) and Achard et al. (2002, 2004) have used remotely sensed tropical deforestation data to estimate releases of 0.3–0.8 PgC yr^{-1} in the 1980s and 0.5–1.4 PgC yr^{-1} in the 1990s. These satellite-based estimates suggested that Houghton and colleagues and Fearnside (2000) have overestimated carbon emissions from land-cover change by up to a factor of two (Table 6), mainly because of different estimates of the rates of tropical deforestation (DeFries & Achard 2002). However, these different studies are not directly comparable. They covered different geographic ranges and time periods, considered different types of land-cover changes, made different assumptions about historical land-cover change, and used different carbon cycle models.

Table 6 *Average annual rates of deforestation (Mio. ha, yr^{-1}) in tropical regions in the 1990s*

	Average annual deforestation rates in tropical regions		
Regions	**FAO (2001)**	**DeFries et al (2002)**	**Achard et al. (2004)**
	[Mha yr^{-1}]		
Amercia	5.2	3.982	4.41
Asia	5.9	2.742	2.84
Africa	5.6	1.325	2.35
Total	16.4	8.049	9.60

Note: *all sources refer to gross rates of forest loss (not including forest area increases)FAO rates are based on forest inventories, national surveys, expert opinion, and remote sensing. The estimates of DeFries et al and Achard et al are based on remote sensing data.*

Source: Houghton 2005

Besides the difference in forest definitions used related to canopy cover and tree heights, the in- or exclusion of plantation areas in the forest estimates also causes differences in total forest areas for individual countries. Despite the apparent precision of the quoted figures for the rates of deforestation, the exact area of forest lost each year is not known. The accuracy of estimates is hampered by the lack of reliable and consistent time-series data, varying standards for forest and non-forest classification, inadequate ground-truthing of satellite imagery, and the institutional weakness of government forest departments in a number of countries (Fuller 2006).

The estimation of C losses due to deforestation at global level in this study required some generalization. The overall forest area loss data were adopted from FRA 2005 (FAO 2006, Table 2.4) and for C stocks the simpler and generally lower above-ground biomass stock values from the arithmetic mean approach of the IPCC default data and from the regional means from FRA 2005 (FAO 2006) were used. In addition a weighted mean for the regions consistent with the approach used on the country level. This required the assumption that the proportion of the respective forest types outlined in the FRA 2000 (FAO 2001) remained constant over the entire observation period. Table 7 shows the global C losses at regional scale. These estimates are most likely a strong underrepresentation of the true magnitude of emissions from deforestation because i) only the above-ground biomass pool is considered and ii) these estimates from the approaches used here have been shown on country-level to be systematically lower than values obtained at higher data resolution.

Table 7 *Carbon lost in the tropics on the regional scale from above-ground biomass (AGB) between 1990 and 2005 through deforestation estimated using two different carbon stock values*

	Carbon lost from above-ground biomass due to deforestation 1990 - 2005 (Tg)						
	FAO (2006) average of all forest	Arithmetic mean of IPCC default values over all tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types		
		mean	min	max	mean	min	max
Caribbean	-79	-120	-40	-155	-164	-93	-218
South & Central America	12913	12137	3845	20922	14254	9665	21534
Northern Africa	359	1328	1056	1598	1863	1863	1863
Western & Central Africa	3822	4199	1581	6806	5330	2869	8430
Eastern & Southern Africa	2167	3247	1817	4672	3874	2755	5858
South & Southeast Asia	6768	8380	3505	12975	9686	5738	12774
Oceania	1174	1282	414	2056	1902	1477	2812
Tropical countries Total	27124	30453	12177	48875	36746	24274	53052

Note: For periods 1990 - 2000 and 2000 - 2005 see annex 4

Source: calculations MPI-BGC, J. Dietz

Currently many projects, such as JRC TREES 3, FAO FRA2010 or NASA Landsat Pathfinder Humid Tropical Deforestation Project, aim at obtaining new information and estimations on emission from tropical deforestation. New data on global emission will only be available around 2010.

Since there are large uncertainties related to the estimates of GHG emissions from past and current tropical deforestation, projections of future emissions from deforestation are even more uncertain and there are not so many recent sources that quantified the emissions from future deforestation.

If today's deforestation rates continue, Houghton et al. (2005) project that another 87 to 130 Pg C will be released from deforestation in the tropics over the next 100 years and that annual C emissions from tropical deforestation will remain at a level of 2.1 Pg C/yr until 2012. The largest forest declines in this long-term projection result from the near elimination of forests in Asia (Myanmar, Indonesia and Malaysia), Latin America (Peru), and Africa (Benin, Ivory Coast, Nigeria, and Zambia) (Houghton et al. 2005).

Another recent estimate for the global deforestation trend has been released by IIASA (Kindermann et al. 2006). The IIASA baseline scenario shows that close to 200 Mio. ha or around 5% of actual forest area will be lost between 2006 and 2025 resulting in a release of additional 17.5 Pg C. Within the next 100 years, today's forest cover will shrink by around 500 Mio. ha, which is 1/8 of the current forest cover. The accumulated carbon release during the next 100 years amounts to 45 Pg C, which is 15% of the total carbon stored in forests today. Thus, the IIASA long-term estimate is only about half of Houghton's low estimate, indicating the considerable uncertainties for such projections. However, even the lower estimate indicates that urgent action is necessary to avoid the release of such huge amounts of emissions.

2.2 Relationship between deforestation drivers and deforestation rates

Any future climate regime addressing incentives for reducing deforestation has to be aware of the multitude of drivers for tropical deforestation. Direct causes of deforestation can be separated into natural and anthropogenic drivers. Geist and Lambin (2002) conclude in a study on deforestation drivers that "tropical forest decline is determined by different combinations of various proximate causes and underlying driving forces in varying geographical and historical contexts." Especially underlying driving forces of deforestation such as national- to global-scale economic opportunities and policies often react in a combined way and depend on several variables, which may be hard to predict. With regard to the quantitative relationship between deforestation drivers and deforestation rates Kaimowitz and Angelsen (1998) reviewed different deforestation models and concluded that *"most researchers agreed that more roads, higher agricultural prices, lower wages and a shortage of off-farm employment generally led to more deforestation, but that the effects of agricultural input prices, household income levels, tenure security, population growth, poverty reduction, national income, economic growth, and foreign debt were unclear"*. They also pointed out the difficulty of using global regression models, since the data limitation and poor quality make it hard to distinguish between correlation and causality. Even if statistical relationships are found, they do not need to be attributed as causes of deforestation. Correlations need to be evaluated carefully by testing them against country case studies. Vanclay (2005) pointed out that a statistical analysis of deforestation might be difficult, since the reliability of deforestation estimates varies by countries. This might increase error ranges and thus limit the significance of results based on global statistics. None of the studies reviewed for this report could find clear factor relationships for deforestation drivers applicable to predict forest area changes.

Despite of these data uncertainties and limitations, in this report statistical relationships between national deforestation rates and biophysical / socio-economic as well as governance-related deforestation drivers in the tropics were elaborated to develop criteria for the robustness in deforestation trend predictions. For the period 2000-2005, for all tropical countries the significant univariate correlations with forest area change were found with the variables 'Population Growth', 'Total fertility rate' and 'Public expenditure for education'. However, these variables showed only an explaining power of less than 15 percent of deforestation each. For 1990-2000 only two variables, 'Human poverty index' and 'Adult illiteracy' showed significant correlations, with the latter yielding only an R^2 of 0.082 as explaining variable in the stepwise regression.

The results of the regression analysis for all tropical countries revealed that the individual country circumstances are often too different from each other to find similar striking correlations in both periods. However, the results indicate that population-related parameters play an important role in explaining deforestation. Furthermore, for both times series the importance of education is clearly visible. Additionally, the security of property rights can be considered a positive incentive to improve countries' economic performance. A government without the mechanisms to enforce property rights gives room for innumerous types of illegal activities related to forest use. As a result, the legal structure and security of property rights make a substantial contribution not only to preserve and sustainably manage natural resources.

2.3 Approximation of the possible magnitude of emission reductions from a RED mechanism

For a rough approximation of the potential magnitude of emission reductions from a RED mechanism three scenarios were calculated:

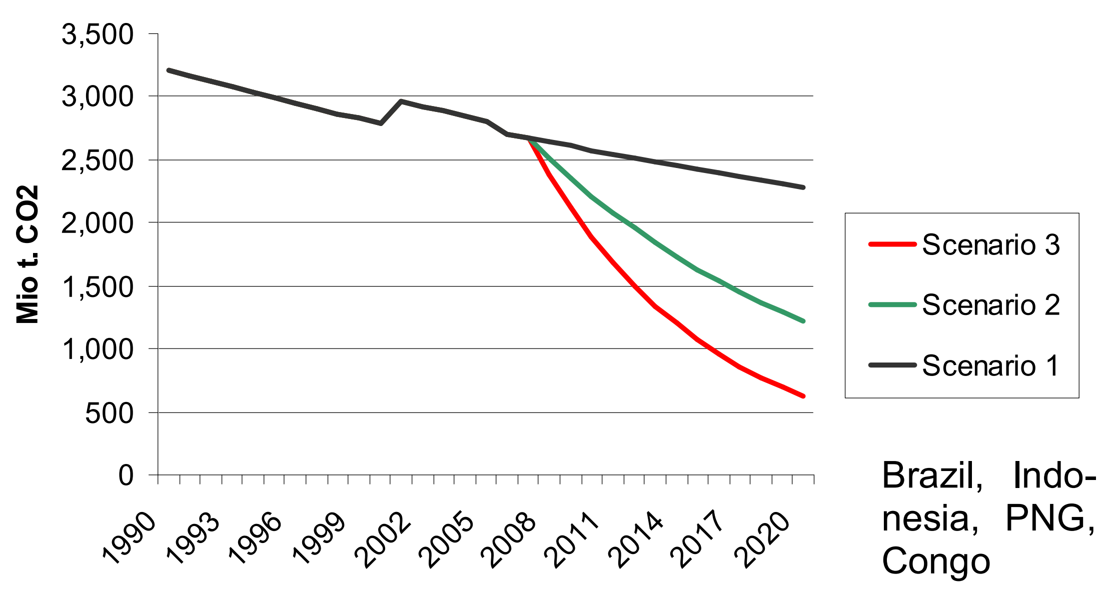
- **Scenario 1**: constant deforestation rate as in the period 2000-2005
- **Scenario 2:** deforestation rate decreases by 5% annually after 2008 (deforestation is reduced by 50% within a decade)
- **Scenario 3:** deforestation rate decreases by 10% annually after 2008: deforestation is reduced by 50% within 5 years

The first scenario could be interpreted as business-as-usual scenario without any changes in deforestation since the year 2000. Such a scenario implies that less emissions are occurring from deforestation as compared to the past because the constant rate of deforestation refers to a shrinking forest area. Countries could therefore reduce their absolute emissions even without a change in the rate of deforestation.

Figure 1 illustrates the CO_2 emissions from deforestation in the three scenarios for Brazil, Indonesia, Papua New Guinea and the Democratic Republic of Congo (for average biomass stock values).

The emissions from deforestation in 2020 could be reduced from 2,278 Mt CO_2 to 1,217 Mt CO_2 or to 620 Mt CO_2 if the deforestation rate would be reduced by 5 % (scenario 2) or 10% (scenario 3) respectively per year as compared to scenario 1 (using average biomass carbon stock values). This is equivalent to an emission reduction of 1,061 Mt CO_2 (if the deforestation rate is reduced by 5 % annually) and 1,658 Mt CO_2 (if the deforestation rate is reduced 10 % annually) in 2020 compared to the BAU scenario (scenario 1). These amounts of emissions reductions due to reduced deforestation (1,061 Mt CO_2 – 1,658 Mt CO_2) for the four countries only would be equivalent to 25-40% of total EU-15 GHG emissions in 2005 or 15-23% of total US emissions in 2005.

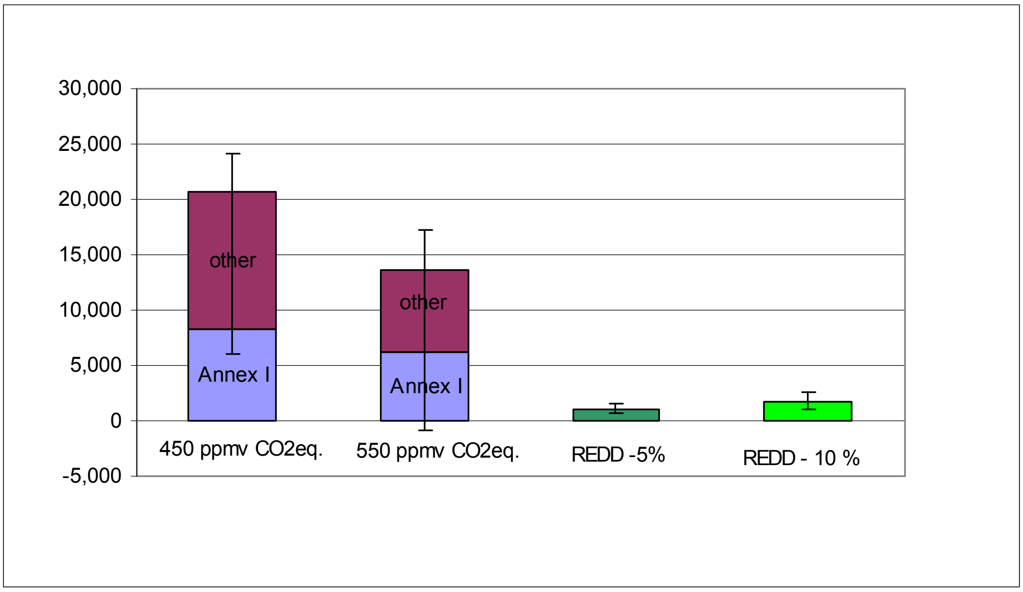
Figure 1 *Aggregated CO_2 emissions from deforestation for the countries Brazil, Indonesia, Papua New Guinea and Congo in the three scenarios*



Notes: *Scenario 1 = constant deforestation rate as in period 2000-2005*
Scenario 2 = deforestation rate reduced by 5% annually after 2008
Scenario 3 = deforestation rate reduced by 10% annually after 2008

Source: calculations MPI-BGC and Ecofys

Figure 2 *Potential emission reductions due to reduced deforestation in Brazil, Indonesia, PNG and Congo compared to global emission reductions necessary in other sectors to reach stabilization of CO_2 concentration at 450 and 550 ppmv CO_2eq. for 2020*



Source: calculations Ecofys, data for global reductions from Höhne et al. 2007

Figure 2 shows the potential reductions due to RED (from Brazil, Indonesia, PNG and Congo) as compared to the global emission reductions (Annex I and Non-Annex I countries) under the 450 ppmv and 550 ppmv scenario. The assumed Annex I GHG reduction target is - 35 % (450 ppmv) and -24 % (550ppmv) as compared to the level of emissions in 1990. If the deforestation rate would be reduced by 5% annually, emission reductions achieved in Brazil, Indonesia, PNG and Congo would represent around 5 % of global emission reductions necessary to reach the stabilization scenario at a level of 450 ppmv CO_2eq. and almost 8 % to reach 550 ppmv level. For the scenario in which the deforestation rate is decreased by 10 % annually, RED would be in the range of 8 % to almost 12 % of global emission reductions necessary to reach the respective stabilization levels. Uncertainty ranges of these values are however considerable. Therefore, we advise to interpret these results against the background of the simplified assumptions made.

Considering that the potentials for emission reductions from reduced deforestation are rather underestimated and that these estimates only include four selected countries, the results show that RED can represent a significant proportion of the overall emission reductions necessary to reach a stabilisation of GHGs in the atmosphere at 450 or 550 ppmv CO_2eq.. If these emission reductions would result in fully fungible credits in an international emission trading market, the potential high supply of credits from a RED mechanism could endanger the stability of the carbon market. Our simplistic calculations do support the argument that under current circumstances a market-based approach with fully fungible RED credits is probably not appropriate.

2.4 Establishment of reference emission levels and accounting issues for a compensation mechanism for reducing deforestation

For a RED mechanism in a post-2012 climate regime it is necessary to establish a measure to calculate the performance of the participating country in reducing deforestation. For this purpose a reference level is necessary against which the achieved efforts of participating countries are compared and then compensated. A number of proposals for reference emission levels have been put forward in the recent discussion on a RED mechanism and this report discusses some of the problems and challenges in the implementation of these proposals.

The simplest option for a reference level is the amount of historic deforestation. Historic deforestation rates are proposed by many Parties under the UNFCCC and by proposals from scientific institutions or NGOs. However, there is a considerable gap in information on current deforestation trends in many tropical countries and for most countries no consistent time series of deforestation areas is available. A second option for the establishment of reference levels are projections of future emissions from deforestation. The lack of data on current deforestation trends automatically leads to high uncertainties for the projection of future deforestation. In addition there are many drivers for deforestation which are interacting in a complex way and which are difficult to predict. Therefore projected reference levels have high uncertainties.

Time series consistency of methods and data is important to ensure credible and reliable estimation of emission reductions. The estimation of forest area changes and related C stocks should follow the same methods for the reference period and the commitment period. The requirement of time-series consistency potentially excludes some of the more recent advances in remote sensing technologies for the first accounting period because such data are not available retrospectively for past deforestation.

For accounting purposes, the final estimates for reference emission levels and commitment period emissions do not necessarily need to be very accurate, but they need to be consistent over time and they should be conservative. Time-series consistent means that the reference level and the level during the commitment period should be based on the same methods to avoid that a shift in methods leads to reduced emissions. Conservative means that the methods should ensure that at least the amount of emissions for which a country is compensated, was really reduced whereas the real emission reduction may be higher. This is an important difference to the task of producing reliable estimates for global, regional or national emissions from deforestation.

The establishment of historic deforestation areas for reference levels requires additional methodological guidance with regard to

- The monitoring approach to be used, e.g. wall-to-wall assessment of the full country area or adequate sampling size for satellite data;
- Forest definition and canopy cover rules to be applied for the detection of forest and non-forest areas with remote sensing technologies;.
- Establishment of required resolution and the minimum clearing size that should be identifiable with remote sensing technologies;
- The determination of the historic period to be used for the establishment of reference emission levels. Time series consistency of methods for the establishment of the reference level and during the commitment period should guide this decision. It is recommended to start the historic data in 1990 where high resolution Landsat data is available. The most recent year that enters the reference level needs to be defined. A recent year should be chosen in the period before the countries decide on their participation in a RED mechanism to avoid that the reference levels can be actively increased by deforesting larger areas.

Biomass

As a second step in the establishment of reference emission levels, detected area changes have to be converted into carbon that was saved. The carbon stocks depends on the forest type concerned, thus depending on the areas where deforestation would have occurred, the amount of carbon that would have been released differs.

The distribution of forest biomass throughout the tropics is poorly known. Many biomass estimates were largely for intact, or undisturbed forests, while both natural disturbances and human activities add variability to the distribution of biomass. However, it is important to note that it may not be essential for the accounting of reduced deforestation that very detailed and accurate data on forest carbon stocks and their spatial distribution in a country are available. On the one hand it is anyway impossible to determine the exact spatial distribution of forests that would have been deforested in the absence of the RED mechanism. This means that the reduced emissions cannot be related to exact spatial areas and default approaches and national reference carbon values have to be developed for the accounting. On the other hand, it is important to develop a conservative accounting approach that uses conservative default factors in countries with poor forest biomass data. From accounting perspective, an approach based on different tiers could be implemented depending on the data availability in the participating countries, similar to current IPCC methods for the estimation of emissions and removals in GHG inventories.

As a simple **default method**, for each country a weighted average of aboveground biomass and C stocks across forest types can be established based on IPCC default C stock estimates for forest types and FAO data on spatial distribution of forest types from global forest ecosystem mapping approaches. To make the approach conservative in the absence of national C stock data, the lower value of the range of C stocks for different forest types should be used for the accounting purposes.

Higher tier methods could take into account more country-specific information at different levels. Instead of the IPCC default, a country-specific weighted estimate for aboveground biomass C stocks across all forest types would be an essential component. This country-specific default estimate should be the same for the reference level and during the commitment period. A default assumption related to the share of intact and degraded forests also needs to be developed. In the absence of country-specific data, a high share of degradation should be assumed. This assumption should be replaced by country-specific data on forest degradation and related carbon stock losses, if available. In case of countries with largely intact forest areas, country-specific biomass inventories can show that forest degradation is not relevant and does not need to be taken into account in the C stock estimation.

In large countries, in particular Brazil, a higher tier method could be based on average regional estimates for C stocks weighted across regional forest types or average estimates based on biome types. However this implies that the historic forest area reference is composed in the same way from regional data or for forest biome types. The national reference emission level would be calculated as the weighted reference emission levels across all regions or biomes.

This approach would not take into account carbon stocks in other forest carbon pools such as belowground biomass, dead wood or soil carbon. This is a reasonable simplification for the accounting of reduced deforestation, because the changes in other pools, in particular soils largely depend on the subsequent land uses to which the deforested areas are converted. The areas where deforestation was reduced can neither be located spatially nor can the subsequent land uses of hypothetical clearings be determined at national level. Therefore the accounting method should only refer to aboveground biomass.

The same arguments apply to the accounting of Non-CO_2 gases. Emissions of non-CO_2 gases are mainly related to the relevance of forest fires for deforestation. It is again hypothetical to determine how areas saved from deforestation would have been cleared. National defaults could be developed based on the role of fires in deforestation and would need to be applied for the historic reference level and the commitment period years. However, the impact of fires faces strong annual variability depending on climate effects in particular years. This means, such national defaults would fluctuate strongly over time. The efforts required to develop a reliable annual and historic national default seem high compared to the benefits of such approach.

In general, the methodological requirements for the accounting of carbon from reduced deforestation are different from the task to establish an accurate estimate for emissions from deforestation in a country and it is possible to use some conservative assumptions for the accounting purposes. Further discussion of these parameters is necessary, but it seems feasible to establish default factors.

A different approach to set reference emission levels for countries with low historic deforestation rates should be established because the objective to underpass historic emission levels is not applicable for such countries. It is suggested to develop criteria for the identification of tropical countries with low historic deforestation levels as a first step. This report discusses two different approaches to establish reference emissions for this group of countries. However, any general approach for the calculation of the compensation not related to national historic data, implies the risk that compensation is disconnected to any efforts necessary for forest conservation at the national level and the compensation received may not be used for forest conservation activities and policies. To avoid free-rider effects, incentives for forest conservation for countries with low past deforestation should be linked to the implementation of specific national policies and action for forest conservation and the implementation of national forest conservation programmes. If incentives are linked to such action, it may be more useful to develop a compensation approach that takes into account the costs for the conservation of forests instead of basing the compensation on a hypothetical amount of emission reductions achieved. A separate fund addressing these particular countries could be established and compensation could then be based on the proposed forest conservation activities and the related monitoring of such activities. Such approach could better take into account specific national circumstances as well as biodiversity aspects.

Periodic updating of reference emission levels is recommended because the reference levels may fail to take into account significant changes in recent years and maybe overly conservative or not sufficiently conservative in relation to the efforts required by Parties. The revision or updating period should correspond with the commitment period length, this means that the reference can be corrected after the first commitment period for the subsequent period. During one commitment period, the reference level should be fixed.

It is recommended not to adjust historic reference emission levels to take into account different national circumstances, socio-economic factors or drivers of deforestation. If the commitments should be further differentiated e.g. in relation to economic potentials of parties (e.g. related to least developed countries), it would be preferable to implement such differentiated commitments through the targets to be achieved and not through the historic reference. The use of a historic reference does not automatically imply that all emission reductions below the historic reference level are compensated, but different targets on this basis can be established, e.g. countries need to decrease emissions at least by 10% or 20% below historic levels before the compensation scheme starts.

An international scheme for financial compensation for reduced deforestation creates the need for a new international process of reporting, review and verification. Reporting requirements under the RED mechanism need to be established. Such reporting requirements would address the reporting of data and information necessary to replicate the estimation of the emission reduction. In addition to such technical estimation information, a second part of reporting requirements should address national forest conservation programmes and national policies for forest conservation implemented by the receiving countries to decrease deforestation. Such reporting would create a transparent link between the financial incentives provided and the forest policies and activities implemented by the receiving countries. The reporting would also promote the exchange on best practice activities across participating countries.

A review of the reported information would check whether the claimed deforestation reductions really occurred and whether the calculation of the associated emissions reductions have been performed in accordance with agreed monitoring and estimation methodologies. Such review could be organized in a similar way as the review of Annex I GHG inventories which are reviewed by international expert review teams in either country visits or in centralized desk reviews at the UNFCCC secretariat. However, the timing of such process would look different as an annual review process does not seem to be necessary. The review of the accounting of emission reductions from reduced deforestation would have two parts, first the review whether the reference emission level was established in accordance with agreed rules and guidance and secondly at the end of the commitment period, the review would check the estimation of the reduced emissions relative to the reference. Such review would mainly check the technical estimation methods.

For the participating countries, the establishment of historic reference levels and the accounting of reduced deforestation require considerable capacity building efforts and institutional arrangements to establish an institutional system able to continuously monitor deforestation, because such data is currently not collected on a systematic basis in many tropical countries.

3 Introduction and background

Forests and especially reducing emissions from deforestation are expected to play an important role in a post-2012 climate regime.

Global emission reductions of all sectors necessary to reach certain ambition levels (stabilising CO_2 equivalent concentrations at 450, 550 and 650 ppmvCO_2eq. have been calculated. As illustrated by Table 8, substantial emission reductions are necessary to achieve the stabilisation goals. Annex I countries would have to reduce emissions by 25 % to 45 % in 2020 and 70 % to 95 % in 2050 below 1990 levels in order to reach a stabilisation of GHG concentrations at 450 ppmv CO_2eq. For a 550 ppmv CO_2eq., the necessary emission reductions for Annex I would have to be between 15 % to 30 % in 2020 and 55 % to 90 % in 2050. However, none of the three above mentioned stabilisation levels can be reached without significant emission reductions in Non-Annex I countries in the long term. Since global deforestation accounts for around 20% of the annual anthropogenic GHG emissions (Gullison et al. 2007, IPCC WG 1 2007), forest conservation offers a considerable potential for emission reductions in developing countries.

Table 8 Emission reductions in all sectors excluding forestry necessary to reach different stabilisation scenarios

		2020	2050
450 ppmv CO_2eq.	Global *	+10%	-40%
	Annex I	-45% to -25%	-95% to -70%
550 ppmv CO_2eq.	Global *	+30%	-10%
	Annex I	-30% to -15%	-90% to -55%
650 ppmv CO_2eq.	Global *	+50%	+45%
	Annex I	-15% to 0%	-75% to -25%

Source: Höhne et al. 2007

In the first commitment period under the Kyoto Protocol, LULUCF activities are included in a limited way in the accounting of emissions and removals from LULUCF activities. Annex I Parties have to account for carbon stock changes resulting from ARD, and can elect whether they want to include forest management, cropland management, grazing land management and/or revegetation in the accounting under the Kyoto Protocol. CDM projects are limited to afforestation and reforestation activities. Emissions from global deforestation, in particular in tropical countries, are not addressed under the Kyoto Protocol, although they contribute with about 20% to global GHG emissions.

Some developing countries (Papua New Guinea, Costa Rica and others) have proposed at COP 11 in Montreal to include reductions of emissions from deforestation at national level in a post-2012 climate regime. This proposal has gained a lot of support and is currently further elaborated under the UNFCCC negotiations.

This report aims at assessing the implications and the implementation needs for a future international agreement to reduce GHG emissions that provides incentives or compensation for reducing emissions from deforestation in developing countries. This assessment includes

- An analysis of availability of data on forest area changes and related losses of biomass and GHG emissions for selected focus countries and at global level;
- An overview of forest area changes, biomass losses and carbon emissions for the focus countries and at global level;
- An attempt to quantify the relationship between deforestation drivers and deforestation rates;
- A discussion of uncertainties and variability of emissions from deforestation;
- An approximation of the possible magnitude of credits from a RED mechanism compared to necessary reductions;
- A detailed discussion of options related to the establishment of reference emission levels and accounting issues for a compensation mechanism for reducing deforestation;

The original objective of this project has also been to estimate emission reduction potentials and to develop estimates for future emissions from deforestation at global level and for focus countries. However, the project team did not succeed in gathering sufficient data to provide reliable estimates for future deforestation trends and related future emissions nor for reliable estimation of emission reduction potentials in individual countries.

4 Methodological approach

This chapter provides the background related to approaches, data sources or methods used in the following chapters of this report.

4.1 Categorization of countries and determination of focus countries

Countries were initially categorized based on their continental distribution in the tropical regions of Latin America, Africa and Asia. Finer categorization of countries within the continents was based on data availability, significance of forest cover, deforestation rates, and socio-economic parameters (e.g. population growth, production and consumption pattern and governance).

The following six focus countries were selected representing a wide range of regions, forest conditions and data availability:

- **Latin America:** Brazil, Peru
- **Africa:** Madagascar, Congo (-Brazzaville)
- **Asia/ Oceania:** Papua New Guinea, Indonesia

These focus countries were used as test areas for improved national estimates of forest area change, biomass stocks and assessment of deforestation trends. Each of the focus countries also represents a region based on the FAO classification: Brazil and Peru for South & Central America, Papua New Guinea for Oceania, Indonesia for South-East Asia, Congo for Western & Central Africa and Madagascar for Eastern & Southern Africa. The classification according the FAO regions was also used to investigate statistical deforestation driver relations in chapter 6.

Brazil (FAO: South America) features globally the largest tropical forest area, yet also one of the highest annual deforestation rates (Table 9). Brazil has a significant political impact on the region. The data situation with respect to remote sensing approaches is good, also owing to intense efforts by national institutions, e.g. INPE. A large number of research facilities maintain inventory and monitoring plots with a focus on the Brazilian Amazon, which harbors the greatest share of the national forest resources. Where these datasets were available, they were used for establishing a reliable estimate of biomass per hectare for the Brazilian Amazon which is the dominant forest type in Brazil.

Peru (FAO: South America) harbors the second largest tropical forest area in Latin America and is distinguished by a comparatively low deforestation rate (Table 9). The geographical classification of the natural landscapes would allow the analysis of several different forest types due to the rise of the Andean mountain range from the Amazon basin. Both, the orography and the current data situation of Peru, constitute a challenge to remote sensing approaches, whereas especially long-term studies have provided sufficient inventory data, with a pronounced focus on lowland rainforests of the Amazon basin.

Madagascar (FAO: Eastern and Southern Africa) has already been deforested to a large extent, fracturing existing tropical forests into patches, which are scattered over the country. However, deforestation still continues (Table 9). This situation has attracted the attention of manifold research projects and NGOs. Madagascar serves also as one of the pilot countries for German project efforts on reducing emissions from deforestation.

Congo -Brazzaville (FAO: Western and Central Africa) Congo-Brazzaville is dominated by lowland tropical rainforest paired with a low annual deforestation rate according to Table 9. The data situation is sparse which qualifies the Congo-Brazzaville as an appropriate training zone for the application of newly established methods for deforestation monitoring. Its neighbor Democratic Republic of Congo comprises globally the second largest area of tropical forest, with similar features as Congo. Despite its significant forest area in Central Africa, the data situation and access is even sparser than for Congo-Brazzaville, so this study focuses on Congo-Brazzaville.

Table 9 Selected characteristics of focus countries

Country	Population	Land Area	Forest Area 2005		Deforestation rate			Available datasets
	million	million ha	million ha	%	1990 - 2000 % / year	2000 - 2005 % / year	1990 - 2005 %	
Brazil	178.7	845.9	477.7	57	0.6	0.6	8.9	24
Peru	27.5	128.0	68.7	54	0.1	0.1	2.1	224
Madagascar	17.3	58.2	12.8	22	0.5	0.3	6.7	3
Congo-Brazzaville	3.8	34.2	22.5	66	0.4	0.1	1.2	1
Papua New Guinea	5.6	45.3	29.4	65	0.5	0.5	7.1	94
Indonesia	217.6	181.2	88.5	49	2.1	2.1	31.7	28

Source: FRA 2005 (FAO 2006)

Indonesia (FAO: South and Southeast Asia) is third globally in terms of tropical forest area which, however, is countered by an enormous annual deforestation rate (Table 9). The strong dissection of the country into numerous islands of the indomalayan archipelago and the overlap of two floristic regions is also reflected in a multitude of forest types. The peat forests of Borneo with their high soil carbon stocks deserve special attention. The national Agriculture University (IPB) and the Center for International Forest Research (CIFOR), both based in Bogor, have conducted research in that region for many years.

In Indonesia since 1989 a National Forest Inventory (NFI) has been established. The first NFI has been funded by World Bank and has been implemented with the technical assistance of FAO (United Nation Food and Agriculture Organization). The NFI design is based on a systematic sampling approach (20x20 km grid) with more than 1200 permanent field sampling plots. The size of these permanent plots is 1ha, and the measurement protocol is focused on above-ground biomass (trees). Since now each of these plots has been measured at least two times, presently national statistics of 1992, 1998, 2003 are available. Indonesia has already provided data on growing stock, biomass stock and carbon stock based on results obtained from NFI in 1992 and 1998. The data show large changes which have been occurred between 1990 and 2005 (e.g. more than 60 % of forest carbon stock). These data, even if probably affected by some inaccuracies, reveal Indonesia capability in reporting on forest degradation.

Papua New Guinea (FAO: Oceania) is endowed with a tropical forest area of significant extent, which, similar to Peru, covers a variety of altitudinal belts and is thus composed of very diverse forest types (Table 9). The political lead function of Papua New Guinea in the negotiations on reduced deforestation also facilitated the access to a large dataset of regularly assessed plot inventory data. Free remote sensing data has been sufficiently available due to own contacts.

4.2 Data sources

4.2.1 Regional assessments

Data sources for the global data assessment – mainly for the analysis of deforestation drivers – are summarized in Table 10. Forest area change as well as biomass and carbon values were adopted from the FAO FRA 2005 (FAO 2006). Default values for emission factors, combustion factors and fuel loads were based on IPCC AFOLU GPG 2006. The governance indicators used in the analysis were compiled from World Bank (control of corruption, government effectiveness, political stability, regulatory quality, rule of law, voice and accountability), International Transparency (corruption perception index), Fraser Institute (level of economic freedom, access to sound money, freedom to trade internationally, legal structure and security of property rights, regulation of credit, labour and business, size of government), and International Institute for Management Development (competitiveness). Data on socio-economic development were obtained from publications of the World Bank, and complemented with data from United National Development Programme (UNDP), United Nations Educational, Scientific and Cultural Organization (UNESCO), and World Health Organization (WHO).

Table 10 Deforestation driver data variables and sources

Type	Indicator	Unit	Source
Forestry	Land area, Forest cover change, plantation change, fire occurrence, forest functions, forest product import, export, production and consumption	relative growth rate	(FAO 2006)
Socio-Economics (Education)	Public expenditure on education (of primary, secondary or tertiary level) Youth literacy rate, Adult illiteracy rate	relative growth rate	(UNDP 2007), (UNESCO 2007)
Socio-Economics (Employment, infrastructure + ownership)	Male / Female un-/employment in forestry, agriculture, industry and services, Roads paved, Access to improved sanitation, public /private ownership	relative growth rate	(FAO 2006)(UNDP 2007), (IMF 2007), (Worldbank 2007), (FAO 2006)
Socio-Economics (Governance)	Corruption index, Control of corruption, Political stability, Government effectiveness, Rule of law, Competitiveness	Rankings	(TI 2007)., (Worldbank 2007), (IMD 2007)

Type	Indicator	Unit	Source
Socio-Economics (HDI+health)	Human Development Index, Life expectancy, People undernourished, Public/private health expenditure, Development Assistance and official aid,	index, relative growth rate	(UNDP 2007), (Worldbank 2007), (WHO 2007)
Population	Population total, density, distribution, urban/ rural population, Fertility rate, growth rate	index, relative growth rate	(UNDP 2007), (Worldbank 2007)
Economy	GDP/ GNI per capita, total growth rate, inflation, Merchandise trade, Inequality, Present value of debt, Wealth	(current US$), relative growth rate	(Worldbank 2007), (UNDP 2007)
Energy	Energy, primary total production, imports, exports, consumptions, energy stock changes, emissions, Electricity consumption	relative growth rate	(Worldbank 2007), (UNDP 2007)
Agriculture	Agricultural area, Agriculture, value added, Permanent crops, pasture; export, import, production, consumption and producer price of palm oil, cattle meat, soybeans and sugar cane	relative growth rate	(Worldbank 2007), (FAO 2006)

4.2.2 Biomass carbon stocks in focus countries

The assessment of biomass and carbon stock, respectively, in the forests for the selected pilot countries was based on available data from plot-based inventories in those countries. Available datasets of plot based forest inventories in the pilot countries were identified through a literature review and through existing contacts and requested from their respective sources (Table 11). Data availability and quality for the biomass assessment varied strongly among the pilot countries and called upon individual approaches for each country (Table 11). The data were checked for consistency and joined in a database.

The minimum requirement for the data was that all individual trees be censused on a plot of at least 0.5 ha, with measurement of the diameter at breast height (dbh), its lower threshold (i.e. the smallest size of trees by diameter which entered the inventory) and at least vernacular names. Desired data were description of the habitat including coordinates, botanical names (at least on the genus level), and tree height measurements (Table 12)

Brazil

Although forest inventory data especially from research project abounds in Brazil, only a fraction of it could be accessed within the project period. Extensive datasets exist among national institutions (INPE, EMBRPA), international institutions (CIFOR, GTZ) and within research networks (RAINFOR, Amazon tree diversity network, Large-scale Biosphere-Atmosphere Experiment, PAN-AMZONIA) and various research projects at European Universities (e.g. Göttingen, Leeds, Edinburgh, Turku). Data available to this project originated exclusively from the lowland rainforest of the Amazon basin, which dominates the country’s forests in terms of area and biomass stock. Using the available dataset synthesized from EMBRPA, RAINFOR, LBA and the Universities of Göttingen (Worbes), Turku (Tuomisto), and Leeds (Phillips) (Table 11) combined with sources from literature (Araújo et al. 1999, Fearnside et al. 1999, 2001, Kauffman et al. 1995) the lowland Amazonian rainforest was therefore the only forest type of Brazil, where biomass and carbon stocks could be reviewed independently in this study. Tree height data was available only for 4 out of 24 plot inventories (Table 12). Allometries used for the conversion of Amazon Rainforest stand data into biomass, were exclusively available for the Amazonian lowland rainforest (Table 13). Using this information, a carbon stock value could be calculated for the lowland rainforest of Brazil (Table 14).

For an improved estimate of emissions from deforestation in Brazil, however, it was essential to rely on distinct biomass stock values for each of the major forest types of Brazil, besides the Amazon Rainforest. Biomass stock data for all other forest types (Cerrado, Caatinga, Pantanal, Atlantic Rainforest) were derived from Ministry of Science and Technology (2006, Appendices 3.1.2, 3.2, 3.4, 3.6), consistent with the respective values for deforestation area in these forest types found in Ministry of Science and Technology (2006, Appendix 4).

Essentially, weighted mean biomass values and thus carbon stocks were calculated and applied for the entire forest area.

Peru

Our review revealed that plot based inventory data exist for Peru at least for the lowland rainforest and the montane rainforests of the eastern slopes of the Andes from a variety of sources. The data from a large number of plot-based inventories from the Peruvian portion of the south-western Amazon were available through the SALVIAS database and a number of individual investigators conducting research in the region (UNALM (Pino), ACCA (Pitman), Manu (Terborgh). Additionally, data from personal research of MPI-BGC members and data obtained from national sources (INRENA) and NGOs (AIDER, Table 11), allowed a description of the submontane and montane rainforests of the eastern slopes of the Andes. Occasionally, also measurements of tree height were available in those datasets (Table 12).

Allometries used for the conversion of forest stand data into biomass, were exclusively available for the Amazonian lowland rainforest (Table 13). For all other relevant forest types of Peru biomass stock data were based on IPCC default parameters from 2006 IPCC Guidelines (IPCC 2006, Table 4.7). Essentially, weighted mean biomass values and thus carbon stocks were calculated using the newly obtained carbon stock value for lowland rainforest and montane rainforest (Table 14) and applied for the entire forest area.

Congo-Brazzaville

The only plot based inventory data found for Congo within the period of this study was of low quality. This had made the Congo a prime example for a country with very limited data availability, where the IPCC default values from 2006 IPCC Guidelines were applied to the entire forest area because lowland rainforest dominates in that country.

Madagascar

The inventory data obtained from Madagascar were restricted to certain already degraded forest types which did not represent the remaining lowland rainforest that was intended as the focus of the study. Also due to a lack of appropriate allometries, the analysis focused on weighting IPCC default values from 2006 IPCC Guidelines according to forest types and their proportional land cover.

Table 11 *Cooperating institutions and their contributions of plot-based inventory data from the selected pilot countries*

Country / Region	Cooperating Institution		Number of contact persons	Datasets available	Datasets received
	National or governmental	Scientific			
Amazonia	CIFOR		1	*n.d.*	1
		RAINFOR	2	~ 90	4
		University of Leeds	2	*n.d.*	6
		University of Turku	1	*n.d.*	2
		University of Göttingen	3	12	4
Brazil	EMBRAPA		1	*n.d.*	2
		LBA	3	*n.d.*	5
Peru	AIDER		1	*n.d.*	4
	INRENA		3	*n.d.*	8
		SALVIAS	2	130	130
		UNALM	2	*n.d.*	6
		ACCA	1	> 120	54
		Manu	3	18	14
		Own Data		8	8
Africa					
Madagascar	GTZ		1	*n.d.*	2
		ETH Zurich	2	*n.d.*	1
Congo	GTZ		1	*n.d.*	1
Asia					
Papua New Guinea	Forest Research Institute		4	94	94
Indonesia	CIFOR		3	~ 70	4
		IPB	5	> 20	4
		UNTAD	2	7	7
		Own data		13	13

Table 12 *Inventory parameters available on plot basis from the selected pilot countries*

	Brazil	Peru	Madagascar	Congo	PNG	Indonesia
Forest type						
lowland	24	204	1	1	91	14
montane		18			3	13
other		2	2			1
Plot size						
< 1 ha	2	122	2			20
≥ 1 ha	22	102	1	1	94	8
dbh	24	224	2	1	94	28
threshold						
> 5 cm	2	62				4
> 10 cm	22	174	3	1	94	24
> 20 cm		8				
Tree height	4	76			94	20
Vernacular names	24	224	1	1	94	28
Botanical names	10	150			94	4
Coordinates	21	209	1		81	21

Papua New Guinea

A network of now 94 active permanent sample plots (PSP) has been created since 1992 mostly in the lowland rainforests of Papua New Guinea (PNG). Each of those plots measures 1 ha and has been revisited within a number of years, also before and after specific management operations.

The quality of the data from these plots is excellent and includes height measurements and botanical names of all trees with dbh ≥ 10 cm (Table 12). Submontane and montane forests are represented only by a very low number of plots, therefore calculation of a weighted average for biomass stock considered the IPCC default values from 2006 IPCC Guidelines for all forests above 1000 m above sea level. An allometric equation which was developed on national forest data by Alder and Synnott (1992) was used for converting inventory data into biomass and consequently carbon stock (Table 13).

Table 13 Allometries applied for converting stand inventory data into biomass volume on a regional and pantropical scale, wood density (ρ) used, and resulting biomass stocks

Forest type/ Country	Equation	Source equation	Wood density ρ (kg m^{-3})	Source	Biomass (Mg ha^{-1})		
					mean	min	max
Pantropical (wet)	$AGB = \rho \times \exp\{-1.239 + 1.98 \ln(D) + 0.207 [\ln(D)]^2 - 0.0281 [\ln(D)]^3\}$	Chave et al. (2005)			n.d.	n.d.	n.d.
Pantropical (moist)	$AGB = \rho \times \exp\{-1.499 + 2.148 \ln(D) + 0.207 [\ln(D)]^2 - 0.0281 [\ln(D)]^3\}$	Chave et al. (2005)			n.d.	n.d.	n.d.
Brazil lowland rainforest	$AGB = \rho / 0.67 \times \exp \{0.33 \ln(D) + 0.933 [\ln(D)]^2 - 0.122 [\ln(D)]^3 - 0.37\}$	Baker et al. (2005)	0.642	Nogueira et al. (2007)	221	142	311
Peru lowland rainforest	$AGB = \rho / 0.58 \times \exp [2.42 \ln(D) - 2.00]$	Baker et al. (2005)	0.608	Chave et al. (2006)	209	107	288
Peru montane rainforest	$AGB = [0.0396 (D^2H)^{0.9362}] + [0.005002 (D^2H)^{1.027}] + \langle 1/(0.025 + \{13.75 \times [0.0396 (D^2H)^{0.9326}]\}$	Ogawa et al. (1968)	0.496	Dietz et al., unpublished	117	46	156
Papua New Guinea lowland rainforest	$AGB = \rho \times -0.001508 + (4.4658 D^2 + 5.310227 D^2H - 0.061883 D^2H^2) / 100000$	Alder and Synnott (1992)	0.549	Eddowes (1977)	175	123	254

Notes: n.d. = not determined, AGB = aboveground biomass, D = diameter, H = height
For IPCC default values, please refer to Table 16.

Indonesia

The dissected shape of the Indonesian archipelago imposes a challenge to a coherent assessment of forest biomass, not only due to difficulties in the assessment of the forest extension but also due to a variety of existing forest types. Acquired data did originate from lowland rainforests on different islands such as Borneo, Sumatra and or montane forests on Sulawesi, however, they could not sufficiently describe the situation for the individual islands or forest types. Data on peat forests was lacking. Therefore, also literature data was used for approximating a common biomass stock for lowland rainforest stocks in Indonesia. For developing a weighted mean, IPCC default values from 2006 IPCC Guidelines were ascribed to montane rainforests and their share of the total forest cover was estimated as best-guess approximation at 10 % owing to a lack of reliable spatial data.

Table 14 Comparison of carbon stocks derived from default values to values calculated directly from inventory data in this study

	Carbon in above-ground biomass (Mg ha^{-1})						Deviation of carbon stocks from this study from IPCC default value (%)		
	Derived from default value (IPCC 2005, Table 4.7)			Calculated in this study from inventory data					
	mean	min	max	mean	min	max	mean	min	max
Brazil lowland rainforest	147	59	196	108	70	152	-26	18	-22
Peru lowland rainforest	147	59	196	102	52	141	-30	-11	-28
Peru montane rainforest	71	29	113	57	23	76	-19	-23	-32
PNG lowland rainforest	172	137	255	86	60	124	-50	-56	-51

Source: calculation MPI—BGC, IPCC

Table 15 Overview of the availability of essential parameters for reliable estimation of carbon stocks at national level.

	Brazil (5)			Peru (7)			Congo (3)			Madagascar (5)			Indonesia (7)			Papua New Guinea (7)		
	√	X	O	√	X	O	√	X	O	√	X	O	√	X	O	√	X	O
Inventories	1	4	0	2	3	2	(1)	1	2	(2)	1	2	1	3	3	1	2	5
dbh	+	+		+	+		+	+		+	+		+	+		+	+	
Wood density	(+)	(+)		(+)	-		-	-		(+)	-		-	(+)		+	+	
Allometry	+	-		+	-		-	-		-	-		-	(+)		+	(+)	
Species identified	(+)	(+)		(+)	(+)		-	-		-	-		-	(+)		+	(+)	
Tree height	-	(+)		-	(+)		-	-		(+)	-		(+)	(+)		+	(+)	

Note: The table lists the parameters with decreasing importance for the pilot country specified as available to this study (√), existent (x) or missing (o) for the distinct forest types in each pilot country (given in their numbers). Brackets indicate that these parameters are uncertain, insufficient or apply not to all forest types. No information can be provided for inventories that are missing or which are beyond our knowledge

4.3 Changes in forest areas in the focus countries

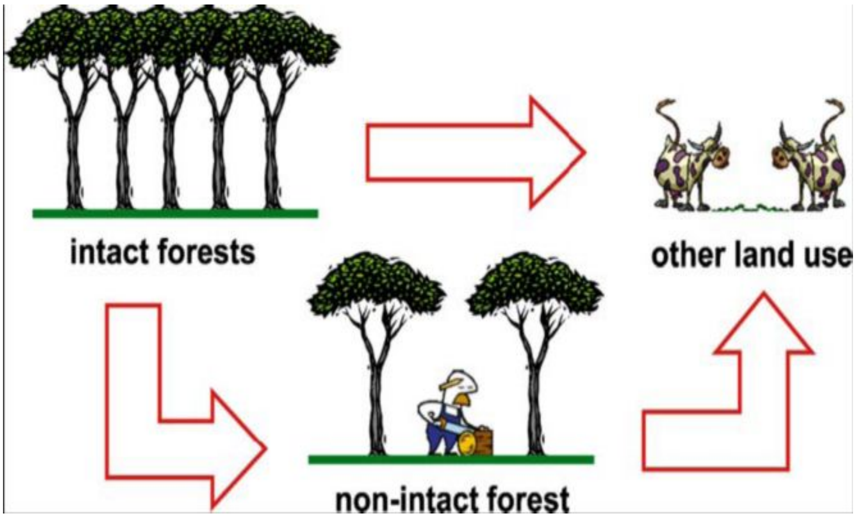
In the context of this research activity the assessment of forest area changes have been done using different approaches. For two countries Congo and PNG direct measurement based on satellite data have been done, while for the other focus countries only available data in literature have been used. Since the publication of data on historical deforestation rates at national level may have sovereignty issue in this report only general indication on the deforestation processes will be provided. Copies of the countries complete set of raw and elaborated data have been consigned to local institutions or country climate change focal points. This section describes the methodology that was used to assess forest area changes in Congo and PNG.

Forest land change is calculated using a systematic sampling approach. The observations are based on 0.5° latitudinal and longitudinal grid. Each observation is done on a plot of 400 km^2 (20x20 km). With that plot density and dimension the potential observed area of a country is 16%. The individual observations measure land forest areas at two dates using fine spatial resolution satellite imagery. The simplified land use classes include three forest classes (“closed forest”, “forest” and “open forest”) and three non-forest classes “plantations”, “rangeland / grassland” “other land use”. As the satellite data do not always correspond to the selected reference dates, 1990, 2000, 2005 we use a linear interpolation to adjust all land use change matrices of individual observations to these dates. The national land use change matrices are then calculated by the sum of each observation site matrix. The total forest cover for the two reference dates is obtained by summation of the individual class contributions (class areas weighted by their class forest proportion) for each date. Satellite images of fine spatial resolution, Landsat TM, Landsat ETM+, and ASTER (15m to 30 m), were selected over the observation sites, from the best quality existing acquisitions and at dates closest to our target years: 1990, 2000, 2005. Image analysis have been done through a two-stage hybrid learning classification approach based, in its first stage, on a fully automated spectral rule-based classification and, in the second stage, on a supervised post classification system, The analysis are pixel based with a minimum mapping unit for change detection elaboration of 1 ha.

In order to assess forest degradation (only in PNG) each forest land-use category has been divided in two sub-categories:

- Intact forests: fully-stocked (tree cover can be anything between 10 and 100% but must be undisturbed, e.g. there has been no timber extraction)
- Non-intact forests: not fully-stocked (tree cover must be higher than 10% to qualify as a forest under the existing UNFCCC rules, but in our definition this forest may have undergone some level of timber exploitation).

Figure 3 Forest conversions considered for each forest type in the assessment of the forest area changes



For the assessment of such forest areas, using satellite remote sensing methodologies, the “negative approach” have be used to discriminate between intact and non-intact forests: disturbance such as the development of roads can be easily detected, whilst the absence of such visual evidence of disturbance can be taken as evidence that what is left is intact (Aksenov et al. 2002).

The definition of intact forest adapted for our purpose is: forest land situated within the forest zone according to current UNFCCC definition; larger than 1,000 ha and with a smallest width of 1 km; containing a contiguous mosaic of natural ecosystems; not fragmented by infrastructure; without signs of significant human transformation (minimum size of isolated deforested or degraded patches to be considered from satellite imagery: 5 ha); and excluding burnt lands and forest re-growths.

Following the negative approach forest conversions between intact forests, non-intact forests and other land uses have been measured for the whole PNG territory. This process have been done using an on-screen visual interpretation approach as input data have been used the two GeoCover Landsat data mosaic realized by Nasa on 1990 and 2000 circa (https://zulu.ssc.nasa.gov/mrsid/mrsid.pl). In this context, the distinction between intact and non-intact forest is important to make given the current limitation in knowledge on the spatial distribution of biomass. Nevertheless this proxy solution is already fulfilling the requirements to report activity data on forest degradation under the Approach 3 of IPCC GPG 2003.

4.4 Biomass and GHG emissions due to biomass losses from tropical deforestation

The acquired data were imported into a database and screened for all available attributes. This was followed by a data consistency check to identify doubtful or possibly faulty entries, which were then corrected where possible, discarded where unacceptable, or replaced by the mean of the total data. Data were then converted to a common level to serve as a national standard depending on the least detailed information given, i.e. if data for a certain country included forest inventories with a dbh threshold of ≥ 10 cm, all trees dbh < 10 cm from other studies were not considered from any other inventories with lower dbh thresholds for the aim of a standardized approach. Only botanical names of tree individuals were maintained wherever available.

Allometric equations for converting stand inventory data to biomass volume were chosen from literature to match the sampled forest type appropriately (Table 13). The further conversion of volume into effective biomass is an inherent component of a number of the allometries used. Where possible and available, regional wood density average values were applied to this conversion; otherwise global means from Chave et al. (2005, 2006) were used.

Table 16 Default values for above-ground biomass in the tropical regions from the 2006 IPCC Guidelines (IPCC 2006)

	Above ground biomass (Mg ha^{-1})			Reference
	mean	min	max	
North & South America				
Tropical rain forest	300	120	400	Baker et al. (2004), Hughes et al. (1999)
Tropical moist deciduous forest	220	210	280	IPCC (2003)
Tropical dry forest	210	200	410	IPCC (2003)
Tropical shrubland	80	40	90	IPCC (2003)
Tropical mountain systems	145	60	230	IPCC (2003)
Subtropical humid forest	220	210	280	IPCC (2003)
Subtropical dry forest	210	200	410	IPCC (2003)
Africa				
Tropical rain forest	310	130	510	IPCC (2003)
Tropical moist deciduous forest	260	160	430	IPCC (2003)
Tropical dry forest	120	120	130	IPCC (2003)
Asia (insular)				
Tropical rain forest	350	280	520	IPCC (2003)
Tropical moist deciduous forest	290	290	290	IPCC (2003)
Tropical dry forest	160	160	160	IPCC (2003)
Tropical shrubland	70	70	70	IPCC (2003)
Tropical mountain systems	155	50	360	IPCC (2003)
Subtropical humid forest	290	290	290	IPCC (2003)
Subtropical dry forest	160	160	160	IPCC (2003)

The classification of the pilot countries' total forest areas into different forest types was taken from their national reports to the FRA 2005 (FAO 2006) where available. The reported forest types were ascribed to the default forest types registered in the 2006 IPCC Guidelines (IPCC 2006). The proportion of the individual forest types was calculated as percentage of total forest area cover. Where own data analysis from the plot based inventory data had produced a biomass value per hectare this value was applied for a particular forest type, else the corresponding IPCC default value was used (IPCC 2006, Table 4.7; cf Table 14 and Table 16). Eventually, a weighted mean was established according to the biomass values and proportions of the different forest types to be applied to the total forest area for the calculation of the total national biomass stock per country including upper and lower margins. Particularly for the regional assessment of carbon loss from above-ground biomass from deforestation, two different scenarios were considered. Country-level reference values were used from FRA 2005 (FAO 2006) or the arithmetic mean of all default ecological zones of the region was applied to the calculated annual forest area loss from deforestation. The carbon content in biomass was calculated at 49 % throughout this analysis (Hughes et al. 2000).

Table 17 Conversion factors used for computing below-ground biomass from above-ground biomass, adopted from the 2006 IPCC Guidelines (2006)

	Ratio below-ground biomass / above ground biomass			Reference
	mean	min	max	
Tropical rainforest	0.37	0.37	0.37	Fittkau and Klinge (1973)
Tropical moist deciduous forest				
AGB < 125 Mg ha^{-1}	0.20	0.09	0.25	Mokany et al. (2006)
AGB > 125 Mg ha^{-1}	0.24	0.22	0.33	Mokany et al. (2006)
Tropical dry forest				
AGB < 20 Mg ha^{-1}	0.56	0.28	0.68	Mokany et al. (2006)
AGB > 20 Mg ha^{-1}	0.28	0.27	0.28	Mokany et al. (2006)
Tropical shrubland	0.40	0.40	0.40	Poupon (1980)
Tropical mountain systems	0.27	0.27	0.28	Singh et al. (1994)
Subtropical humid forest				
AGB < 125 Mg ha^{-1}	0.20	0.20	0.25	Mokany et al. (2006)
AGB > 125 Mg ha^{-1}	0.24	0.24	0.33	Mokany et al. (2006)
Subtropical dry forest				
AGB < 20 Mg ha^{-1}	0.56	0.56	0.68	Mokany et al. (2006)
AGB > 20 Mg ha^{-1}	0.28	0.28	0.28	Mokany et al. (2006)

The application of wood density data, however, must be performed as an average value over all trees within an investigated forest stand (representing its particular species composition) and upscaled to the region. Therefore, a thorough application of these data requires detailed information on the species composition of a forest stand. As the taxonomic reliability of ‘local names’ has been proven to be dramatically low, a certain degree of botanical skills is required for the identification of trees to the species or at least genus level. However, inventory datasets are commonly fragmentary and/or taxonomical information is often incomplete which needs to be compensated. Since field and sampling work for botanical identification can be a laborious and often impossible task, a model approach is currently developed at the MPI-BGC drawing on Bayesian inference. The model is developed, based on appropriate inventory data from Papua New Guinea’s 94 permanent sample plots, and will soon allow the quantification of errors when compensating for incomplete datasets. The model inherits information from taxonomic levels and ascribes specific wood density values to trees of which only family or genus data are available with the associated error. In this way, such a model is intended to assist in facilitating and characterising upscaling processes of wood density data to stand and, depending on the inventory data, also to national levels.

All non-above-ground biomass carbon pools were assessed using 2006 IPCC Guidelines (IPCC 2006) defaults. For dead wood (coarse woody debris, CWD) 18.2 Mg C ha^{-1} was used as an average value; litter was assumed to contain 1.05 (1.0 – 1.5) Mg C ha^{-1}; below ground biomass was calculated from above-ground biomass stocks according to the default ratios provided by 2006 IPCC Guidelines (2006, Table 4.4; cf. Table 17), again weighted for the forest types' proportional contribution to the total forest area; also soil organic carbon stocks were calculated with reference to default values from 2006 IPCC Guidelines (IPCC 2006). To account for realistic scenarios, below-ground biomass was essentially assumed to be released after deforestation at 80 % and soil organic carbon at 40 %.

Conversion of carbon emissions to the mass of gaseous CO_2 occurred by simple multiplication of carbon mass by the factor 3.6667. Due to the lack of consistent data particularly on the area of deforestation by burning, the greenhouse gas emissions were calculated for the pilot countries in two scenarios:

i) A high greenhouse gas scenario assuming all deforestation to occur due to burning of the forests, accounting for CO_2, CH_4, N_2O. Conversion factors were only readily available for some Brazilian forest types and varied considerably. However, according to Fearnside (1999, 2007) all carbon lost from biomass through burning would constitute 42 % of all initial biomass carbon for the mean value. According to Fearnside (2001) the lower end would be at 29 % of all carbon released from biomass through burning and at most 51 % (Kauffman et al. 1995). For the partitioning of greenhouse gases produced per ton of carbon burnt, the conversion factors from the high trace gas scenario in Fearnside (2000) were applied, assuming above-ground biomass to be subject to flaming combustion, litter and dead wood to smoldering combustion and below-ground biomass and soil organic carbon to decay. For consistency with the low greenhouse gas scenario and to comply with current conventions, the unburnt amount of carbon was calculated to be purely emitted as CO_2.

ii) A low greenhouse gas scenario assumed, in consistency with IPCC reporting conventions, the conversion of all carbon stocks into emissions, which would be converted purely into CO_2, except for soil litter and dead wood which would be lost to decay, producing also traces of methane (CH_4). In this scenario, carbon would be emitted almost purely in form of CO_2 instead of other gases such as CH_4 and N_2O with a higher GWP.

Comparison between both scenarios was done on the basis of CO_2 equivalents based on IPCC global warming potentials. Methods for the estimation of emissions from forest fires are presented in Annex 2.

4.5 Methods for the investigation of quantitative relationships between drivers and tropical deforestation

4.5.1 Data sources

Data sources for the analysis of deforestation drivers in section 6 – are summarized in Table 18. Forest area change as well as biomass and carbon values were adopted from the FAO FRA 2005 (FAO 2006). The governance indicators used in the analysis were compiled from World Bank (control of corruption, government effectiveness, political stability, regulatory quality, rule of law, voice and accountability), Transparency International (corruption perception index), Fraser Institute (level of economic freedom, access to sound money, freedom to trade internationally, legal structure and security of property rights, regulation of credit, labour and business, size of government), and International Institute for Management Development (competitiveness). Data on socio-economic development were obtained from publications of the World Bank, and complemented with data from United National Development Programme (UNDP), United Nations Educational, Scientific and Cultural Organization (UNESCO), and World Health Organization (WHO).

Table 18 Deforestation driver data variables and sources

Type	**Indicator**	**Unit**	**Source**
Forestry	Land area, Forest cover change, plantation change, fire occurrence, forest functions, forest product import, export, production and consumption	relative growth rate	(FAO 2006)
Socio-Economics (Education)	Public expenditure on education (of primary, secondary or tertiary level) Youth literacy rate, Adult illiteracy rate	relative growth rate	(UNDP 2007), (UNESCO 2007)
Socio-Economics (Employment, infrastructure + ownership)	Male / Female un-/employment in forestry, agriculture, industry and services, Roads paved, Access to improved sanitation, public /private ownership	relative growth rate	(FAO 2006)(UNDP 2007), (IMF 2007), (Worldbank 2007), (FAO 2006)
Socio-Economics (Governance)	Corruption index, Control of corruption, Political stability, Government effectiveness, Rule of law, Competitiveness	Rankings	(TI 2007), (Worldbank 2007), (IMD 2007)
Socio-Economics (HDI+health)	Human Development Index, Life expectancy, People undernourished, Public/private health expenditure, Development Assistance and official aid,	index, relative growth rate	(UNDP 2007), (Worldbank 2007), (WHO 2007)
Population	Population total, density, distribution, urban/ rural population, Fertility rate, growth rate	index, relative growth rate	(UNDP 2007), (Worldbank 2007)
Economy	GDP/ GNI per capita, total growth rate, inflation, Merchandise trade, Inequality, Present value of debt, Wealth	(current US$), relative growth rate	(Worldbank 2007), (UNDP 2007)
Energy	Energy, primary total production, imports, exports, consumptions, energy stock changes, emissions, Electricity consumption	relative growth rate	(Worldbank 2007), (UNDP 2007)
Agriculture	Agricultural area, Agriculture, value added, Permanent crops, pasture; export, import, production, consumption and producer price of palm oil, cattle meat, soybeans and sugar cane	relative growth rate	(Worldbank 2007), (FAO 2006)

4.5.2 Methodological approach

To investigate the complexity of deforestation drivers and conditions, several classifications were used. Drivers of deforestation were divided according to their origin into ´biophysical´ and ´socio-economic´ drivers and according to their effect into ´proximate´ (like agricultural expansion, wood extraction, infrastructure extension, etc.) and ´underlying´ (demographic, economic, technological, policy, institutional, etc.) factors.

For the statistical analysis of the first part of the study we simply divided the data into a dependent variable (Forest area change rate) and independent variables (deforestation driver / conditions). Besides the complete analysis for all tropical countries, a distinction into geographical regions similar to the FAO classification was applied to compare regional differences in deforestation drivers. Leaving all non-tropical regions, we included the Caribbean (21 cases), Eastern and Southern Africa (19 cases), Northern Africa (16 cases), Oceania (24 cases), South and Central America (20 cases), South and South-east Asia (23 cases) and Western and Central Africa (22 cases).

The stratified driver data was assessed by establishing a correlation matrix of the different variable comparisons to investigate single-factor relationships through univariate regression analysis. Here, the Pearson coefficient and its significance helped to point to strong relationships between deforestation and its drivers. To test multi-factor relationships (chain-logical or concomitant dependencies) leading to deforestation, all univariate drivers with high correlations were grouped together or according a causal-chain hypotheses, which had to be proven through the subsequent stepwise regression analysis.

Single-factor causation: For the univariate regression analysis, the different variable correlations were regarded in a table and scatterplot matrix. All promising correlations ($R^2 > 0.1$; Sig. < 0.10 ; $n > 5$) were examined by running them separately with the SPSS regression function “Curve Estimation”, allowing the control of linear and non-linear regressions and their visual examination.

Multi-factor causation: Multivariate regression analysis of the data appears difficult, since the data gaps for some essential variables are huge. The more these gaps are distributed among variables and cases, the more cases will be excluded in the regression. Since the degree of freedom (df) is calculated from the number of cases minus the number of variables minus one, a reduction in the quantity of cases might result in low or no df at all. To overcome this, missing data was set 0 for variables of agriculture and forestry import, export and plantation area growth. However, this has to be regarded as an assumption, which was made due to data shortage. Consequently, all correlations for these variables have to be viewed with caution. Another technique applied to overcome the shortage of data was that variables with a large amount of missing cases were left out of the regression. For the last option, the choice of variables was determined based on hypotheses about the causal chains of deforestation drivers, as shown in Figure 18. Multivariate regression calculations were separated according to the steps displayed in the boxes on different levels. The splitting helped to maintain a higher degree of freedom. The changes in 1st level variables were investigated for leading to changes in the target variables. In the following, the changes in 2nd level variables were investigated for leading to changes in the 3rd level variables etc. Each variable was only considered further as dependent variable, if it showed the lowest significance (and the highest R^2). All of the selected variables were subsequently used for a final stepwise regression analysis to calculate the explaining independent variables.

Alternatively, promising correlations ($R^2 > 0.1$; Sig. < 0.10; n > 5) were simply grouped in random order to investigate multivariate regressions. Since for the regions, the number of variables was so high, that their total summary in one group would have led to no results, subgroups were formed. The explaining variable(s) of the stepwise regression for each subgroup were then put together for the final stepwise regression.

In order to avoid the methodological and conceptual mistakes pointed out by Barrett et al (2005), the correlation analyses in this part of the study were not made by directly using forest loss data as dependent variable and governance indicators as independent variables. Instead, the analysis was based on the results for the period of 2000-2005 (deforestation drivers) as dependent variables. This second round of analysis were carried out with the purpose of finding correlations with (1) socio-economic development and (2) governance indicators, which are both 3rd level variables, according to Figure 18. A complete list of the used governance variables and their meanings are further explained in Table 19. The same classification of countries into regions and a complete analysis for all tropical countries was used.

For the statistical model all data were divided into dependent and independent variables, given that the independent variables previously used to estimate the trends of deforestation (which used "annual forest area change rate" as single dependent variable) were applied as dependent variable in this phase of the study. In the case of the socio-economic analysis, a bivariate Pearson's (R) coefficient test was first applied, in order to find the inter-correlation between all of them. Then, a linear (univariate) regression analysis was performed by using the same correlation coefficients (i.e. Pearson's correlation). For the governance analysis, however, the non-parametric Spearman's (Rho) correlation coefficient was utilized, since it is based only on the ranks of values, rather than the values themselves, which is more appropriate for the complexion of the governance data.

In all cases, a result has to fulfil the same exclusion levels to be considered promising, that is R2>0.1, Sig<0.10, and N>5. Where possible, some selected correlations were afterwards used for a stepwise regression modelling in order to determine the explaining independent variables.

Table 19 Definitions of governance indicators

Indicators	Units	Definition
Access to sound money	Rating (out of 10)	This component is designed to measure how countries follow policies and adopt institutions that lead to low (and stable) rates of inflation and avoid regulations that limit the use of alternative currencies.
Competitiveness	Ranking	Measuring the competitiveness of nations, ranking and analyzing how a nation's environment creates and sustains the competitiveness of enterprises.
Control of corruption	Rating (-2.5 to +2.5)	Measuring the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.
Corruption Perceptions Index	Index (0 to 10)	CPI score relates to perceptions of the degree of corruption as seen by business people and country analysts, and ranges between 10 (highly clean) and 0 (highly corrupt).

Freedom to trade internationally	Rating (out of 10)	The components in this area are designed to measure a wide variety of restraints that affect international exchange: tariffs, quotas, hidden administrative restraints, and exchange rate and capital controls.
Government effectiveness	Rating (-2.5 to +2.5)	Measuring the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.
Legal structure and property rights	Rating (out of 10)	It is focused on the protection of persons and their rightfully acquired property, and it is designed to indicate how well the protective function of government is performed.
Level of economic freedom	Rating (out of 10)	Economic freedom is the extent to which one can pursue economic activity without interference from government. It is built upon personal choice, voluntary exchange, the right to keep what people earn, and the security of property rights.
Political stability and absence of violence	Rating (-2.5 to +2.5)	Measuring perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including domestic violence and terrorism.
Regulation of credit, labor, and business	Rating (out of 10)	It is designed to identify the extent to which regulatory restraints and bureaucratic procedures limit competition and the operation of markets. This variable measures how countries allow markets to determine prices and refrain from regulatory activities that retard entry into business and increase the cost of producing products.
Regulatory quality	Rating (-2.5 to +2.5)	Measuring the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.
Rule of law	Rating (-2.5 to +2.5)	Measuring the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence.
Size of government: expenditures, taxes, and enterprises	Rating (out of 10)	Indicate the extent to which countries rely on the political process to allocate resources and goods and services. This item measures the degree to which a country relies on personal choice and markets rather than government budgets and political decision-making.
Voice and accountability	Rating (-2.5 to +2.5)	Measuring the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. It measures political, civil and human rights.

5 Status of forests and forest changes in the tropics

5.1 Changes in forest area

5.1.1 Information sources on tropical forest cover

5.1.1.1 FAO data

FAO provides data on forests based on national data submitted by the individual countries, in particular the Global Forest Resources Assessments provide relevant information on forest extension in periodic intervals. The first resources assessment started in 1948 and the most recent Global Forest Resources Assessment 2005 includes information on current status of forests and other wooden land and recent trends for about 40 variables for 229 countries. The results are available in global result tables in Excel format, but also the specific country reports. FRA 2000 was the first assessment to employ a homogeneous set of definitions for all countries and territories. The Forest assessments before 2000 are therefore not comparable over time.

For forest area data national data submitted is either based on field survey/mapping, remote sensing or on expert estimates. To provide results that are comparable among countries, FAO has to reclassify the national forest classifications into the global classification scheme developed over past decades for the global assessments. In most cases, the reclassification is simply a remapping to a corresponding global class, but sometimes national definitions overlap with several global classes and the national class has to be split between two or more global classes.

Sometimes FAO receives references from different parts of a country that need to be merged to one country level estimate. For some countries only survey information from one point in time is available and all other years are extrapolated. The years for which country information is available do often not coincide with the reference years used in the FAO assessment and are therefore inter- or extrapolated.

FRA 2005 provides forest area data for 1990, 2000 and 2005. The area data for 2005 is extrapolated for all countries. FRA 2005 tables include a detailed overview on the information status on areas of forest, growing stock and biomass. The following assessment is derived from this table.

For central and southern Africa (North excluded because the forest areas are not very relevant), for 44 countries included in the assessment, only for 6 countries national data after the year 2000 was submitted, experts estimates were available for 9 countries for years after 2000. For countries with significant forest areas, for example Democratic Republic of Congo, FRA 2005 data is based on remote sensing data for 1982 and 1989. For 11 of these 44 countries the reported figures are based on data for one point in time. For East Asia, multi-year data is available for most countries mostly both from surveys and remote sensing and for all major countries at least expert estimates from years after 2000 were available. For South America, sources after 2000 are mostly available, for six from 15 countries (e.g. Bolivia, Guyana, Paraguay, Suriname) only a single recent source has been available, however these sometimes cover time-series data.

For the forest area projections in 2005, only for 23 from 229 countries, projections are based on separate studies on deforestation or forest area changes. For many smaller territories, no changes were assumed and for most countries linear extrapolation was used.

For the purposes of monitoring and accounting for reduced deforestation, reliable country-level data is required. The previous sections showed that FAO data – due to its different purpose – faces considerable uncertainties in particular for African countries. Globally the data provide a good overview on forest area changes, however at country-level, data is sometimes based on rather old and few national sources, in particular for Africa, and thus the data is partly connected with high uncertainties. It is also important to note that FRA 2005 only provides monitored data for 1990 and 2000 while data for the year 2005 is extrapolated.

To complement the national reporting and to provide an independent picture of forest cover trends FAO conducted two pan-tropical remote sensing surveys as part of FRA 1990 and FRA 2000, but not as part of FRA 2005. It is now planned to further strengthen the concept of previous remote sensing surveys and a first FAO global Remote Sensing Survey of Forests (RSS) within the framework of the upcoming FRA 2010. The expected outputs are forest area change data for 1975-1990, 1990-2000 and 2000-2005 and the global remote sensing approach will be complementary to the national reporting. FRA 2010 will produce area and area change statistics as well as change matrices on forest cover using the FAO Land Cover Classification System (LCCS),[1] forest characteristics and other land uses (Ridder 2007).

5.1.1.2 Remote sensing data

Largely due to the launch of earth-observation satellites in the 1970s, satellite sensors have complemented the traditional estimation of forest cover from field samples and aerial surveys. Many country-level and regional studies demonstrated the usefulness of satellite data for the monitoring of land-use cover change and deforestation. Table 20 provides an overview of the most common available satellite sensors, their resolution, application, costs and time coverage.

Table 20 Overview of available satellite sensors, application and coverage period

Types of current sensors	Sensor resolution	Utility for monitoring	Cost	Coverage period
Very high resolution (< 5m)				
IKONOS, Quickbird, OrbView 3	Very high spatial resolution (< 5m), low temporal resolution, 60 days revisit period	Validation of small areas of results from coarser resolution analysis	Very high, 350-1800 US$ per km^2	Start in 2000
High (10-60m)				
Landsat MSS		inferior quality of the MSS im-	Circa 1975, acquisition period	1973-1988

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[1] Forest definition to be used in FRA 2010 is “Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.” (Ridder 2007)

Types of current sensors	Sensor resolution	Utility for monitoring	Cost	Coverage period
		agery	1973 – 1988	
Landsat 5 TM (NASA)	High (30 m), 16 day revisit period	Primary tool to identify deforestation	Free data available for 1990 ±3 years (1986-1993), 2000 ±3 years (2000-2003), search for individual years about 450 US$ per scene	Start in 1984, 1990 ±3 years and 2000 ±3 years, theoretically from 1986-2005, but not for all regions could-free annual time series
Landsat ETM+ (NASA)	High (30 m), 16 day revisit period	Primary tool to identify deforestation	30 US$ per scene, but not all scenes available	Launched in 1999, Scan line detector failure in May 2003, not for all regions continuous annual time-series (Asia)
ASTER (NASA)	High 15-90 m, 16 day revisit period	Objective to obtain a cloud-free map of the earth's land surface at the end of the 6-year mission	Free for NASA-funded researchers, other researcher about 100 US$ per granule	Launched in 1999, 6-year mission
CBERS (China-Brazil Earth Resources Satellite	5 m, 3-5 days revisit period	Primary tool to identify deforestation	Free	Start in 1999
ResourceSat (India), AWiFs LISS III	56 m, 5 days revisit period	Primary tool to identify deforestation	Few ground receiving stations, thus no global coverage	Start in 2003
SPOT HRC (European)	5-20 m, 26 days return period	One scene 60 + 60 ha, 9 sport scenes needed to cover 1 ETM+ scene	High, 1599 US$ for an archived SPOT scene, US$ 4000 for a programmed product	SPOT 1,2 and 4 since 1995, SPOT 5 since 2002
Medium (250-1000 m)				
MODIS (NASA)	Medium (250 m), 1-2 days revisit period	Consistent global annual monitoring to identify large clearings (>10-20 ha) and locate "hotspots"	Free, including land cover products, such as vegetation indices	Start in 2000
AVHRR (NOAA S)	1- 8 km	Consistent global annual monitoring to	Free, few costs for programmed products	Since 80s

Types of current sensors	Sensor resolution	Utility for monitoring	Cost	Coverage period
		identify large clearings		
SPOT vegetation cover (EU)	1 km, 1-2 days revisit period	Consistent global annual monitoring to identify large clearings	Free, Products with vegetation classes available	2000

Of the different satellite sensors used in studies of tropical forest, the literature suggests that Landsat imagery has been the most commonly applied. Since its launch in 1972, the Landsat satellite platforms have carried three main sensors, which have evolved since the system was first designed: the MSS (Multispectral Scanner), TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus). Several factors explain the widespread and recent use of ETM+ imagery, its free or moderate cost, centralized and improved online search and download through the internet, and a spatial resolution (30 m for the six optical bands) appropriate for the detection of change in canopy condition as well as land use around forested areas. In recent years, several Landsat data archives have greatly improved the availability of imagery over tropical areas to the user community, including the Global Land Cover Facility at the University of Maryland (http://glcf.umiacs.umd.edu/index.shtml) and Tropical Rain Forest Information Centre (http://bsrsi.msu.edu/trfic/) at Michigan State University.

Three global NASA/USGS Landsat data sets are available free of charge, a fourth dataset is foreseen to be made available:

- circa 1975 (acquisition period 1973 through 1988),
- circa 1990 (acquisition period 1986 through 1992),
- circa 2000 (acquisition period 2000 through 2003),
- circa 2005 (acquisition period 2004 through 2007, expected to be made available by end 2008)

For some regions, Landsat scenes for individual years back to 1986 can be purchased, but the other years do not have global coverage. NASA and USGS recently announced their decision to carry out the mid-decadal global land survey (MDGLS) based on a fourth global Landsat dataset, ca. 2005, primarily consisting of Landsat TM and ETM+ imagery. Islands will be covered by ALI and ASTER imagery filling the data gap caused by the malfunctioning ETM+ (Ridder 2007). However, this dataset will not be available before the end of 2008.

The global Landsat data sets are more or less impacted by atmospheric conditions like haze and clouds, as well as by seasonality. For some regions in the tropics the sensor often delivers less than one usable image (with less than 20% cloud cover) per scene per year (Ridder 2007, Fuller 2006). Thus, low temporal coverage over cloudy tropical regions can make an annual forest area monitoring process difficult in some regions (Fuller 2006).

Since May 2003 Landsat ETM+ delivers stripy images due to operating in scan line corrector (SLC) off mode. Trigg et al. (2006) found that SLC-off mode hardly affects the accuracy of estimates of forest areas and rates of change, however the analysis found that several years of SLC-off data will likely be required to obtain a cloud-free scene in cloudy tropical regions and that therefore the SLC-off failure will delay the detection of some new forest openings and new deforestation areas.

For global- and regional-scale monitoring, coarse-resolution sensors (250 m or greater) are generally considered superior to moderate- and fine-resolution systems because they have a higher overpass frequency and can therefore deliver a sufficient number of cloud-free views of the land surface in the tropics to enable observations at monthly-to-annual intervals. MODIS data, in particular, represent a quantum leap in data availability as these are preprocessed as a set of validated land cover products and provided free of charge over the Internet (Fuller 2006). MODIS researchers associated with NASA and the Geography Departments at the University of Maryland and Boston University have developed a series of land products including calibrated surface reflectance, land surface temperature, thermal anomalies (active fires), albedo, vegetation index and land cover type, among others (Justice et al., 2002), all of which are potentially useful to researchers interested in mapping and monitoring tropical deforestation and other forms of land degradation. The big advantage of medium resolution data is that it is able to provide globally consistent tree cover changes on an annual basis at low cost.

Apart from medium resolution data, there are fine-resolution multispectral commercial systems such as IKONOS, Quickbird and OrbView 3. However, these sensors are unlikely to meet the needs for routine monitoring of moist forest canopies because they have low temporal resolution, relatively small-area coverage (e.g. 11 × 11 km for a standard IKONOS scene) and they are costly. Fine spatial resolution may increase classification errors due to the increased internal variability of canopy reflectance from sunlit, shaded and background components in such data. Nevertheless, cloud-free fine-resolution imagery is likely to be useful as a source of verification of forest cover maps derived from coarse-resolution imagery.

Due to the problems with cloud coverage of optical imaging systems, researchers have turned increasingly to cloud-penetrating radar imagery as an alternative to study tropical forest cover. Most notable is the JERS-1 mosaic of Southeast Asia, Central Africa and the Amazon produced by the global moist forest monitoring project undertaken jointly between government space agencies in Japan, USA and the European Commission Joint Research Centre (EU) (Podest and Saatchi 2002). These JERS-1 mosaics provide a robust measure of canopy texture and allow detection of forest vegetation at 100 m spatial resolution. Although such radar imagery generally do not provide as much spatial detail on land use and cover as cloud-free Landsat imagery, Sgrenzaroli et al. (2002) and Podest and Saatchi (2002) reported acceptable forest classification accuracies and thus recommend this type of synthetic aperture radar (SAR) imagery for upscaling deforestation estimates to the continental scale due to its all weather capability. A new research activity started one year ago with the launch of a new Japanese radar satellite by the Japanese Space Agency (JAXA). However radar is not yet widely used because optical imagery provides greater spatial detail on land cover type, numerous image classification algorithms and software availability, and its greater availability in image archives.

5.1.1.3 Forest inventories and national surveys

Few tropical nations regularly conduct national forest inventories, and many are incomplete and out of date (Ridder 2007). In addition to the incompleteness of forest inventory information for tropical countries, available data is connected with several constraints. *"Each nation* *optimises their own national forest inventory within their own funding constraints to address their own national issues; and the importance of international comparability is too rarely considered. Funding disparities among nations cause differences in methods and data quality. Definitions and methods in each nation can change over time. Some national governments use expert opinion to adjust for these shortcomings but expert opinion is difficult to validate and vulnerable to unknown biases"* (Czaplewski, 2003). Thus forest inventories are a very useful source of information in the countries where they are available, however they are currently not implemented as a standard method on a regular basis to assess forest cover change in most tropical countries.

Field surveys are necessary to improve the interpretation and to verify remote sensing data. The rates of deforestation reported from field studies and surveys (FAO 1995, 2001) are often higher than estimates based on remote sensing (Houghton 2005, Mayoux 2005). The national data on land cover can be derived from different sources and national forest statistics. They often include cleared land areas that can potentially support forests as forest areas. For Indonesia results from forest inventories and satellite data differ considerably. Thus, the verification of satellite data by on-site inspections and field data is another area where more research and further guidance is required.

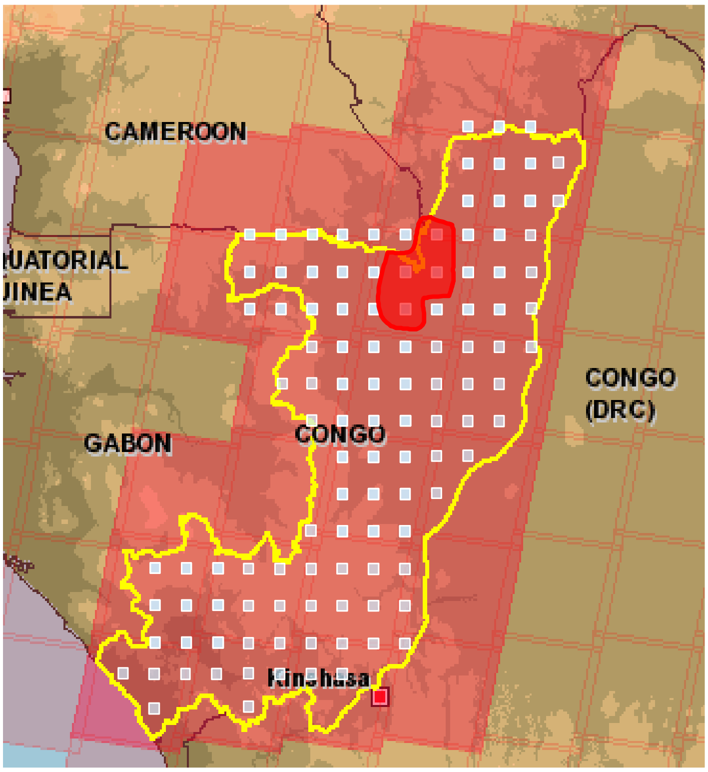
5.1.2 Focus countries

5.1.2.1 Congo

Forest area change assessments have been done on 118 observation plots. In this case only Landsat class data (TM and ETM+) have been used and the reference dates are 1990 and 2000. On 34 observation plots (29% of the total plots) change detection analysis was not done because of large disturbance by clouds. So the change detection analysis was performed on circa 11.3 % of the Congo territory. The forest land change assessment was completed in six weeks with efforts of two operators.

The results showed that on 80 observation plots no changes were occurring between 1990 and 2000, and only in 4 observations there were some relevant changes (more than 1%). Thus historical deforestation in Congo is insignificant, in total between 1990 and 2000 there were less than 1% of forest loss, and almost all the deforestation has been concentrated along the border with Cameroon. Moreover the analysis detected also a moderate but diffuse natural process of expansion of the forest areas (e.g. closure of gaps in canopy cover and small open areas).

Figure 4 Distribution of the observation plots in Congo and satellite data coverage

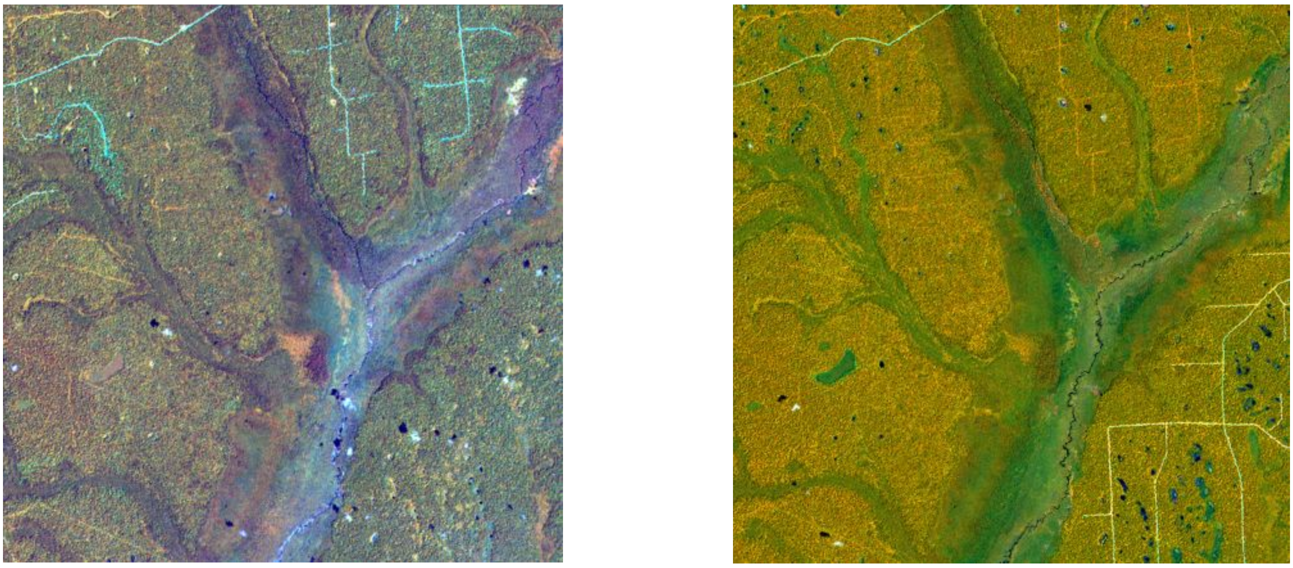


Note: *Observation plots in Congo: white square dots, satellite data coverage: light red zone. The purple red poligon shows the only area of the country where consistent deforestation actions were occurring between 1990 and 2000.*

On the other hand analysis detected that logging operation in Congo are well spread in many regions and that logging activities are moving in new intact forest area (Figure 4). A recent paper on Science (Laporte et al. 2007) regarding the expansion of industrial logging in Central Africa reports that the most rapidly changes in forest area was in northern Congo, where the rate of logging road construction increased from 156 km year^{-1} for the period 1976–1990 to over 660 km year^{-1} after 2000.

The analysis done in Congo did not assess the area changes due to forest degradation, but as an expert judgment it could be estimated that since 1990 more than 10% of the Congo forest have been degraded, while more than 40% of the existing forest is already under logging concession. Thus historically and presently forest degradation is the main process which lead to GHG emissions, but the existence of a well spread road network may push Congo to fast deforestation processes in the near future, as they are now occurring at the border with Cameroon.

Figure 5 Development of logging road in intact forest of Congo



Note: On the left a Landsat TM image acquired on 1990, where in the upper zone is possible to notice recent development of logging road; on the right a Landsat ETM+ image acquired on 2000 representing the same forest area. On the lower-right part is possible to note further development of logging roads.

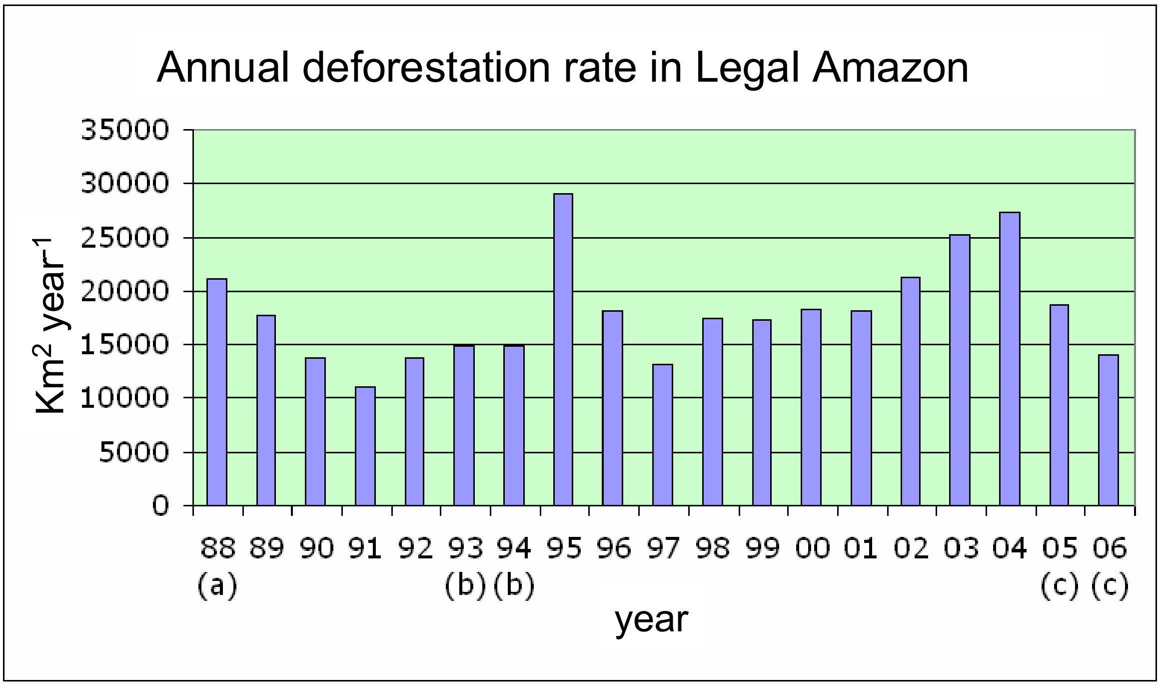
5.1.2.2 Brazil

The considerations on the forest area change in Brazil have been done using the existing official statistics (http://www.obt.inpe.br/prodes/). Brazil is the only country besides India, which is able to report on historical and present deforestation rates with a detailed degree which almost fulfil the IPCC Good Practice Guidance approach 3 requirements.

This country has established a monitoring system of the deforestation process since 1988. Actually the monitoring is focused only on the Amazon region, but Brazil has capabilities to extend the analysis to the other country regions. The monitoring system is operated by INPE, who has now an operational program, PRODES, which provide free access to all data through a WEB portal. The analysis of forest area changes have been done using NASA/Landsat class data (MSS, TM and ETM+). Now Brazil in cooperation with China, has realized its one constellation of earth observation satellites, CBERS (www.cbers.inpe.br). These satellites provide data which are comparable with the Landsat class data specification. Data from these satellites (CBERS 2 and CBERS 2bis) have been used with success to perform some of the analysis on deforestation in 2005 and 2006. In the next few years almost only CBERS data will be used to monitor deforestation in the Amazon region.

Brazil had a continued high deforestation in the past due to the ongoing transformation of forest in agriculture area. The Brazilian data on deforestation in the Amazon region (fig.5) show a large interannual variability with a minimum in 1991, 11,030 km^2, and a maximum in 1995, 29,059 km^2. It is difficult to delineate a consolidated trend as there were many ups and downs. But some important indication could be obtained on factors which lead to forest area conversion. The 1995 peak is corresponding with a land reform by government which granted land in the Amazon to roughly 150,000 families. This new factor was reported to be responsible for almost 40% of the deforestation for that year. The other deforestation peak, 2004, took place at the end of two other severe years which are corresponding with the last financial crisis in Brazil and with the highest level of land battles in Brazil's countryside in the last 20 years. Another interesting indication comes out from 2005. During that year all Amazon regions suffered a long and extreme drought, but although that climate condition may favour deforestation (see Indonesia and Papua New Guinea) the forest area converted to other land use was considerably less than in the previous year.

Figure 6 Brazilian national statistic on deforestation

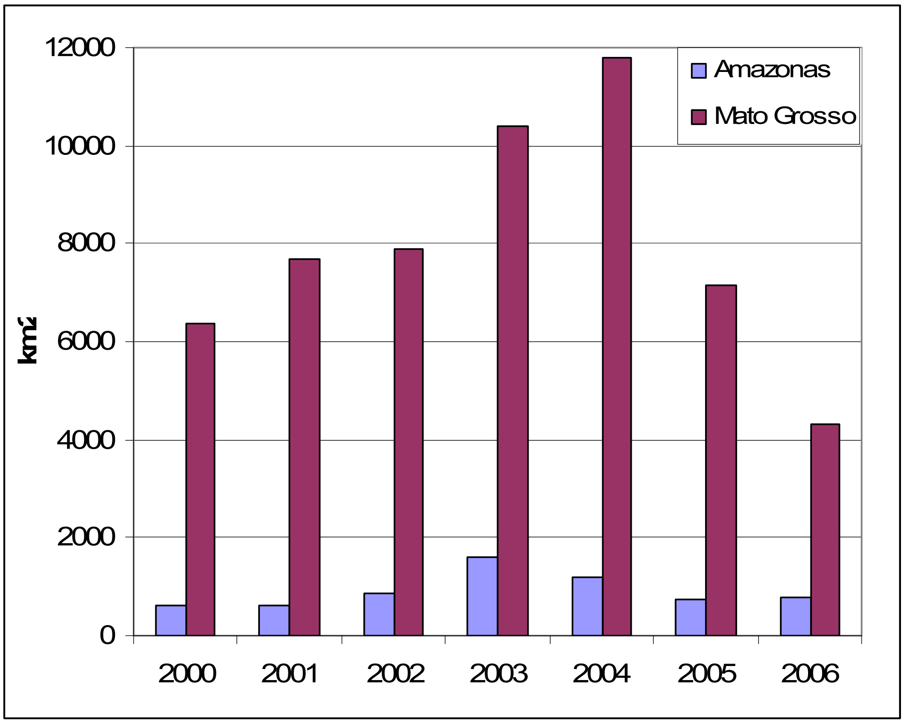


Source: Prodes data from INPE

Unfortunately official statistics do not report data on forest area change due to forest degradation. A recent paper (Asner et al., 2005) on forest degradation in the Amazon region from 1999 and 2002 highlighted that degradation is equivalent and sometimes even larger than deforestation. So it is really difficult to evaluate the current data for example the recent decrease of deforestation, in 2005, 2006. For 2007 preliminary data confirmed a decreasing trend in deforestation, however recent press briefings confirmed a strong increase in deforestation for 2007 similar to the levels in 2003-2004 (BBC 2008). However the official data published by INPE still show a decreasing deforested area for 2007.

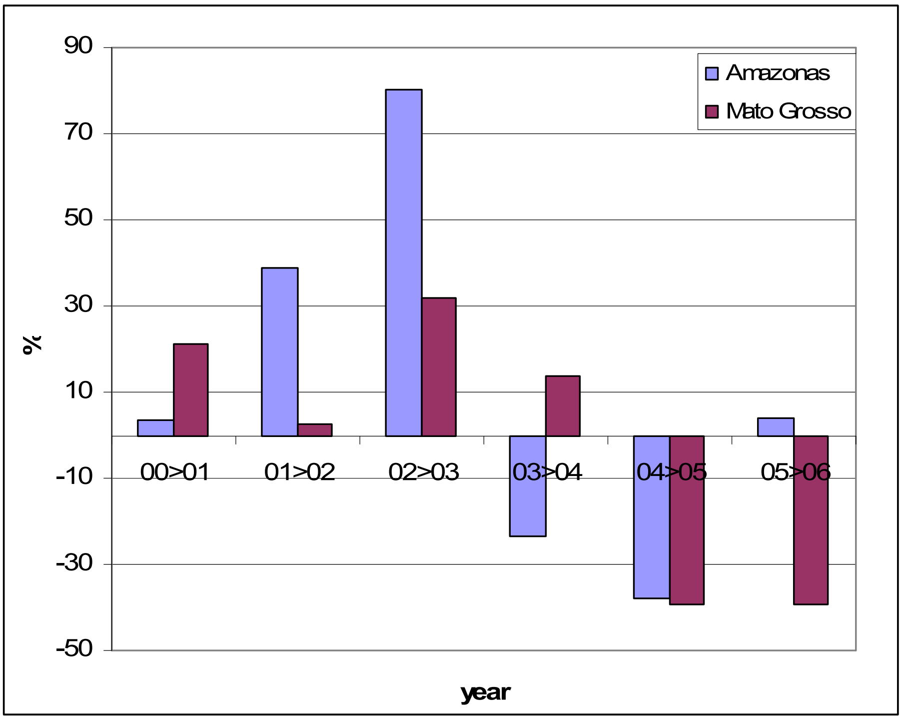
The capability of Brazil to assess annual deforestation with a ‘wall to wall’ approach, allows obtaining detailed data for each Amazon states. In Figure 7 shows data since 2000 for two Amazon states: Amazonas and Mato Grosso.

Figure 7 Amazonas and Mato Grosso statistics on deforestation, annual extension of deforestation



Source: Prodes data from INPE

Figure 8 Amazonas and Mato Grosso statistics on deforestation - annual relative variation



Source: Prodes data from INPE

The data in Figure 7 and Figure 8 show that Mato Grosso has many times higher deforestation rates than Amazonas, but Mato Grosso obtained a large relative reduction for the years 2005 and 2006. This example shows the problem which could arise if the accounting for emission reduction from deforestation will be realised with a subnational approach (as requested by some Parties). Mato Grosso which is heavily converting its remaining forests could theoretically get larger advantages from a RED mechanism than Amazonas state which is promoting the conservation and the sustainable management of its forests. A national approach to assess emission reductions does not solve *per se* the question of an equitable distribution of the positive incentives under the expected RED mechanism, but gives such responsibility to the participating governments.

5.1.2.3 Indonesia

This country has already provided forest area change assessment derived from Landsat class data using a ‘wall to wall’ approach and a visual interpretation methodology. The satellite data have been used to produce three land cover maps of Indonesia. These maps reflect the country situation at 1996, 2000, 2003. The maps are published at scale 1:250.000 while the data process has been done at 1:50.000 scale; the minimum mapping unit is 6.25 ha, and the last two maps have a legend with 23 land cover classes, six of them related to forest land. The land cover maps have been used to assess the forest area extension and based on these numbers, Indonesia has reported to FAO Global Forest Resources Assessment 2005 forest area changes from 1990 to 2005. Under the control of the Ministry of Forestry, there are five operational RS-GIS laboratories located in each of the five main country islands. A large satellite image archive already exists in Indonesia, and it could be used for further analysis or revisions.

Data on deforestation rates are available from many sources (Indonesia Country Report to FAO FRA 2005, WRI Global Forest Watch, etc.) but in this case it is difficult to evaluate the quality of these estimations. Anyway the broad dimension of the deforestation process is clear: Indonesia in the last 15 years has lost more than 20 % percent of its forests. During the 90s the more severe years were 1997 and 1998 when large climate anomalies (El Niňo, la Niňa) facilitated human actions to convert forest areas. In each of these years around 18.000 km^2 of forest were lost, much of the forest clearing were done by fires. After these years deforestation was declining, but raised again in 2004 and 2005 with circa 8.000 and 11.000 km^2 per year respectively. Also in Indonesia like in Brazil the main deforestation peaks are corresponding with country financial crisis.

National data on the extension of forest degradation are not available, but degradation occurs in all forest regions and probably could be equivalent or even larger than deforestation. In Indonesia large forest areas have been converted to forest plantation and circa 60 % of the remaining forest are under logging concession.

5.1.2.4 Madagascar

Madagascar lost an average of 37,000 hectares per year between 2000 and 2005 according to the U.N. This represents a 42 percent drop since the 1990s. The rate of primary forest loss fell by almost 45 percent since the close of the 1990s despite considerable international conservation efforts.

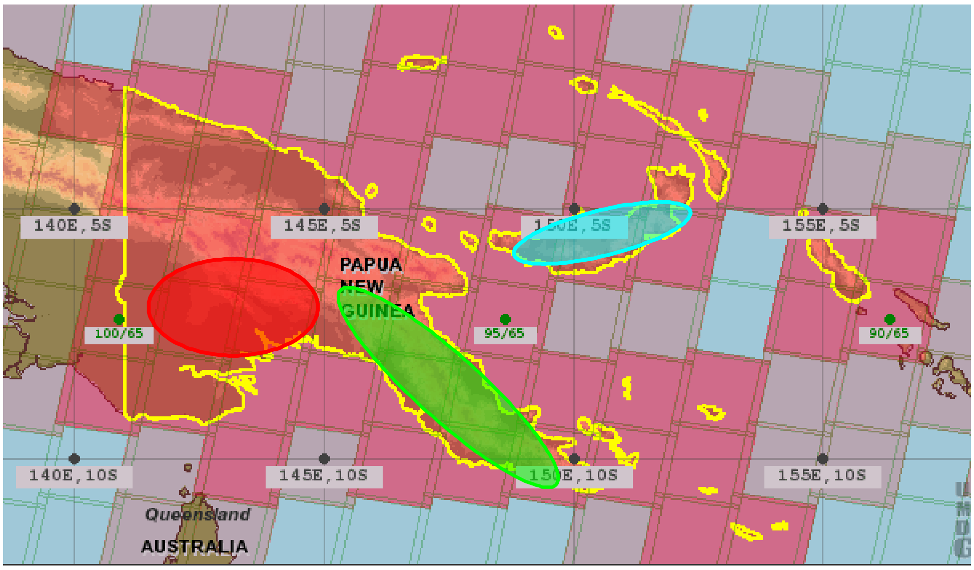
Starting in the 1980s, conservation efforts led by the World Bank were successful in introducing several conservation measures and projects in Madagascar. In 1984, Malagasy government in coordination with the World Bank, drafted a National Strategy for the Conservation and Development and introduced conservation management into the national development paradigm (Gezon, 1997). Subsequently in 1985 it organized an International Conference on Conservation and Sustainable Development which eventually led to the establishment of the National Environment Action Plan (NEAP) in 1987. It resulted in significant legal and structural adjustments and the establishment of several governmental institutions responsible for the protection of the environment (Gezon, 1997). The First stage of NEAP, which began in 1990, was characterized by the creation of Integrated Conservation and Development Projects (ICDPs) and the Malgasy National Parks Association. The integrated development projects became the primary conservation tool in the first stage of the plan. They offered alternative income generating activities for the local population in exchange for their support of conservation measures. In addition to institutional and financial reforms, conservation measures on the island included the establishment of national parks. Ranomafana national park was created 1991 and in 1991 Masoala national park was established (Gezon, 1997).

Despite these efforts, the overall results have been small (Harezga 2007). Conservation laws are not enforced and highly structured environmental institutions do not cooperate with each other (Gezon, 1997). The failure of the global conservation efforts on Madagascar can be largely attributed to socioeconomic factors (Harezga 2007). The financial aid did not improve the economic conditions of the general population. Structural programs introduced by the World Bank failed to achieve the desired goals, and trade liberalization in the early 1990s further deteriorated Madagascar's economy. In recent years (mid 1990s) the inflation on the island averaged 21%, and the ability of the average family to feed itself has declined (Gezon, 1997). Poor socioeconomic conditions created a situation where the local population is in direct conflict with the conservation needs (Ferraro, 2002).

5.1.2.5 Papua New Guinea (PNG)

In the case of PNG, remote sensing data have been analysed in order to assess forest area changes due to deforestation and forest degradation. For PNG three types of data have been used: Landsat TM, Landsat ETM+ and Aster. The reference dates are 1990, 2000 and 2005. In this case a field expedition was realized in order to obtain ground truth data and data were processed with the support of Forest Research Institute of PNG. Forest area change assessments have been performed on 142 observation plots, but many of these plots are shared between land and sea. On 28 observation plots (20% of the total plots) change detection analysis was not done because of large disturbance by clouds. So the change detection analysis was performed on circa 11.3 % of PNG territory. In the PNG case, together with JRC scientist, some testing with different sampling schemes and different image analysis methods were performed in order to evaluate more suitable area change assessment approaches.

Figure 9 Geographical distribution of forest losses patterns



Note: The blue polygon indicates large concentration of oil palm plantations; the purple red polygon indicates large expansion of logging roads; the green polygon a great concentration of deforested area due to unsustainable fire use.

The results showed that PNG has been affected by large deforestation and forest degradation processes. These processes are well spread across the total country but in PNG there is a high regionalization of the forest change patterns. Indeed drivers which lead to forest area changes are quite different in relation to the geographic regions. In general it could be reported that massive conversion of low land forest in oil palm plantations occurred especially in the New Britain island; large deforestation occurred due to unsustainable use of fire in the mountain and in the costal regions of the Papua island, and that forest degradation due to logging was occurring in the internal region with lowland forests like in the Gulf and West Provinces.

Although PNG is a well populated country since many centuries large losses of forest area are only a recent process, that has started during 80’s and that has reached its maximum during 90’s when circa 0.5 - 0.9 % of forest area was converted every years. The most critical years were 1997 and 1998 when a lot of large fires occurred all around the country which were facilitated by climate anomalies (El Niňo, la Niňa). Since 2000 deforestation rates were constantly decreasing being always below 0.5%.

Considering forest degradation, it can be reported that the area affected by this process was equivalent to deforestation from 1990 to 2000 while between 2000 and 2005 the area extension of forest degradation was larger than forest area converted to other land use.

5.1.2.6 Peru

A recent paper (Oliveira et al., 2007) provided a clear analysis on deforestation processes in Peru. Even if data on deforestation are lower than those reported by the Peruvian Government to FAO (943 km^2 per year compared to 630 km^2 per year provided by Oliveira et al., 2007 for the period 2000-2005, see Table 22 and 23), the paper reveals an equivalent area of new disturbed forest per year (634 km^2) and it additionally shows a very large inter-annual variability with a range from 192 to 1174 km^2 of deforested area per year (Table 23). The last year for which data is available is the year from 2004 to 2005, with a maximum of deforestation area of 1174 km^2, and a maximum of degraded forest of 1070 km^2. This leaves room for a rising trend for deforestation in Peru, but data are still not sufficient to determine a consolidated trend. For verification of data Peru, through cooperation with INPE, is establishing a national forest monitoring system. This system will adopt the Brazilian Prodes project methods and techniques.

Summarizing the previous sections, Table 21 and Table 22 show the forest area changes for the focus countries of this study.

Table 21 Past forest areas in focus countries of this study

Forest area	Sources	1980	1990	2000	2005
			[1000 ha]		
Congo-Brazzaville*	MPI-BGC, o.a.		22 100	22 250	22 350
Brazil**	INPE		520 027	493 213	477 698
Indonesia	FAO		116 567	97 852	88 495
Madagascar	FAO		21 148	13 023	12 838
Papua New Guinea	MPI-BGC, o.a.	33 000	30 195	27 390	26 300
Peru	FAO		70 156	69 213	68 742

*Notes: * Tropical humid forest only*

*** forest extension related only to Amazon regions*

Source: MPI-BGC, o.a. = MPI-BGC, own assessment

Table 22 Past forest area changes in focus countries

Forest area change	Sources	1980-1990	1990-2000	2000-2005
			[1000 ha]	
Congo-Brazzaville*	MPI-BGC, o.a.		+ 150	+ 100
Brazil**	INPE		- 26 814	- 15 515
Indonesia	FAO		- 18 715	- 9 357
Madagascar	FAO		- 8 125	- 185
Papua New Guinea	MPI-BGC, o.a.	- 2 805	- 2 805	- 1 090
Peru	FAO		- 943	- 471
Peru	Oliveira (2007)			- 315
			[%/year]	
Congo-Brazzaville*	MPI-BGC, o.a.		+ 0.1	+ 0.1
Brazil**	INPE		- 0.5	- 0.3
Indonesia	FAO		- 1.6	- 1.0
Madagascar	FAO		- 3.8	- 0.1
Papua New Guinea	MPI-BGC, o.a.	- 0.9	- 0.9	- 0.4
Peru	FAO		- 0.1	- 0.1

Table 23 Past forest area changes in Peru

Forest area change	Source	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005
				[1000 ha/year]			
Peru	Oliveira (2007)	- 73.1	- 69.8	- 61.6	- 47.0	- 19.2	- 117.4

5.1.3 Regional and global assessment

According to Houghton (2005), tropical deforestation, including both the permanent conversion of forests to croplands and pastures and the temporary or partial removal of forests for shifting cultivation and selective logging, is estimated to have released CO_2 emissions in the order of 1-2 PgC/yr (15-35% of annual fossil fuel emissions) during the 1990s. Recent estimates, including both surveys and satellite data, vary by more than a factor of two ((Table 24), adopted from Houghton 2005).

Table 24 Average annual rates of deforestation (10^6 ha, yr) in tropical regions in the 1990s

	Average annual deforestation rates in tropical regions		
Regions	**FAO (2001)**	**DeFries et al (2002)**	**Achard et al. (2004)**
	[10^6 ha yr^{-1}]		
Amercia	5.2	3.982	4.41
Asia	5.9	2.742	2.84
Africa	5.6	1.325	2.35
Total	16.4	8.049	9.60

Note: All sources refer to gross rates of forest loss (not including forest area increases), FAO rates are based on forest inventories, national surveys, expert opinion, and remote sensing. The estimates of DeFries et al and Achard et al are based on remote sensing data.

Source: Houghton 2005

Fuller (2006) compared forest definitions used for different international initiatives mapping land cover and highlighted that the different forest definitions used for different studies will lead to differences in total forest areas from individual approaches (see Table 25).

Table 25 Major land cover mapping initiatives and definitions of 'forest' used according to Fuller (2006)

Organization/project	Reference	Class	Definition
FAO/Forest Resources Assessment 2000	Zhu and Waller (2003)	Closed forest	>40% canopy cover >5 m height
Land Cover Classification System of FAO/Global Land Cover 2000	Giri *et al.* (2005)	Tropical rain forest	>15% canopy cover >3 m height
IGBP/MODIS land cover	Giri *et al.* (2005)	Evergreen broad leaf forest	>60% cover >2 m height
European Space Agency, Joint Research Centre/Tropical Ecosystem Environment observation by Satellite (TREES)	Mayaux *et al.* (1998)	Evergreen and semideciduous forest	>70% cover in an AVHRR pixel

Source: Fuller (2006)

Besides the difference in canopy cover and tree heights, the in- or exclusion of plantation areas in the forest estimates also causes differences in total forest areas for individual countries.

Despite the apparent precision of the quoted figures for the rates of deforestation, the exact area of forest lost each year is not known. The accuracy of estimates is hampered by the lack of reliable time-series data, varying standards for forest and non-forest classification, inadequate ground-truthing of satellite imagery, and the institutional weakness of government forest departments around the world (Fuller 2006).

Mexico is a good example of the monitoring and reporting problem. According to FAO (FAO 1997), Mexican deforestation in the period 1990-1995 averaged 510,000 hectares annually. However, for the 1980s it is difficult to find a reliable estimate. In a recent government planning document, 13 different estimates are quoted for the annual deforestation rate ranging from 370,000 to 1,500,000 hectares annually with most estimates about 670,000 hectares per annum (Anon, 1995).

The monitoring of deforestation has improved in recent years, but it is still far from acceptable. Deforestation estimates underestimate the rate of forest cover loss. The following sections provide an overview on tropical forest cover and forest cover changes

5.1.4 Issues related to forest area changes that should be addressed in a monitoring scheme under a future RED mechanism

5.1.4.1 Monitoring approach and coverage

Only monitoring of the full forested area within a country can ensure that leakage does not occur in a future RED mechanism. Analysis that covers the full spatial extent of the forested area is termed ‘wall-to-wall’ coverage. Wall-to-wall analysis is ideal, but may not be practical due to large areas and constraints on resources for analysis (DeFries et al. 2006). Each Landsat scene covers approximately 170 km × 170 km and many scenes are required to cover a large area – 215 scenes are needed for the Legal Amazon in Brazil (Fuller 2006). Several approaches have been suggested to sample within the total forest area to reduce both costs and the time for analysis (DeFries et al. 2006):

- Identification of areas of rapid deforestation through expert knowledge – Subsampling based on knowledge of deforestation fronts identifies areas to be analyzed with high resolution data (Achard et al. 2002). Experts with detailed knowledge of the country are needed to ensure that areas of major change are not overlooked.
- Hierarchical, nested approach with medium resolution data – Analysis of medium and coarse resolution data can identify locations of rapid and large deforestation and these locations are analysed with high resolution data.
- Statistical sampling designed to capture deforestation patterns. Because deforestation events are not randomly distributed in space, particular attention is needed to ensure that the statistical design is adequately sampling within areas of potential deforestation (e.g. in proximity to roads) or through a high density systematic sampling.

Critical questions remain, however, about the appropriate sample size (number of scenes) and spacing of scenes to ensure adequate estimation of the deforested area. The variability among Landsat scenes can be as high as to require >80% coverage of a region for an accurate estimate of deforestation (Tucker and Townshend, 2000). In Brazil, INPE's had published an estimate for the deforestation rate estimate for 2001 in 2002 based on 49 Landsat scenes using the percentage difference from the previous year between the regional total from complete 'wall-to-wall' coverage (229 Landsat scenes) and the same sample of 49 'critical' scenes. In 2003 estimate was later revised based on the full analysis of all scenes and the deforestation estimate increased by 15%. Whereas the first estimate had shown a significant decrease in deforestation, the final 'wall to wall' estimate did no show a decrease (Fearnside and Barbosa 2004).[2] It is also possible, especially in densely populated regions, that the size of clearings is too small for a change in tree cover to be recognized. Fearnside and Barbosa 2004 further investigated certain regions in the Brazilian Amazon for which official satellite data indicated rather low deforestation. The visits revealed new settlement areas and related clearings, however no satellite scenes covering these areas had been available for interpretation of these areas.

Another sampling approach for forest cover change estimation is currently being implemented within the NASA Land Cover and Land Use Change program. This method relies on MODIS change indicator maps to stratify biomes into regions of varying change likelihood. Using a block sampling strategy based on the aggregated MODIS-indicated change, Landsat-7 TM+ image pairs are analyzed to quantify biome-wide area of forest clearing. Coarse spatial resolution sensor data, such as MODIS, are imaged daily at the global scale from year 2000, providing the best possibility for cloud-free observations. As coarse spatial resolution data do not directly allow for estimations of land area change, MODIS data are used as a stratification tool in combination with medium spatial resolution Landsat data to estimate forest area cleared. The targeted sampling of change reduces the overall resources typically required in assessing change over large nations, such as Indonesia.

5.1.4.2 Forest definitions

Different methodologies and ways of interpreting satellite imagery still produce results that can generate controversy. Fearnside and Barbosa (2004) report discrepancies of an area as big as Belgium between deforestation monitoring data from the state government's environmental agency (FEMA) and national INPE estimates for the state of Mato Grosso in 2001. The potential explanations for the discrepancies show that differences in definitions of forest and conversions can have a strong impact on the fact whether a decrease or increase in deforestation is registered for a particular year.

Most countries apply own forest definitions that are suitable to their climatic and geographic conditions and own interests. Also according to the IPCC Good Practice Guidance for LULUCF (IPCC 2003) every country should adopt a national forest definition. There is no consent whether country-specific forest definitions or a generic forest definition should be applied in a future RED mechanism. Some countries suggest the application of the UNFCCC forest definition while others recommend using country specific forest definitions to include different geographic and climatic conditions. The most important issue is that the same forest definition is used over the entire time series, for the reference emission level as well as for a commitment period.

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[2] In contrast, the sampling for derive global or regional deforestation estimates such as by Achard et al. (2004) was only for 6.5% coverage, after stratification based on regional expert opinion.

The experiences from Brazil with two different definitions at national and regional level show that unambiguous monitoring requires precise, unambiguous and harmonized definitions, probably at a more detailed level as currently agreed under the Kyoto Protocol.

5.1.4.3 Harmonization of interpretation, land use classification systems and methodologies

When land-use or land cover change results from different research teams are compared, there are often considerable differences. Houghton reports that two estimates of deforested areas in the Brazilian Amazon, both based on data from Landsat, differed by 25% (Houghton et al., 2000). The reasons for the difference have not been fully resolved. DeFries and Townshend (1999) also highlighted large discrepancies in the extent of broad-leaved, evergreen forest among widely used global land cover maps and emphasized the need for a more consistent use of remote sensing technology to adjust and update global land cover estimates. Gili et al. (2005) compared the recently available Global Land Cover 2000 (GLC-2000) and MODerate resolution Imaging Spectrometer (MODIS) global land cover. These two global land cover data sets were prepared using different data sources, classification systems, and methodologies, but using the same spatial resolution (i.e., 1 km) satellite data. They found considerable discrepancies for detailed land cover classes. These results show the need for further methodological guidance. Appropriate methods and data sources depend on the specific national circumstances and there is no single method applicable in all countries. However, it is necessary to define acceptable methodologies and best practices. Current IPCC Guidelines (neither IPCC Good Practice Guidance for LULUCF (2003), nor 2006 IPCC Guidelines) are sufficiently detailed with regard to the analysis of satellite data for the assessment of forest area changes under different national circumstances (e.g. wall-to-wall or sampling size, minimum clearing size to be identified, monitoring intervals) and do not address the existing challenges and problems. Therefore further methodological work should be developed in this area that ensures a transparent, comparable and consistent application of remote sensing technologies across countries and time. The role of Global Observation for Forest and Land Cover Dynamics (GOFC-GOLD) is to establish the link between space agencies, science community and the users of earth observation data and data products. The primary function of the Land Cover Implementation Team (LC-IT) is to develop and evaluate methods, tools and products for land cover measurements and monitoring using space-borne and in-situ observations. The LC-IT assesses current needs and deficiencies for global and regional monitoring to support Global Change research, national and regional forest inventories and international policy. Important work in the coordination of land cover harmonization and validation activities is conducted by GOFC-GOLD which is a coordinated international effort working to provide ongoing space-based and in-situ observations of the land surface for the sustainable management of terrestrial resources and to obtain an accurate, reliable, quantitative understanding of the terrestrial carbon budget. The GOFC-GOLD Land Cover Project Office (GOFC-GOLD LC PO) was established in February 2004 and is funded by ESA (European Space Agency). However, in addition to such useful regional and international activities it may be useful under the UNFCCC to develop further specific methodological guidance as part of the work of the IPCC Task Force on National Greenhouse Gas Inventories (TFI).

5.1.4.4 Time-series consistency and coverage of current decade

In the past remote sensing technologies have been developing rapidly and the focus has been on improved accuracy or improved global coverage. The remote sensing community mostly do not focus on consistent time-series data. The high resolution datasets that are made available globally have a rather high temporal uncertainty of several years. The data do not precisely refer to the year of the dataset, but to the best cloud-free scene of a period of ± 3 years of the acquisition period (e.g. Landsat 1990 data is from the period 1986 through 1992). For the monitoring and accounting of reduced deforestation it is particularly important that area changes are measured over time with the same methods and that the point in time of monitoring is precisely known. The overview of Table 20 shows that for a time series from 1990 to recent years, a number of sensors and methods have to be combined. There is currently not much analysis of time-series consistency of available satellite data and further research and guidance is necessary to ensure time-consistent data in the future. FAO FRA-2010 will be the first global approach developing a time-series from 1975 to 2005 based on the same methods, however no annual time-series, but data for the years 1975, 1990, 2000 and 2005 will result. Further improvements in technologies and methods may continue, but new data and methods cannot be extrapolated backwards. Therefore it will remain challenging to ensure consistent time-series in a rapidly developing research area and the principle of consistent time-series data over long period should gain more importance.

While satellite data is available for the 1990-2000 period, problems arise for the years after 2000 due to the malfunction of ETM+sensor.

5.1.4.5 Frequency of monitoring and reporting

Reporting frequency under the UNFCCC and the Kyoto Protocol is usually annually for GHG inventories while accounting of emissions and removals extends to 5-year periods. Different to data in all other emitting sectors, high resolution satellite data is not available on an annual basis for many countries. Only medium resolution data from MODIS is available on an annual basis, but not high resolution data. At the same time, deforestation shows a strong annual variation partly due to natural factors, but also due to the large variety of deforestation drivers and their different importance over time. The large variability seems to require annual monitoring data. For seasonal tropical forests, the appropriate method must ensure that annual climate variations are not leading to false identification of variations in canopy cover as deforestation. Multiple observations throughout the year may be required.

In addition, high resolution global satellite data at no cost and with global coverage faces a comparable long delay in release. Global Landsat 2005 data is announced for the end of 2008. Data can be purchased earlier from other commercial providers, but it is no longer cost-free. Data of lower resolution may be available earlier; however any approach combining lower resolution global data with high resolution data for hot spots or certain areas will face similar delays in time.

5.1.5 Conclusions and recommendations

While monitoring systems are generally available that would satisfy the needs for reporting and accounting of reduced deforestation in an international RED mechanism, considerable efforts are needed until such monitoring systems will be implemented in all relevant countries.

- Continuous monitoring of land cover changes with remote sensing which is currently in most countries an area of research work (with the exception of Brazil and India) has to be implemented at the national level on a periodic (annual) basis in all participating countries. This involves considerable capacity-building activities and the establishment of an institutional framework and related financial needs.

- It is necessary to develop further methodological guidance and best practices for the assessment of forest area changes under different national circumstances (e.g. wall-to-wall approach or sampling size, minimum clearing size to be identified, monitoring intervals, harmonized classification schemes).
- The availability problems for high resolution data for the current decade must be improved.
- A stronger focus on consistent time-series data is necessary for a routine application of remote sensing data as part of a future RED mechanism. Only medium resolution data are available on an annual basis, while high resolution data may not be available for cloudy regions. Datasets from different sensors with different resolution have to be combined to derive a time series covering historic and current years. Few research or guidance is available how time-series consistency can be ensured using different satellites and sensors over time. There are only a few years for which there are global sets of earth observation data that can be used for assessing forest cover in tropical areas (ie the the years 1975, 1990, 2000). This means that accurate forest cover trend analyses are available for only a few points in time since 1975 for most countries.
- Cost-free high resolution global satellite data faces a comparable long delay in release. Landsat 2005 data is announced for the end of 2008. Such delays have to be taken into account in the future development of reporting and accounting approaches and the resources involved.
- It will be essential to develop clear, harmonized and unambiguous definitions for land use cover and forests and it has to be ensured that such definitions are consistently applied over time.

5.2 Carbon losses from biomass due to deforestation

5.2.1 Focus countries

The carbon stock per hectare was calculated for the forest types using four different approaches with three different degrees of accuracy. Table 26 lists the carbon stock in above-ground biomass according to the following methods:

1. the **regional averages** established by Marklund and Schöne (2006);
2. the **averages of all forest types** reported in the FAO FRA 2005 (FAO 2006). The carbon stock values from FRA 2005 (FAO 2006) were applied in the regional assessment of carbon losses from deforestation (chapter 5.2.2) and are therefore of significance also on the pilot country level.
3. an average value was established at country level as the **arithmetic mean of the IPCC carbon stock default values** (IPCC 2006, AFOLU Volume, Table 4.7) of all forest types relevant to an ecological zone (referred to as ‘arithmetic mean’ approach). Naturally, this approach carries a high level of uncertainty but at the cur-

rent state of knowledge it is an adequate measure for estimations at coarser resolution, i.e. on the regional scale.

4. a **weighted average** was established at country level **based on the IPCC carbon stock default values** (IPCC 2006, AFOLU Volume, Table 4.7) **for forest types and their proportion in the national forest area**. The proportion of forest types in the total forest area was collected mainly from the countries' national communication to the FRA 2005 (FAO 2006). The resolution of forest type data varied greatly between countries (Table 13). According to the information given, all reported forest types were ascribed to forest types as presented in 2006 IPCC Guidelines and their biomass stock entered the country's mean, minimum or maximum biomass carbon stock according to the individual contribution to the country's forest area. Therefore the resulting value, established separately for the reporting periods to FAO FRA 2005 for 1990, 2000, and 2005, was then apt to be multiplied with the total national forest cover of each pilot country. Uncertainty increased especially with the number of reported forest type classes. It was assumed that forest type classes were defined in a consistent way throughout the FRA 2005 communications between 1990 and 2005.

A particular advance in terms of uncertainty reduction was that for some countries new reliable data were now available from analyses of this study (see chapter 4.2.2). These new values - especially for the most dominant forest types of Brazil, Peru and Papua New Guinea – were included into the new approach of weighing the carbon stocks by the proportion of the forest types.

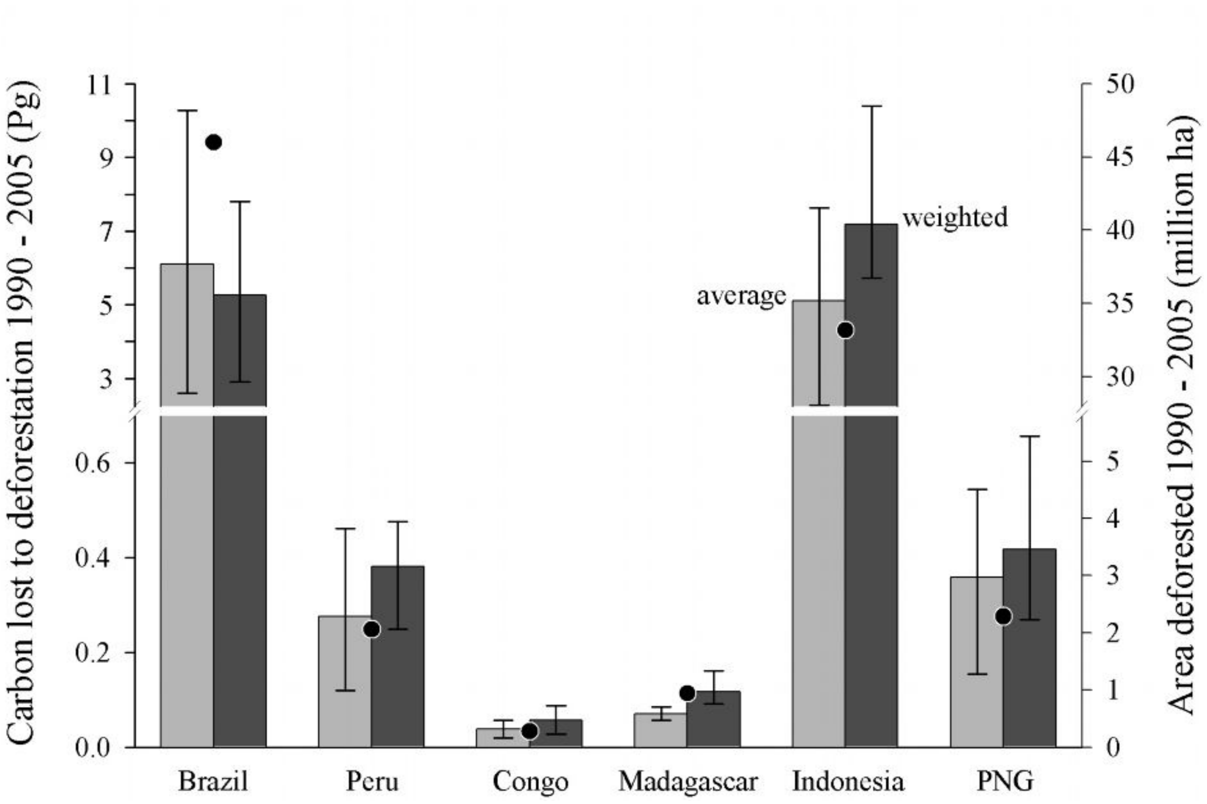
Table 26 Overview of carbon stocks per hectare in above-ground biomass from different sources

	Carbon in above-ground biomass (Mg ha^{-1})												
	Marklund & Schöne (2006) regional average	FAO (2006) average of all forest	Arithmetic mean of IPCC default values for all relevant tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types			Number of forest types		Deviation of IPCC weighted mean from IPCC all forest average (%)		
			mean	min	max	mean	min	max	reported	used	mean	min	max
Brazil*	110	105	94	29	170	81	36	129	5	5	-14	23	-24
Peru	110	123	94	29	170	141	86	182	16-39	7	51	193	7
Congo	155	107	94	35	152	155	65	255	1	1	65	84	68
Madagascar	64	97	48	35	60	92	69	134	2	2	93	96	122
Indonesia	77	68	106	34	171	167	129	252	0	2	57	275	48
Papua New Guinea	55	29	106	34	171	132	79	219	9	7	24	131	28

*Notes: * For the weighted approach, carbon stock values were derived from Ministry of Science and Technology (2006) and not from IPCC (2006.)*
Only natural forest cover considered, excluding plantations
The application of an arithmetic mean across all forest types per continent is compared relative to a weighted average across forest types and their proportion in the national forest area.

Source: calculations MPI-BGC, J. Dietz

Figure 10 *Carbon losses through deforestation in the pilot countries during 1990 – 2005 based on the deforested area and considering default values from 2006 IPCC Guidelines as regional arithmetic mean or weighted mean per country including biomass C stock data from analyses of this study*



Note: *Black dots indicate the forest area lost during that period. For periods 1990 - 2000 and 2000 - 2005 see annex 4.*

Source: calculations MPI-BGC, J. Dietz

Results from Table 26 suggest that carbon stocks estimates based on the weighted average default values from 2006 IPCC Guidelines are considerably higher than the approach based on the arithmetic mean. This phenomenon is closely linked to the selection of pilot countries. The pilot countries were selected, among others, for featuring a reasonable share of tropical rainforest. The arithmetic mean approach assumes equal proportions of each forest type (as included in Table 16) to contribute to the total forest cover of a country which does not represent realistic condition. More so, especially in countries like Brazil or Congo the high-biomass tropical rainforests constitutes the majority of the rainforest which is accounted for in the weighted average approach. Remarkably, this renders much higher biomass stocks even compensating the fact that a much lower value of 221 t ha^{-1} was estimated in this study, (Table 13) instead of 300 t ha^{-1} (IPCC default from 2006 IPCC Guidelines, Table 16) which were used as biomass stock for this forest type in the arithmetic mean approach. The effect of the lower, yet less uncertain biomass stock value is especially reflected in the lower maximum C stock resulting form that approach for Brazil (Figure 10). The inverse effect of the weighted mean approach could be expected for countries where low-biomass forest types such as savannahs prevail, while the arithmetic mean method is likely to overestimate C stocks in comparison to results from a weighted mean approach. Therefore the emissions from the weighted means approach come out lower for Brazil compared to the arithmetic mean approach. According to the figures from the Ministry of Science and Technology (2006, Table 4), Brazil lost almost as much low-biomass cerrado type forest (40 % of total forest loss) as the high-biomass Amazon Forest (42 %).

Although above-ground biomass constitutes the largest carbon pool in tropical forests, also any other carbon pools accountable under the IPCC methods for the estimation of carbon stocks (IPCC 2006) were assessed: carbon from dead wood, litter, below-ground biomass (BGB), and soil organic carbon. While all carbon from above-ground biomass is emitted from deforestation by definition, not all other C pools are subject to equally exhaustive processes after deforestation. When adding carbon stocks from different pools to the total emitted carbon from deforestation, dead wood and litter were assumed to be emitted completely, while 20 % of below-ground biomass and similarly 60 % of all soil organic carbon (Guo and Gifford 2002) would remain sequestered in the soil under a rather conservative scenario (Figure 11, Table 27) For the total amount of carbon emitted from deforestation, dead wood did not play any significant role which was owed to an extremely low default value used, an effect that was observed in all studied countries.

Table 27 *Carbon lost from above-ground biomass (AGB) and all pools (Total) between 1990 and 2005 through deforestation estimated using different carbon stock values.*

		Carbon lost to deforestation 1990 - 2005 (Tg)											
		FAO (2006) average of all forest	Arithmetic mean of IPCC default values for all relevant tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types			Number of forest types		Deviation of IPCC weighted mean from IPCC all forest average (%)		
			mean	min	max	mean	min	max	reported	used	mean	min	max
Brazil	AGB	4805	4311	1352	7819	3706	1668	5912	5	5	-14	23	-24
	Total*	*n.d.*	6107	2590	10271	5261	2903	7810			-14	12	-24
Peru	AGB	252	193	61	350	291	177	374	16-39	7	51	193	7
	Total*	*n.d.*	276	119	462	381	249	477			38	109	3
Congo	AGB	29	26	10	41	42	18	70	1	1	65	84	68
	Total*	*n.d.*	38	19	57	56	28	88			48	47	54
Madagascar	AGB	91	45	33	57	86	65	125	2	2	93	96	122
	Total*	*n.d.*	71	56	85	116	91	161			64	62	90
Indonesia	AGB	2255	3527	1138	5656	5523	4262	8358	0	2	57	275	48
	Total*	*n.d.*	5108	2268	7636	7176	5726	10391			40	152	36
Papua New Guinea	AGB	66	243	78	390	303	181	499	9	7	24	131	28
	Total*	*n.d.*	358	155	545	418	269	656			17	74	20

Notes: *Only natural forest cover considered, excluding plantations.*
** Combines the loss of 100% above-ground biomass, 80% below-ground biomass, 100% litter, 100% dead wood, 40% soil organic carbon.*
The application of an arithmetic mean over all possible forest types per continent is compared relative to a weighted mean over various forest types. For periods 1990 - 2000 and 2000 - 2005 see annex 4.

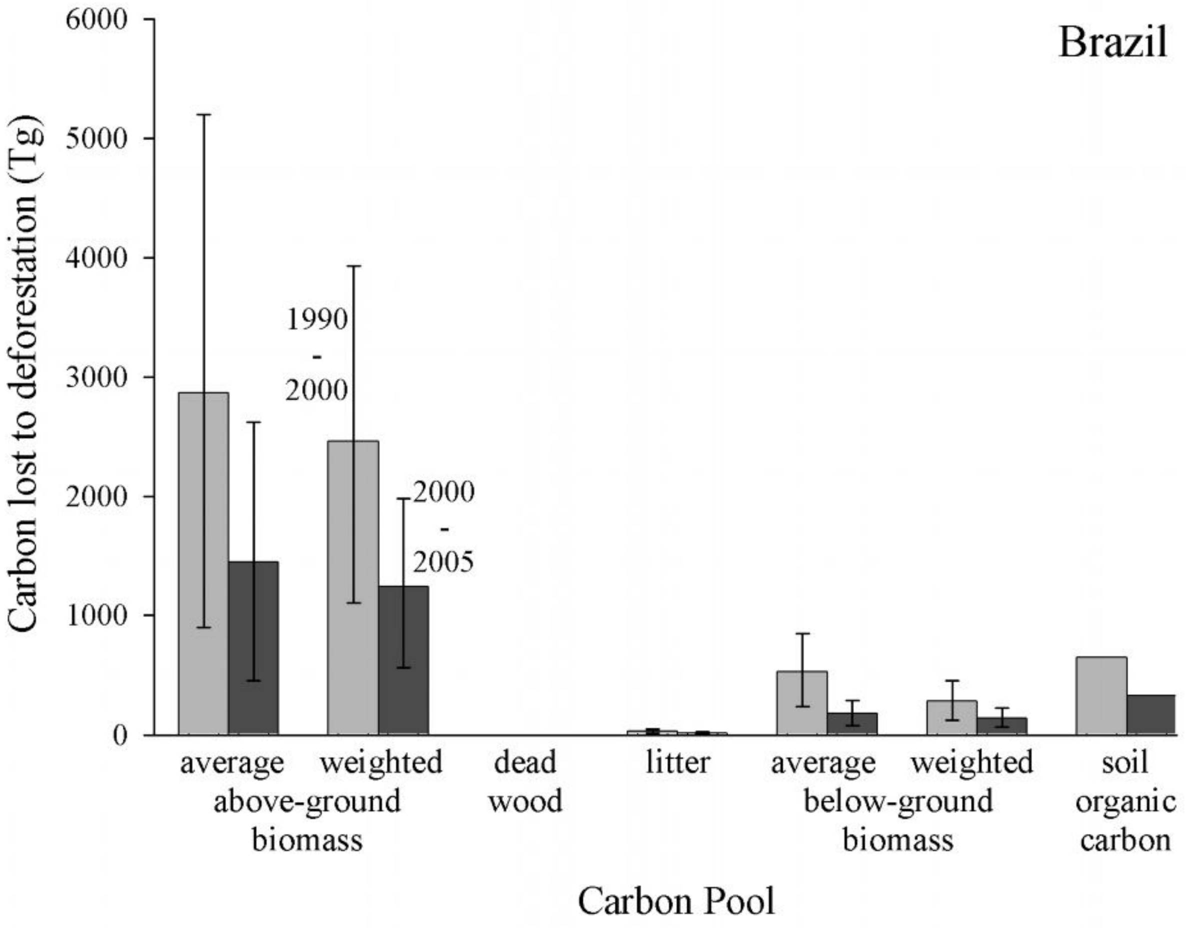
Source: calculations MPI-BGC, J. Dietz

Brazil

The emissions from Brazil's tropical forests are highest worldwide (Figure 10, Table 27). The largest share of the forest still covers the Amazonian states with tropical moist rainforest. However, according to the Ministry of Science and Technology (2006, Table 4), Brazil lost almost as much cerrado type forest (40 % of total forest loss) as the Amazon Forest (42 %). In this study, a biomass value of 221 (142 - 311) tons per hectare (108 (70-152) t C ha^{-1}) was calculated from 24 plot inventories, mainly from the Western Amazon region, which is below the IPCC default value of 300 (120 – 400) t ha^{-1} hectare (147 (59-196) t C ha^{-1}) provided by Baker et al. (2004) and Hughes et al. (1999). This is probably also due to the application of latest wood density values from Nogueira et al. (2007) whose recent review indicated that wood densities in neotropical natural rainforests have long been overestimated. It needs to be noted, though, that the lower margin calculated in this study is still above the one used as IPCC default value (IPCC 2006) raising the lower end of the biomass stock although the mean value is lower.

This biomass stock value was included in the weighing of five forest type classes according to their share of forest area lost. This method is considered more accurate compared to ascribing merely regional average values for above-ground biomass stock. In respect to the approach using an average of available neotropical forest type defaults, this resulted for Brazil not necessarily in a higher maximum value as the newly computed maximum for the tropical rainforest was lower than the default value, yet it still lifted particularly the minimum value and thus the most conservative estimate above the one from the arithmetic mean approach (Figure 11). For the total amount of carbon emitted from deforestation in Brazil, dead wood did not play any significant role which was owed to an extremely low default value used, an effect that was observed in all studied countries for that reason. Below-ground biomass is linearly correlated to above-ground biomass through the conversion factors (Table 17).

Figure 11 *Deforestation carbon losses from Brazil during 1990 – 2005, split into the contributing carbon pools*



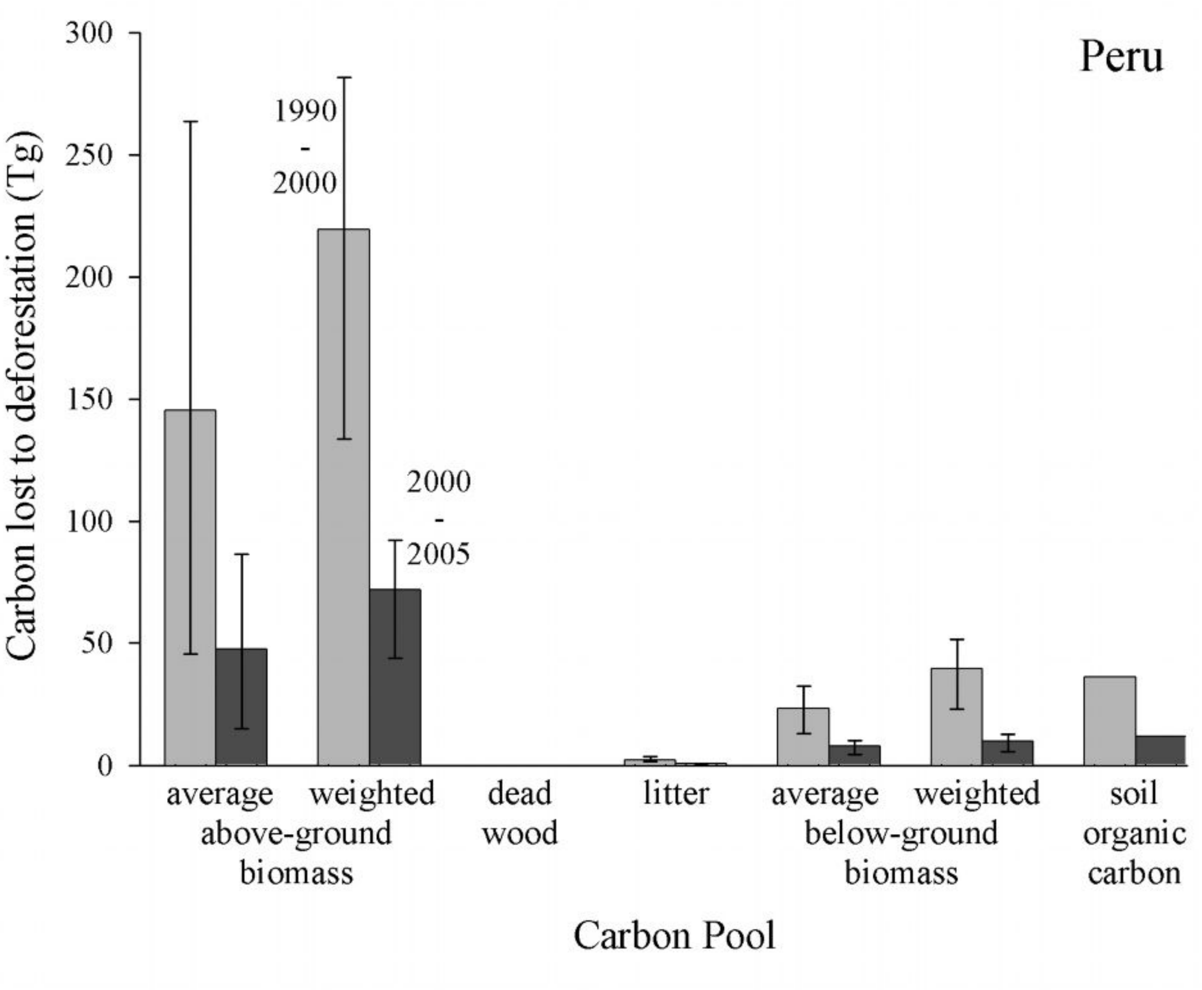
Note: *Shown are estimation methods for biomass using average and weighted carbon stock values. Below ground-biomass shown is 80 % and soil organic matter 40 % of their total stocks.*

Source: calculations MPI-BGC, J. Dietz

Peru

The forest cover of Peru is also dominated by Amazonian lowland moist rainforest. For this dominant forest type, most inventory data were found among all pilot countries (Table 11). Available inventory data allowed to calculate a reliable biomass stock value of 209 (107 – 288) tons per hectare (102 (52-141) t C ha^{-1}) for the lowland rainforest which is also below the IPCC default value for neotropical lowland rainforests (IPCC 2006, Table 4.7) but corresponds well with other sources, particularly when it is included into the weighted integral over all forest types (Table 26). The calculation of a weighted biomass stock mean also raises especially the mean and minimum level of biomass, and less so the maximum, against the arithmetic mean approach (Figure 12). This effect may also be enhanced by the presence and explicit consideration of Peru's remaining tropical mountain forests. Although spatially condensed, 18 inventories of premountain forests in Peru yielded a biomass stock of 117 (46 - 156) t ha^{-1} (57 (23-76) t C ha^{-1}) which is comparatively low and probably owing to rather low wood densities found in these regions.

Figure 12 Deforestation carbon losses from Peru during 1990 – 2005, split into the contributing carbon pools

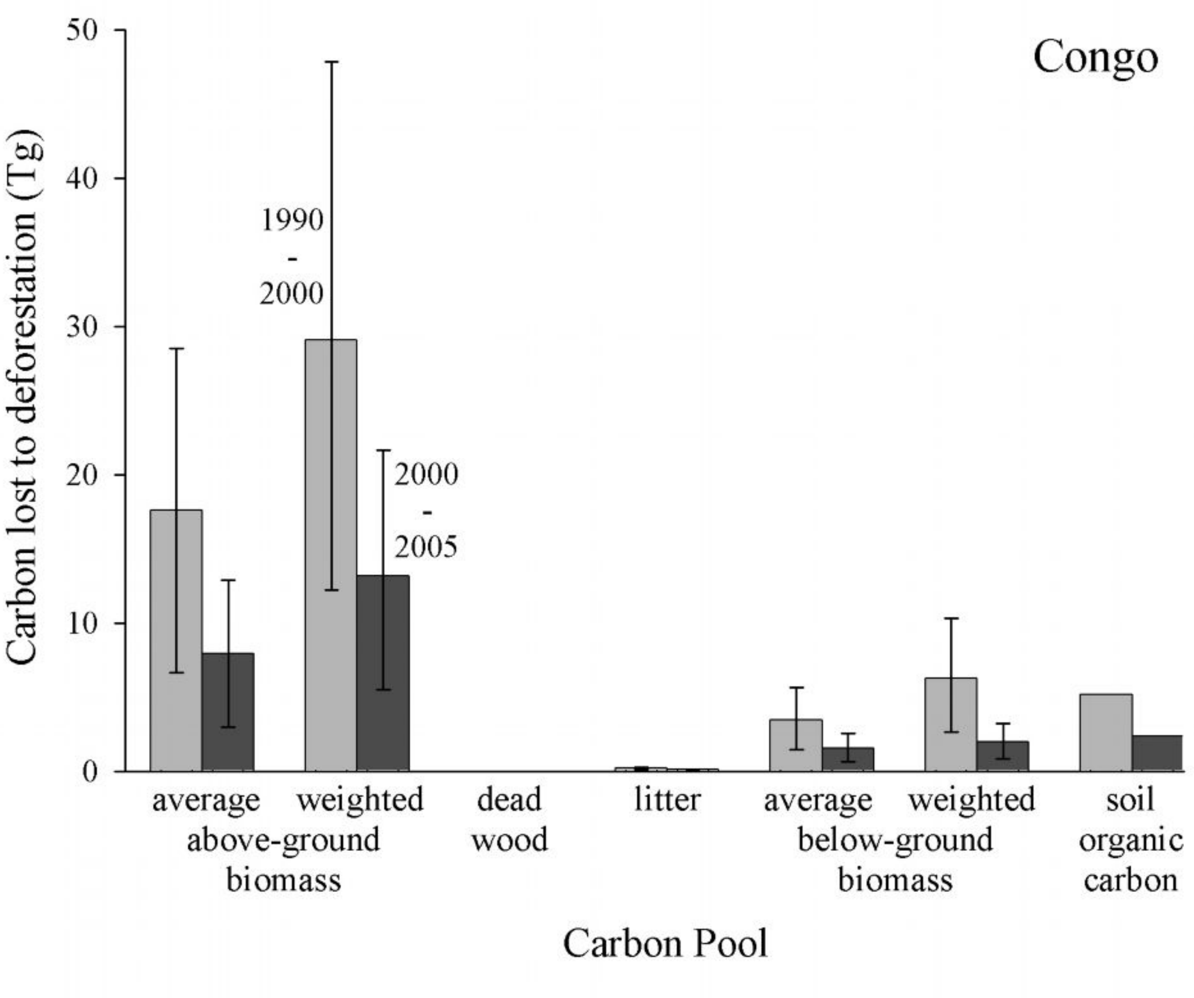


Note: Shown are estimation methods for biomass using average and weighted carbon stock values. Below ground-biomass shown is 80 % and soil organic matter 40 % of their total stocks.

Source: calculations MPI-BGC, J. Dietz

Although in terms of detailed reporting, the Peruvian dataset was very elaborated, it formed a challenge to its evaluation. The detailed classification of individual forest types, as many as 39 in the national communication to the FRA 2005 (FAO 2006) and the inconsistency between the forest classes among the successive communications made it difficult to ascribe them to a standardised set of more generally characterised forest types. It is also remarkable that a significant time shift existed between the data collection and the time of reporting (e.g. the data reported 1990 was assessed in 1975) which certainly increased the measure of uncertainty. For compensating this effect, the data were transferred to their original year of collection and linearly interpolated to the years in question. It can, however, not be ruled out that such discrepancies in time also exist in many other communications, yet may not be stated so explicitly as it was the case for Peru.

Figure 13 Deforestation carbon losses from Congo during 1990 – 2005, split into the contributing carbon pools



Note: Shown are estimation methods for biomass using average and weighted carbon stock values. Below ground-biomass shown is 80 % and soil organic matter 40 % of their total stocks.

Source: calculations MPI-BGC, J. Dietz

Congo-Brazzaville

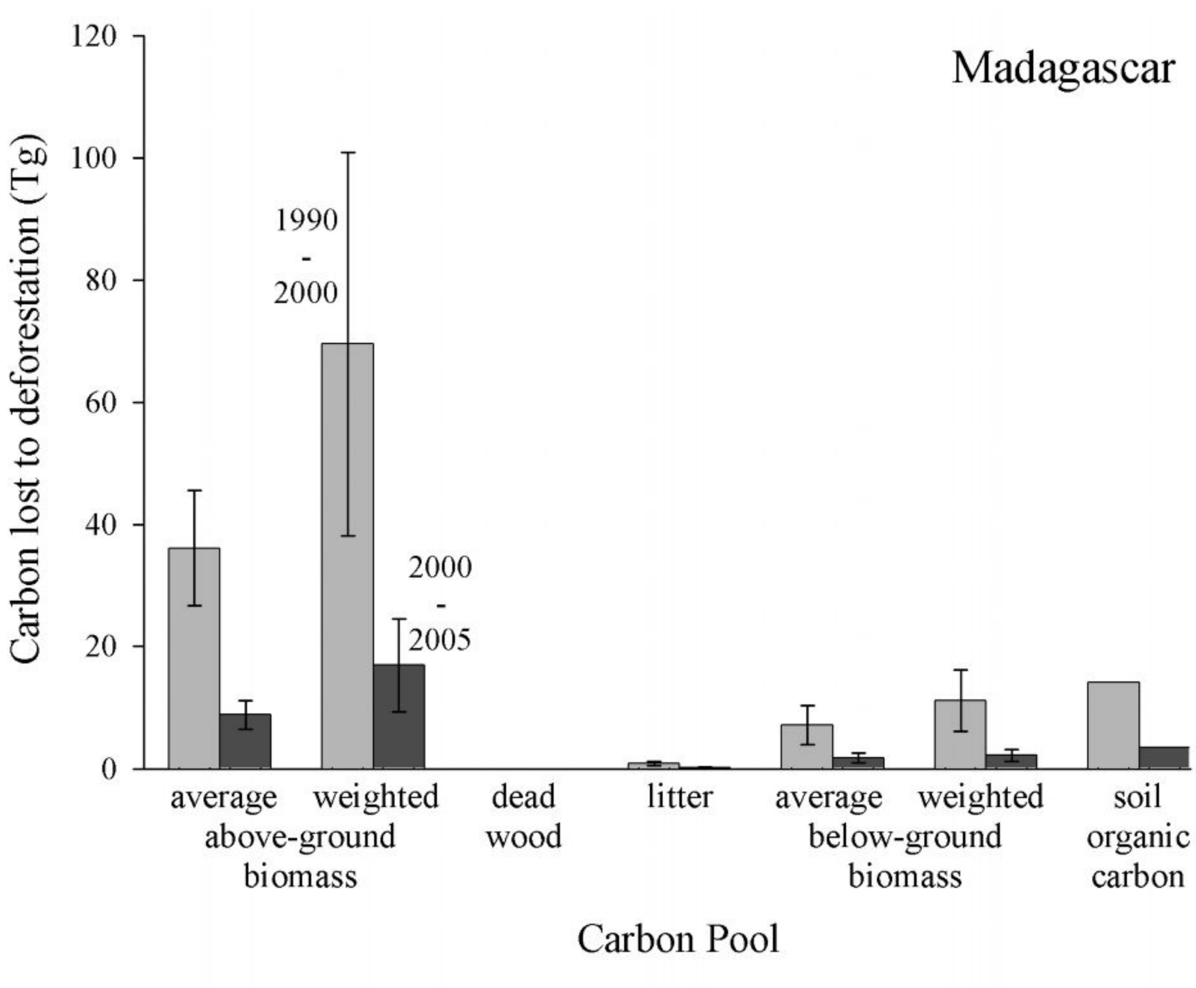
The data situation for the Congo was least favorable. For this study, data from merely one rather poor inventory could be acquired within the project period (Table 12); the national communication to FRA 2005 (FAO 2006) also lacked common details. This is, however, a situation that can currently easily occur in a number of other tropical countries and there is a clear indication that, although data exist, they are not readily available, possibly due to ailing infrastructure.

Consequently, there was little ground for establishing a weighted mean across all present forest types. Fortunately, the Congo maintains almost entirely lowland rainforest systems, thus the corresponding IPCC default value for biomass (IPCC 2006) was applied directly without further adaptation. The fact that the specific value for Central African lowland rainforest was directly adopted for the Congo explains why the biomass stock per hectare (155

Mg C ha^{-1}) largely exceeds the one originating from approaches averaging the value over several different forest types (107 Mg C ha^{-1}) while the agreement with the value of Marklund and Schöne (2006) suggests that they had also assumed a predominant cover by lowland tropical rainforest (see Table 27).

This situation also causes the carbon emissions, especially from biomass, under the current estimate to largely exceed the ones computed from the biomass stock for Central Africa (IPCC 2006) (Table 27, Figure 13).

Figure 14 *Deforestation carbon losses from Madagascar during 1990 – 2005, split into the contributing carbon pools*



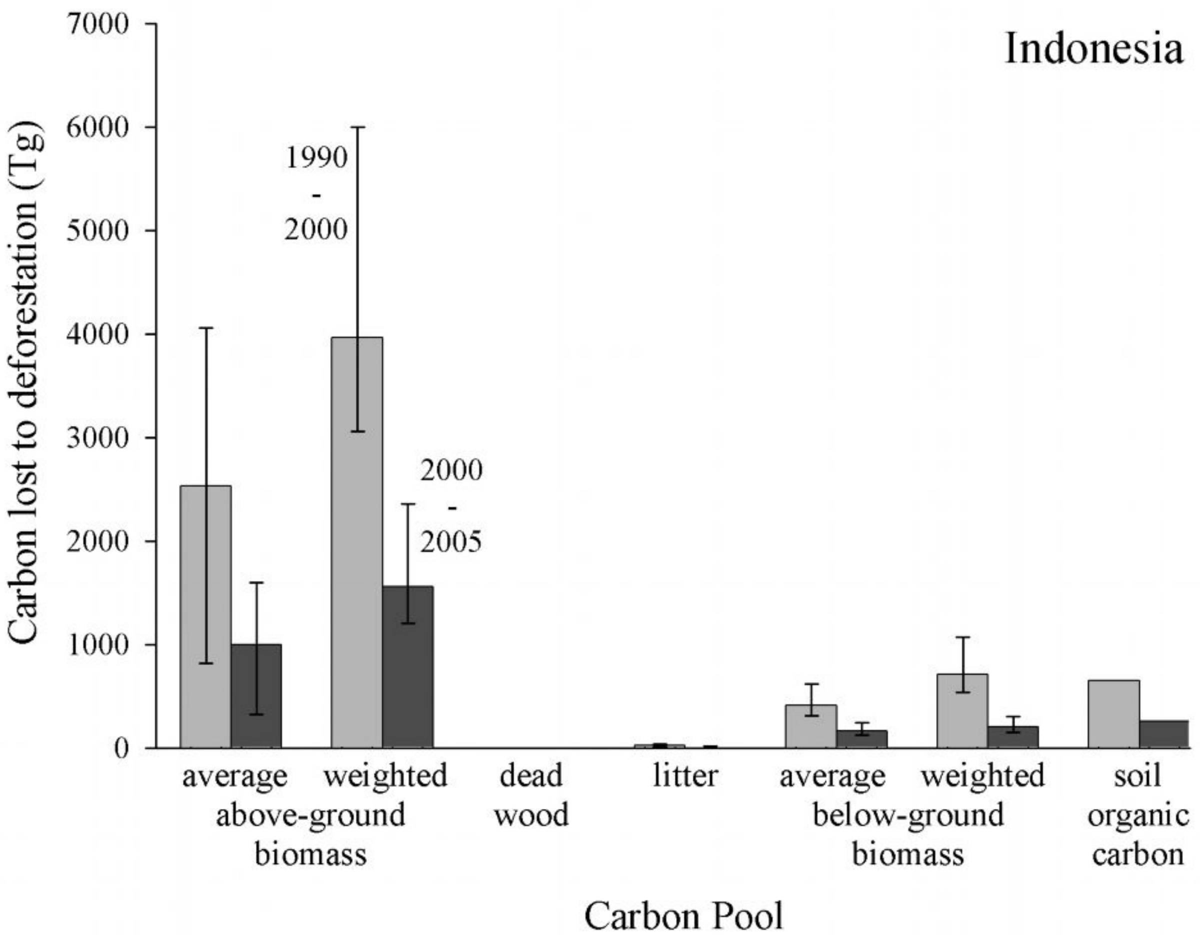
Note: *Shown are estimation methods for biomass using average and weighted carbon stock values. Below ground-biomass shown is 80 % and soil organic matter 40 % of their total stocks.*

Source: calculations MPI-BGC, J. Dietz

Madagascar

Lying in the East and Southern African domain, the forests of Madagascar contain the lowest biomass according to default values from 2006 IPCC Guidelines (IPCC 2006). Using the arithmetic mean approach, clearly underestimates the biomass stock from Madagascar's tropical forests with 48 (35 - 60) t ha^{-1}. Marklund and Schöne (2006) find 64 t ha^{-1} and averaging values from FRA 2005 (FAO 2006) yield 97 t ha^{-1}. A particular challenge is the reporting by Madagascar on their forest types which they divide into the western and eastern forests, each specifically comprising several contrasting forest types. Such uncertainty certainly impedes a precise weighing of forest types for biomass and area cover and causes substantial uncertainty in the resulting estimate itself. Unfortunately, also within this study, not sufficient independent inventory data could be collected to rely on a separate estimate. Therefore, especially in Madagascar an effort in characterizing forest cover and forest types would undoubtedly assist in deciding whether in this particular case the average approach may be even more precise compared to a weighted mean which yield higher biomass stocks and consequently emissions although based on very vague data.

Figure 15 Deforestation carbon losses from Indonesia during 1990 – 2005, split into the contributing carbon pools



Note: Shown are estimation methods for biomass using average and weighted carbon stock values. Below ground-biomass shown is 80 % and soil organic matter 40 % of their total stocks.

Source: calculations MPI-BGC, J. Dietz

Indonesia

The forests of Indonesia, with its large spatial extension, its difficult stature, split into a myriad of islands and only very vague reporting on the forest status in terms of forest types, remain another true challenge. Undoubtedly, Indonesia's emission from deforestation of tropical forests range among the highest in the world (Figure 10). Therefore, refining the estimates of forest carbon stocks and forest cover data for Indonesia would drastically reduce the uncertainty also in emissions from tropical deforestation on a global scale.

Drawing on the country report to the FRA 2005 (FAO 2006), there is no specification of particular forest types available. Although few, existing and available inventory data (which apparently did not suffice for Indonesia for reporting them to the FAO) could have provided some information on the true biomass stock of Indonesian forests. However, the variation in botanical composition and forest management policies between the islands make it difficult to upscale since most inventories were rather specific to one or two particular islands or split between specific forest types (Table 12) without much validity for applying them to the entire country.

Special forests such as the biomass rich Dipterocarp forests of Kalimantan or peat forests with rich soil carbon pools, likely sources to CO_2 emissions (Hadi et al. 2005, Takakai et al. 2006), were not explicitly targeted in this study, in part due to the lack of spatial data. However, due to the lack of information on forest types and their distribution, only the IPCC default values for tropical mountain systems and tropical rainforests of the insular Asian domain (Table 16) were included in the weighted average, proposing a proportion of 10 % for tropical mountain systems.

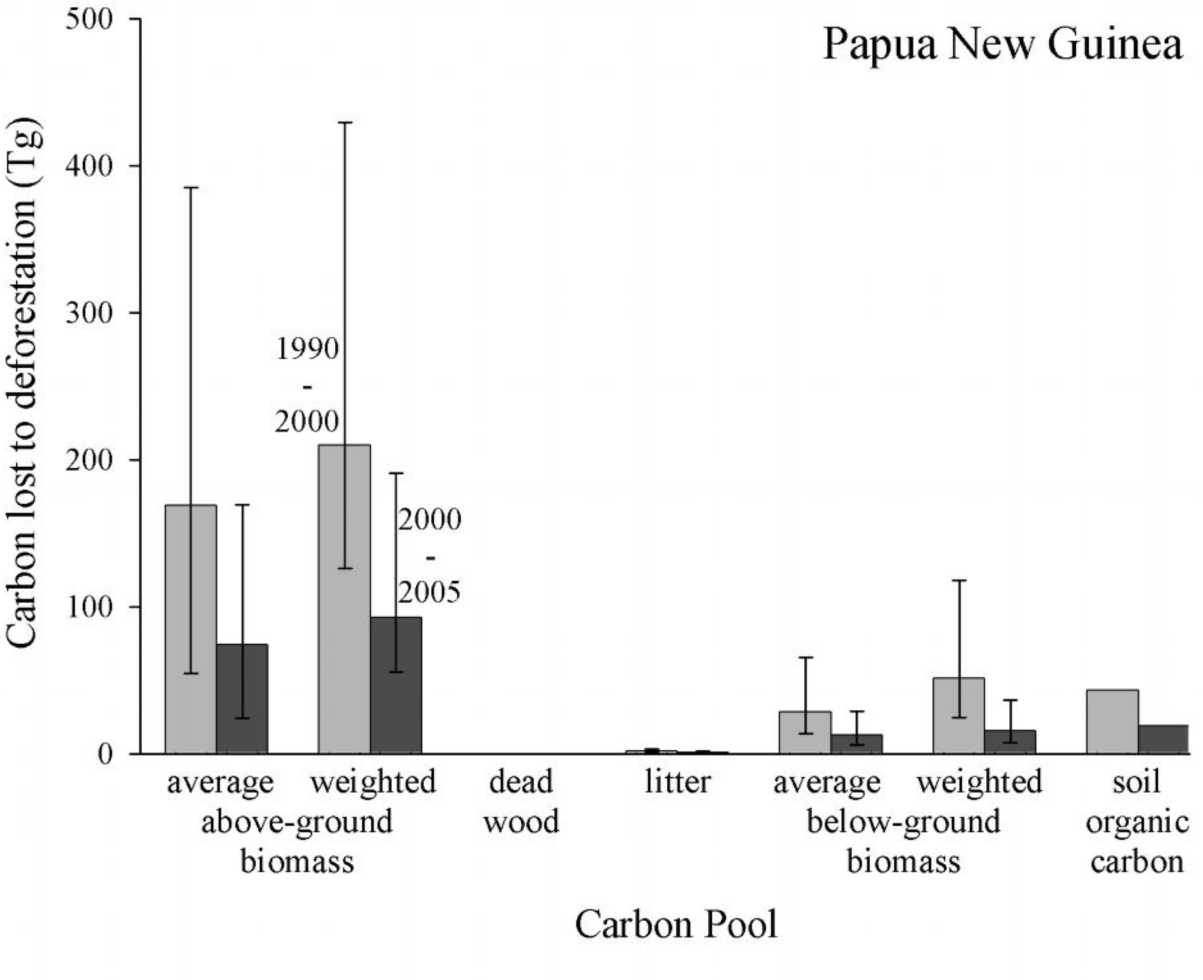
Average values of biomass stock in Indonesian forests ranging between 68 and 106 t ha^{-1} put forward by other authors (Table 26) appeared very low compared to the few data that had been examined. The values for natural forest estimated with the weighted average approach (167 (129-252) t C ha^{-1}) exceed those considerably and may, due to the assumptions made, be considered rather on the upper margin (Figure 15), yet still within a reasonable range. The emissions from soil organic carbon presented here are certainly a very conservative estimate by disregarding the deforestation occurring on peat soils.

Papua New Guinea

Due to the close cooperation with the National Forest Research Institute of PNG, the data situation was very favourable. Raw inventory data from more than 90 1-ha inventory plots including botanical identifications and tree height data facilitated a thorough description of the biomass stocks in dominating lowland rainforest (Table 12). Data in the also abundant montain forests from the mainland of PNG were less abundant because the monitoring plots largely followed the preferred locations of concessionaries in the lowlands.

Additional information was provided in a detailed description of forest types occurring in the country within the Papua New Guinean communication to the FRA 2005 (FAO 2006). This assisted in establishing a reliable weighted mean across all forest types including the newly calculated biomass stock of 175 (123 - 254) t ha^{-1} for the tropical lowland rainforest portion. In comparison to this, values of 55 and even as low as 29 t ha^{-1} used by other authors appear very low and probably owe to the fact that PNG is commonly ascribed to the Oceanian domain, where forests seldom live up to the biomass developed by the lowland rainforests on the mainland.

Figure 16 Deforestation carbon losses from Papua New Guinea during 1990 – 2005, split into the contributing carbon pools



Note: Shown are estimation methods for biomass using average and weighted carbon stock values. Below ground-biomass shown is 80 % and soil organic matter 40 % of their total stocks.

Source: calculations MPI-BGC, J. Dietz

5.2.2 Regional assessment

Bringing such investigations from the pilot countries to regional scale requires some generalization. The overall forest area loss data were adopted from FRA 2005 (FAO 2006, Table 2.4) and initially the simpler and generally lower above-ground biomass stock values from the arithmetic mean approach and from the regional means from FRA 2005 (FAO 2006) were used. An attempt was made to establish also a weighted mean for the regions consistent with the approach used on the country level. This required the assumption that the proportion of the respective forest types outlined in the FRA 2000 (FAO 2001) remained constant over the entire observation period (Table 28). Comparison with data from the country level analyses (Table 27) reveals that strongly emitting countries such as Brazil and Indonesia cover the bulk of all emissions in their respective region.

When basing further analyses upon these figures, it should be considered that these are most likely a strong underrepresentation of the true magnitude of emissions from deforestation because i) only the above-ground biomass pool is considered and ii) these estimates from the approaches used here have been shown on country-level to be systematically lower than values obtained at higher data resolution (Table 14).

Table 28 Carbon lost in the tropics on the regional scale from above-ground biomass (AGB) between 1990 and 2005 through deforestation estimated using two different carbon stock values

	Carbon lost from above-ground biomass due to deforestation 1990 - 2005 (Tg)						
	FAO (2006) average of all forest	Arithmetic mean of IPCC default values over all tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types		
		mean	min	max	mean	min	max
Caribbean	-79	-120	-40	-155	-164	-93	-218
South & Central America	12913	12137	3845	20922	14254	9665	21534
Northern Africa	359	1328	1056	1598	1863	1863	1863
Western & Central Africa	3822	4199	1581	6806	5330	2869	8430
Eastern & Southern Africa	2167	3247	1817	4672	3874	2755	5858
South & Southeast Asia	6768	8380	3505	12975	9686	5738	12774
Oceania	1174	1282	414	2056	1902	1477	2812
Tropical countries Total	27124	30453	12177	48875	36746	24274	53052

Note: For periods 1990 - 2000 and 2000 - 2005 see annex 4.

Source: calculations MPI-BGC, J. Dietz

5.2.3 Conclusions and recommendations

There exists a very large variation in data structure, quality and availability between the investigated tropical countries. Currently, a large proportion of the uncertainty in estimating carbon stocks and emissions is caused by highly generalized and aggregated values on regional levels which do not allow a reasonable application to national situations. In order to refine the data resolution to country level and thus substantially improve estimates of carbon stocks in above-ground biomass the following information and steps are necessary, given the availability and accessibility of spatially explicit data on area of deforestation:

- A partitioning of the overall national forest area into **distinct forest types** of sufficiently homogeneous structure and thus biomass and carbon stocks. Such information has been made readily available by some of the pilot countries (Brazil, Peru, and Papua New Guinea) and has contributed considerably to a reduction in uncertainties of national carbon stock estimates allowing for establishing a weighted average of national forest carbon stocks as shown in this study. This step constitutes enormous progress towards more realistic estimates on the magnitude of emissions from deforestation.

  The default forest types specified in the IPCC Guidelines (2006, Table 4.7) proved to be practical within this study and could serve as a good basis for such a predefined and standardized partitioning of tropical and subtropical forests into more precisely defined forest types. It was also shown that such partitioning is feasible for countries of different sizes and geographical preconditions. Therefore it seems realistic to require a reporting specifically on such a predefined set of default forest types from each country. It would, however, be desirable to standardize such forest types pantropically, but a consistency of these forest type classes over time should be ensured or else at least a proper conversion matrix would need to be elaborated. For increased accuracy, these forest type classes could be further divided into subclasses, possibly in the context of a higher tier level. Such refining of forest type resolution would, however, have to correspond to the need of

- **Forest inventories** which should at least cover 0.5 ha of size each and account at least for the diameter at breast height (dbh) for all stems ≥ 10 cm as a minimum requirement. Additionally recorded data on tree height, species composition, and dead wood stocks would further improve the quality of inventories. Such inventories must eventually represent each forest type with a sufficient number of replications; else a conservative default value would have to be applied. This study showed again that at least for both Latin American countries such data were available and accessible and although such inventories are still not available in all tropical countries for all respective forest types, this requirement can be met by each of the countries with reasonable effort as also the staff of the Forest Research Institute of Papua New Guinea has demonstrated on their permanent sample plots, having revisited them at least on a 3-year basis for over 12 years now.
- **Allometric equations** are necessary for the conversion of inventories into biomass and carbon stocks which ideally have been developed from forests in the region, which would then best reflect the structural characteristics of these forests. Unfortunately, the development of such allometries is a rather laborious task, both for the extensive and destructive sampling and for the statistical evaluation. Not surprisingly, appropriate allometries were only discovered for some lowland forest types in Latin America and south-east Asia. However, allometric equations would eventually be required for each forest type separately for each region. Although challenging, aiming at the establishment of such equations would probably be the step next in importance after defining forest types. Until the present day, most information on relationships between measurable tree dimensions and the corresponding biomass of a tree or log has been gathered at different degree of sophistication within various logging companies. Theoretically, a target-oriented cooperation can lead to relatively quick establishments of such allometries.
- **Wood density** values are necessary to convert yield biomass/ timber volumes into mass values of biomass. Their validity and applicability have been much under discussion and investigation. It is, however, beyond dispute that among the intrinsic parameters of allometric models for carbon stock conversion, improved knowledge on wood density holds the highest potential for refining above-ground biomass estimates since the variation of wood density between continents, regions and forest types varies considerably (Chave et al. 2005, 2006; Nogueira et al. 2006, 2007). Work on wood density has been carried out throughout the tropics, starting with commercial timber species and recently also expanding to the entire tropical species pool, par-

ticularly in Amazonia. Data bases provide relatively reliable information on wood density for the most common tropical trees. Further research is required for methods to compensate for incomplete datasets with reliable wood density values, preferably at the genus or even species level.

The research for this study revealed that a wide variety of valuable data on forest inventories has already existed worldwide. It would be desirable to channel and compile these data and make them publicly available, also beyond intellectual property concerns. First steps have already been undertaken, e.g. online databases on wood density (maintained by ICRAF) or on neotropical rainforest inventories (SALVIAS, ATDN) have emerged forming invaluable resources from which this study already profited tremendously.

5.3 GHG emissions from deforestation

To account for the emission reduction achieved by reducing tropical deforestation, the avoided emissions have to be calculated as described in chapter 4.4, scenarios i) and ii). The following section provides two different scenarios of calculation emissions based on different assumptions related to the role of burning in deforestation, however consistently adhering to the IPCC approach considering deforestation to lead to an immediate loss of all carbon:

1. One scenario assumes no burning activities. Deforestation converts forest carbon stocks to CO_2 and some CH_4 emissions from decay of litter and dead wood arise (low GHG emission scenario).
2. The second scenario assumes that all deforestation occurs through burning. Besides CO_2, N_2O and CH_4 emissions arise from forest fires (high GHG emission scenario).

These two scenarios should indicate the differences in greenhouse gas emissions if non-CO_2 emissions from forest fires are taken into account, as only burning is considered to release substantial amounts of non-CO_2 emissions.

5.3.1 Focus countries

Greenhouse gases are emitted from deforestation predominantly through the burning of biomass at all stages, i.e. when forests are burnt as such or remaining biomass is burnt after slashing or logging. Therefore, knowledge on the extent of burning in tropical forests would be essential for an accurate estimation of greenhouse gas emissions. Although such data are approximated on the regional scale (FAO 2006), no such information was available on a national level for the focus countries. Compensating for this data shortage, the above described contrasting greenhouse gas scenarios were applied. Results can be found in Table 30 (scenario 1) and Table 29 (scenario 2).

Table 29 *Greenhouse gases released in the period 1990 – 2005 under the assumption that all forest lost during that time would have been lost due to burning activities (high GHG scenario)*

		Greenhouse gases released from all forest lost in the period 1990 - 2005, if burnt								
		Carbon Dioxide (CO_2)			Methane (CH_4)			Nitrous Oxide (N_2O)		
		mean[a]	min[b]	max[c]	mean[a]	min[b]	max[c]	mean[a]	min[b]	max[c]
Brazil	AGB[d]	12222	5400	19750	18.7	5.8	36.2	8.1	2.5	15.7
	Total[e]	19572	10740	28803	23.8	7.3	50.7	10.0	3.1	21.4
Peru	AGB[d]	961	574	1249	1.5	0.6	2.3	0.6	0.3	1.0
	Total[e]	1385	910	1725	1.7	0.7	3.0	0.7	0.3	1.3
Congo	AGB[d]	139	57	232	0.2	0.1	0.4	0.1	0.0	0.2
	Total[e]	205	102	317	0.3	0.1	0.6	0.1	0.0	0.2
Madagascar	AGB[d]	285	210	419	0.4	0.2	0.8	0.2	0.1	0.3
	Total[e]	422	333	582	0.5	0.3	1.0	0.2	0.1	0.4
Indonesia	AGB[d]	18213	13795	27921	27.8	14.8	51.2	12.1	6.4	22.2
	Total[e]	26089	20886	37598	32.2	17.1	67.3	13.7	7.3	28.6
Papua New Guinea	AGB[d]	998	587	1667	1.5	0.6	3.1	0.7	0.3	1.3
	Total[e]	1519	982	2373	1.8	0.7	4.2	0.8	0.3	1.8

Notes: *Only natural forest cover considered, excluding plantations.*

[a] *calculated with 51 % of all carbon lost through fire (Kauffman et al. 1995).*

[b] *calculated with 42 % of all carbon lost through fire (Fearnside et al. 1999, 2007).*

[c] *calculated with 29 % of all carbon lost through fire (Fearnside et al. 2001).*

[d] *Lost completely through flaming combustion using the high trace gas scenario of Fearnside (2000).*

[e] *Combines the loss of 100 % above-ground biomass through flaming combustion, 80 % below-ground biomass through decay, 100 % litter through smoldering combustion, 100 % dead wood through smoldering combustion, 40 % soil organic carbon through decay (Fearnside 2000).*

For periods 1990 - 2000 and 2000 - 2005 see annex 4.

In the low greenhouse gas scenario (Table 30), all available carbon was calculated as direct emission in form of CO_2, under the assumption that no burning occurs. Very low emissions of methane (CH_4) may be expected from natural decay of litter and dead wood carbon pools.

Irrespective of differences in the CO_2 emissions between both scenarios shown here, the essential difference expressed is related to CH_4 and nitrous oxide (N_2O). While under the high greenhouse gas scenario the emissions of all these trace gases range for the pilot countries equally at Tg-scale (Table 29), they are not produced under the no-fire assumption with the exception of traces of CH_4 originating from the natural decay of litter or dead wood (Table 30).

Note: *For periods 1990 - 2000 and 2000 - 2005 see annex 4.*

Table 31 compares both scenarios on the basis of CO_2 equivalents. This shows that clearing all deforested areas through burning could lead to an increase of greenhouse gas emissions from above-ground biomass alone by 11 % (3 – 17 %) and considering all carbon pools this increase is enhanced to 17 % (11 – 25 %).

Table 30 *Greenhouse gases released in the period 1990 – 2005 under the assumption of no burning activities turning the entire biomass stock into CO_2 with the only non-CO_2 greenhouse gas produced would be methane from the decay of litter and dead wood (low GHG scenario)*

		Greenhouse gases released from all forest lost in the period 1990 - 2005, without fire								
		Carbon Dioxide (CO_2) (Tg)			Methane (CH_4) (Gg)			Nitrous Oxide (N_2O)		
		mean	min	max	mean	min	max	mean	min	max
Brazil	AGB	13588	6118	21679	0.0	0.0	0.0	0	0	0
	Total	19292	10646	28635	5.1	2.6	7.2	0	0	0
Peru	AGB	1068	651	1370	0.0	0.0	0.0	0	0	0
	Total	1397	915	1747	0.2	0.1	0.3	0	0	0
Congo	AGB	155	65	255	0.0	0.0	0.0	0	0	0
	Total	206	103	322	0.0	0.0	0.0	0	0	0
Madagascar	AGB	317	238	460	0.0	0.0	0.0	0	0	0
	Total	426	334	589	0.1	0.1	0.1	0	0	0
Indonesia	AGB	20249	15628	30648	0.0	0.0	0.0	0	0	0
	Total	26313	20997	38102	3.7	1.8	5.2	0	0	0
Papua New Guinea	AGB	1109	665	1830	0.0	0.0	0.0	0	0	0
	Total	1532	986	2405	0.3	0.1	0.4	0	0	0

Note: *For periods 1990 - 2000 and 2000 - 2005 see annex 4.*

Table 31 *Comparison of greenhouse gases as CO_2 equivalents released in the period 1990 – 2005 under the high and low greenhouse gas scenarios*

		Greenhouse gases released from all forest lost in the period 1990 - 2005 (Tg CO_2 equivalents)								
		High GHG scenario			Low GHG scenario			Additional GHG emissions in the case of total loss due to burning		
		mean[a]	min[b]	max[c]	mean	min	max	mean	min	max
Brazil	AGB[d]	15123	6302	25370	13588	6118	21679	1535	184	3691
	Total[e]	23164	11849	36492	19292	10646	28635	3873	1203	7857
Peru	AGB[d]	1189	670	1604	1068	651	1370	121	20	233
	Total[e]	1646	1020	2190	1397	915	1747	249	105	442
Congo	AGB[d]	172	67	298	155	65	255	18	2	43
	Total[e]	243	113	404	206	103	322	37	11	83
Madagascar	AGB[d]	353	245	538	317	238	460	36	7	78
	Total[e]	500	373	737	426	334	589	74	38	148
Indonesia	AGB[d]	22537	16099	35867	20249	15628	30648	2288	471	5219
	Total[e]	31010	23498	47879	26313	20997	38102	4697	2502	9777
Papua New Guinea	AGB[d]	1235	685	2142	1109	665	1830	125	20	312
	Total[e]	1799	1094	3018	1532	986	2405	267	108	613

Notes: *Only natural forest cover considered, excluding plantations.*
[a] calculated with 51 % of all carbon lost through fire (Kauffman et al. 1995).
[b] calculated with 42 % of all carbon lost through fire (Fearnside et al. 1999, 2007).
[c] calculated with 29 % of all carbon lost through fire (Fearnside et al. 2001).
[d] Lost completely through flaming combustion using the high trace gas scenario of Fearnside (2000).
[e] Combines the loss of 100 % above-ground biomass through flaming combustion, 80 % below-ground biomass through decay, 100 % litter through smoldering combustion, 100 % dead wood through smoldering combustion, 40 % soil organic carbon through decay (Fearnside 2000).

5.3.2 Regional assessment

5.3.2.1 Regional CO_2 emissions from fire

To allow a comparison with the GHG emission results for the focus countries the regional study was divided into GHG emission scenario with and without burning.

The greenhouse gas scenario without burning was calculated based on the same methods as in the previous chapter, its data for the regions was acquired using the FRA 2005 (FAO 2006) for forest area change as well as the IPCC (2003) defaults for different forest type above-ground biomass carbon contents. To calculate the GHG emissions the carbon content was simply multiplied by the area of deforestation and the CO_2 conversion factor.

The GHG emission scenario assuming burning as deforestation method for the entire biomass stock used an IPCC GPG (2006) calculation approach for fire-based emissions with a default fuel mass and combustion factor as well as GHG-specific emission factors (see Annex 2).

To account for carbon, this approach assumes that only a fraction of available carbon in the biomass is lost due to fire. The remaining carbon is expected to be released through decay at a later stage and excluded from the estimation. Thus, the calculation methods used here differ from those in Chapter 4.4. Consequently, they are not directly comparable to the country results in the previous section.

Table 32 *CO_2 emissions released in the period 1990 – 2005 under the assumption of no burning activities turning the entire biomass stock into CO_2*

Region/subregion	**Carbon emissions 1990-2000 in Tg CO2**			**Carbon emissions 2000-2005 in Tg CO2**			**Carbon emissions 1990-2005 in Tg CO2**		
	mean	min	max	mean	Min	max	mean	min	max
Caribbean	-346	-197	-461	-260	-148	-346	-606	-346	-807
South & Central America	33,877	22,971	51,179	18,372	12,458	27,760	52,249	35,429	78,939
Northern Africa	4,600	4,600	4,600	2,230	2,230	2,230	6,829	6,829	6,830
Western & Central Africa	13,806	7,432	21,834	5,739	3,090	9,078	19,545	10,522	30,911
Eastern & Southern Africa	9,522	6,770	14,398	4,681	3,328	7,080	14,202	10,099	21,478
South & Southeast Asia	22,870	13,548	30,159	12,646	7,491	16,679	35,515	21,039	46,838
Oceania	4,991	3,874	7,376	1,983	1,539	2,931	6,974	5,414	10,308
Tropical Countries Total	**89,336**	**59,014**	**128,977**	**45,372**	**29,972**	**65,516**	**134,708**	**88,987**	**194,493**

Source: calculations MPI, M. Hüttner

Table 33 Greenhouse gas emissions in the period 1990 – 2005 under the assumption that burning activities occur for the entire biomass stock

Region/subregion	Sum of burned and subsequent GHG emissions, calculated as CO2 equivalent (in Tg)								
	1990-2000			2000-2005			1990-2005		
	mean	min	max	mean	min	Max	mean	min	max
Caribbean	-341	-129	-519	-256	-97	-389	-596	-225	-909
South & Central America	33,243	14,989	57,894	18,028	8,129	31,397	51,271	23,118	89,291
Northern Africa	4,446	2,666	6,226	2,155	1,292	3,018	6,601	3,958	9,244
Western & Central Africa	13,559	4,319	24,452	5,636	1,795	10,165	19,195	6,114	34,617
Eastern & Southern Africa	9,259	3,466	17,177	4,552	1,704	8,445	13,811	5,170	25,622
South & Southeast Asia	22,479	8,627	34,298	12,430	4,770	18,965	34,908	13,397	53,263
Oceania	4,923	3,019	8,096	1,956	1,200	3,217	6,879	4,219	11,312
Tropical countries Total	**87,568**	**36,957**	**147,625**	**44,502**	**18,794**	**74,817**	**132,070**	**55,751**	**222,442**

Source: calculations MPI, M. Hüttner

In the GHG scenario assuming burning activities for the entire biomass stocks the GHG emissions are lower than for the scenario without burning. This can be explained due to the IPCC method used, which assumes that only a fraction of the available carbon in the biomass is lost due to fire and the other fraction is not taken into account. This fraction might be different from the factors used by Fearnside (2000). This is expressed through a combustion and emission factor.

Table 34 Comparison of greenhouse gases as CO_2 equivalents released in the period 1990 – 2005 under the GHG scenario with and without burning.

Region/subregion	Deforestation area (in 1000 ha) Based on FAO (2006)	Total CO2 equivalent emissions (in Tg) 1990-2005* Burning of entire biomass stocks			Total CO2 equivalent emissions (in Tg) 1990-2005** No burning and immediate release of Carbon (based on weighted mean for forest types)		
		mean	min	max	mean	min	max
Caribbean	-624	-596	-225	-909	-600	-342	-800
South & Central America	64 506	51 271	23 118	89 291	52 264	35 439	78 957
Northern Africa	15 045	6 601	3 958	9 244	6 833	6 833	6 833
Western & Central Africa	23 085	19 195	6 114	34 617	19 545	10 521	30 909
Eastern & Southern Africa	25 820	13 811	5 170	25 622	14 205	10 101	21 481
South & Southeast Asia	40 029	34 908	13 397	53 263	35 517	21 040	46 837
Oceania	6 260	6 879	4 219	11 312	6 975	5 415	10 309
Total	**174 121**	**132 070**	**55 751**	**222 442**	**134 738**	**89 007**	**194 526**

*Notes: *using the IPCC AR4 (2007) GWP of 25 for CH_4 and 298 for N_2O*
*** expecting that no CH_4 and N_2O emission occur under the scenario without burning*

Source: calculations MPI, M. Hüttner

Besides the emission calculations following the greenhouse gas scenario with and without burning, data on the observed forest area burned was available for each region based on FAO FRA 2005. Table 35 shows the associated emissions from the reported burning. Since the percentage of forest loss burned is mostly only around 1-2 percent, the overall emissions are much lower than in the previous scenarios. In the first four columns emissions are calculated according to the formula from the IPCC Good Practice Guidance for LULUCF (see Annex 2 on GHG emissions from tropical forest fires, equation 1), using IPCC global default fuel and emission factors for primary and secondary forests and values for the area burned based on FAO FRA 2005 data. The results show large differences in biomass emissions between secondary and primary forests. These values are connected with high uncertainties of more than 50%. The emission results of the last two columns were derived assuming that all biomass carbon on the specific regional burned forest areas was completely converted into CO_2.

Table 35 *Comparison of emission calculation methods using IPCC and FAO values the observed forest fires from 1990-2005*

	IPCC default calculation for all primary tropical forests		**IPCC default calculation for all secondary tropical forests**		**IPCC regional average if assumed that total area is burnt**	**FAO average. if assumed that total area is burnt**
	Biomass emissions from fire	**Uncertainty range**	**Biomass emissions from fire**	**Uncertainty range**	**Biomass emissions**	**Biomass emissions**
Region	**Tg CO_2**	**+/-**	**Tg CO_2**	**+/-**	**Tg CO_2**	**Tg CO_2**
Caribbean	2.3	1.2	0.9	0.6	7.4	4.9
Central +South America	507.7	258.9	190.0	123.1	1044.8	1111.6
Northern Africa	1100.6	561.2	411.8	266.9	6486.7	1753.6
Western and Central Africa	92.5	47.2	34.6	22.4	1077.4	980.7
Eastern and Southern Africa	86.1	43.9	32.2	20.9	435.6	290.7
South and Southeast Asia	1965.4	1002.2	735.4	476.6	4604.4	3718.5
Total	**3754.6**	**1914.5**	**1404.8**	**910.4**	**13656.3**	**7860.0**

5.3.2.2 Causes of tropic forest fires

The main reasons for non-CO_2 GHG emissions from tropical forests are forest and peatland fires. Such forest fires in the wet tropics are almost exclusively directly or indirectly caused by human activities. The FAO estimates that 80 - 90 % of wildland fires are caused by human activities, primarily through the uncontrolled direct use of fire for clearing forests and woodlands for agriculture, livestock management, extraction of non-wood forest products, industrial development, resettlement and hunting (Persson and Azar 2005). Forest fires might also occur indirectly through other forms of human influence, such as forest clearance and forest fragmentation, road construction and logging. These forms of land use change lead to changing fuel loads and humidity, increasing the fire susceptibility of the forest (Cochrane 2003).

Three preconditions favour forest fires: 1) dry conditions, 2) adequate fuel loads and 3) an ignition source. Dry conditions depend mainly on climate and weather patterns, but can also be influenced by human drainage, logging or other forms of land use change. Adequate fuel loads depend on vegetation characteristics and the disturbance history. Human management affects fuel loads in ambiguous ways: while most of the land use change and logging activities increase fuel loads, prescribed burning and fire management aim at reducing the susceptibility of forests to fire. Humans are the dominant ignition source. Lightning may contribute as natural factor, but fire frequencies often show almost an anti-correlation with lightning frequency because most fires occur during the dry season when the thunderstorm activity is low. Consequently, it is likely that most fires are human-induced although natural factors also contribute to the pre-disposition of forests to fire. A clear distinction between natural and anthropogenic causes of forest fire is difficult. The simplest valid assumption for a RED mechanism would be to assume all forest fires as human-induced.

5.3.2.3 Regional GHG emissions from tropical peatland fires

The peat layer in tropical soils can reach a thickness of up to 20 m and can constitute an enormous emission source. Due to the high carbon stocks on peatlands, peat fires can release large amounts of greenhouse gases. Peatlands have become increasingly susceptible to fire due to anthropogenic drainage for land conversion. Estimates of CO_2 emissions from burning peatlands in Indonesia in 1997 range from 13% to 40% (Page et al., 2002) of the mean global annual carbon emissions from fossil fuels (Langmann and Heil 2004).

Fires from drained peatlands were the dominant source of emissions for the South-East Asian region during the extraordinary El Niño/La Niña Period in 1997/1998 (Page, Siegert et al. 2002). Since this specific case is best documented, we will mainly refer to associated research in this section. Peatlands are assumed to have higher fuel loads than forests (Werf, Randerson et al. 2006). Some studies even state that biomass loads for peat deposits could be 10 times higher compared to rain forests (see Table 36) (Levine 2000). Table 36 shows the differences in biomass load and GHG emissions for both. The related data on emission factors can be found in Annex 3.

Table 36 Comparison of peatland and forest fire emission properties in Indonesia for 1997-98 based on a case-study example of Levine ((Levine 2000), cited in (Langmann and Heil 2004))

	Biomass load (in t/km^2) (B)	**Area burned (km^2) (A)**	**Total biomass consumed by burning (in Tg) (M)**	**CO_2 emissions released from burning (in Tg) (CO_2eq)**	**CO_2 equivalent from CH_4 emissions (in Tg)**
Rainforest / A1	10000	39640	79.3	32.1	0.1
Rainforest / A2	10000	39640	79.3	32.1	0.1
Peat areas / A1	97500	14190	691.8	266.3	2.8
Peat areas / A2	97500	68140	3321.8	1278.9	13.3

A1 = Standard emission scenario

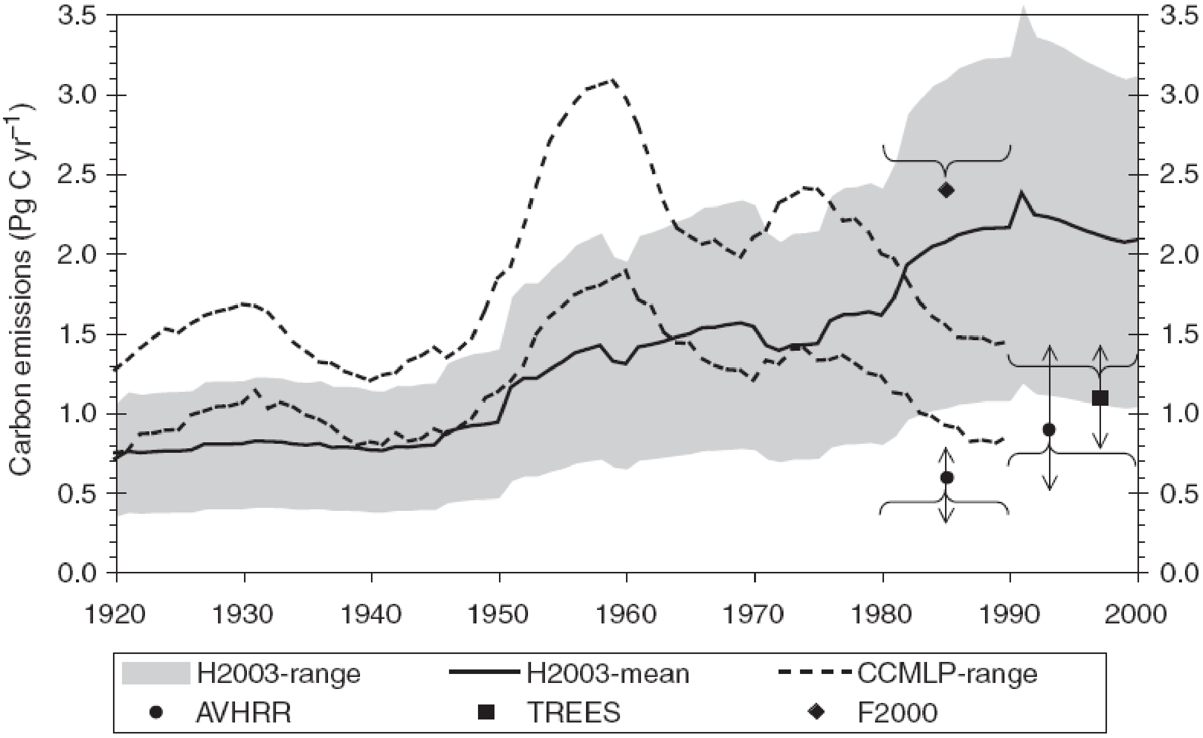
A2 = High emission scenario

The quantitative detection of greenhouse gas emissions released from peat fires in tropical regions still involves many uncertainties. Since the low-temperature, smoldering peatfires burn above-ground vegetation as well as different depths of the below-ground organic soil, their detection with satellite techniques is difficult. Uncertainties in the detection of the soil type and the depth of the soil burned complicate the emission detection as well (Langmann and Heil 2004). Consequently, for the case of peatfires in Indonesia from July 1997 to June 1998, the calculation results in Table 35 range from circa 270 up to 1291 Tg CO_2 emission equivalents, from CO_2 and CH_4 emissions (Langmann and Heil refer also to CO and total particulate matter emissions, which are however not considered in this report since they do not appear under the IPCC GPG) (Levine 2000; Langmann and Heil 2004).

5.3.3 Global assessment

The first attempt to assess emissions from deforestation has been performed by Houghton and colleagues (Houghton et al., 1983, 1985; Houghton, 1999, 2003). They have compiled land-cover change information from forest inventories and used them to estimate global carbon emissions of 2.2 PgC yr^{-1} in the 1990s (compared with 6.4 PgC yr^{-1} from fossil-fuel emissions) and a total release of 156 PgC over the 1850–2000 period (Achard et al. 2007). Recently, several new estimates of carbon emissions from deforestation have emerged (Figure 17). Fearnside (2000) estimated that tropical land-cover changes resulted in a net emission of 2.4 PgC yr^{-1} during the 1981–1990 period. More recently, DeFries et al. (2002) and Achard et al. (2002, 2004) have used remotely sensed tropical deforestation data (from the Advanced Very High Resolution Radiometer, AVHRR, and Landsat TM, respectively) to estimate releases of 0.3–0.8 PgC yr^{-1} in the 1980s and 0.5–1.4 PgC yr^{-1} in the 1990s (Table 1; Fig. 1). These satellite-based estimates and the CCMLP study suggested that Houghton and colleagues and Fearnside (2000) have overestimated carbon emissions from land-cover change by up to a factor of two, mainly because of different estimates of the rates of tropical deforestation (DeFries & Achard 2002). However, these five different studies are not directly comparable. The studies covered different geographic ranges and time periods, considered different types of land-cover changes, made different assumptions about historical land-cover change, and used different carbon cycle models. Currently many projects, such as JRC TREES 3, FAO FRA2010, NASA Landsat Pathfinder Humid Tropical Deforestation Project, aim at to obtaining new information and estimations on emission from tropical deforestation. New data on global emission from deforestation in tropical countries will be available in 2010.

Figure 17 Intercomparison of five different estimates of carbon emissions from global land-cover change



Notes: The Houghton (2003a; H2003) and McGuire et al. (2001; Carbon Cycle Model Linkage Project; CCMLP) estimates were global, while the DeFries et al. (2002; AVHRR), Achard et al. (2004; TREES), and Fearnside (2000; F2000) studies were pan-tropical. H2003 and CCMLP estimated annual values, while the other three studies estimated decadal averages.

Sources: Ramankutty et al. 2007

5.3.4 Conclusions and recommendations

An accurate estimate of greenhouse gas emissions from deforestation depends upon the availability of data on fire regimes within the deforestation patterns. The current lack of this information on national scales impairs such estimation considerably. The general assumption of no fire occurrence would lead to an overall lower and thus more conservative emission estimate, the general assumption that all deforestation areas are burnt would lead to an overestimation of GHG emissions. For a RED accounting mechanism the conservative assumption of no fires would be an appropriate default assumption for those countries where data on forest fires are missing, because the key function of the accounting mechanism is not to overestimate the accounted emission reductions.

According to the current IPCC GPG, countries only need to report fires on managed land or on unmanaged land, which becomes managed land after the fire. Up to date, only very insufficient information exists about the fire intensity and the fuel available, but globally harmonized remote sensing based products for monthly burnt area are becoming available (GLOBCARBON; see (Plummer et al. 2006)). Up to now, the FAO only has fire area data for less than 20 % of the total forest area for Africa, worldwide this figure expands to approximately 80 % of the total forest area and to 60.4 % for the tropics (FAO 2006). Recently University of Maryland in collaboration with NASA has released the MODIS Burnt Area Products (Roy et al. 2005)[3]. This is the first attempt to set up an operational system to monitor and assess burnt area at global scale. In the near future countries may use these products to assess their emission from forest fires.

2006 IPCC Guidelines recommend conducting an annual fire reporting. Specific country values are suggested instead of IPCC default values, since the fire intensity and the fuel availability strongly depend on the current land use change and climate conditions as well as the corresponding ecosystem's vegetation and soil properties. Thus, in countries where forest or peatland fires constitute an important fraction of GHG emissions (such as Indonesia) it is strongly recommended to develop specific methodologies according to the IPCC Tier 2 or Tier 3 method.

The most uncertain parameters in the calculation of fire emissions are the area burnt and the amount of fuel load. Satellite measurements are currently limited by cloud cover, coarse satellite grids, and heterogeneous fuel loads, causing the largest uncertainties in global biomass burning estimates on deforestation regions and in areas where peat fires occur. To address these uncertainties, finer resolution satellite measurements and bottom-up modelling (such as CASA) need to progress (Werf et al. 2006). Since only a fraction of the available fuel load burns during a fire, the combustion completeness must be assessed. New satellite-based approaches can detect this through the fire radiative energy to directly estimate emissions (Werf et al. 2006). To improve the monitoring and assessment of forest fires and associated emissions, data-collection systems need to be made directly comparable by harmonizing definitions as well as methods of data collection and sharing information (FAO 2006). It is recommended to combine satellite data of deforestation area, biomass / vegetation carbon and fire occurrence (and intensity) in the future to quantify associated GHG releases.

Under the current methods the estimation of greenhouse gas emissions from forest fire will always remain with a relatively large uncertainty and the distinction between human-induced, human-influenced and natural fire is still beyond current capabilities.

Besides the mentioned uncertainties, current methods for the non-CO_2 emission calculations need improvement under country-specific applications. Since non-CO_2 emissions are temporally and spatially more variable, verification is much more difficult than for CO_2 emissions.

Peat fire emissions deserve consideration in the climate negotiations, since uncertainties are still high, despite of its greenhouse gas emissions – including CH_4 and CO – bearing a large significance for the emissions of certain tropical countries. To reduce the measurement uncertainties, continuous monitoring of peat areas is necessary, including the spatial distribution, depth and modification by fire (Langmann and Heil 2004).

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[3] available at: http://modis-fire.umd.edu/MCD45A1.asp#1

6 Drivers for tropical deforestation

6.1 Causes of Deforestation

Any future climate regime addressing incentives for reducing deforestation has to be aware of the multitude of drivers for tropical deforestation. Direct causes of deforestation can be separated into natural and anthropogenic drivers:

Anthropogenic drivers for deforestation

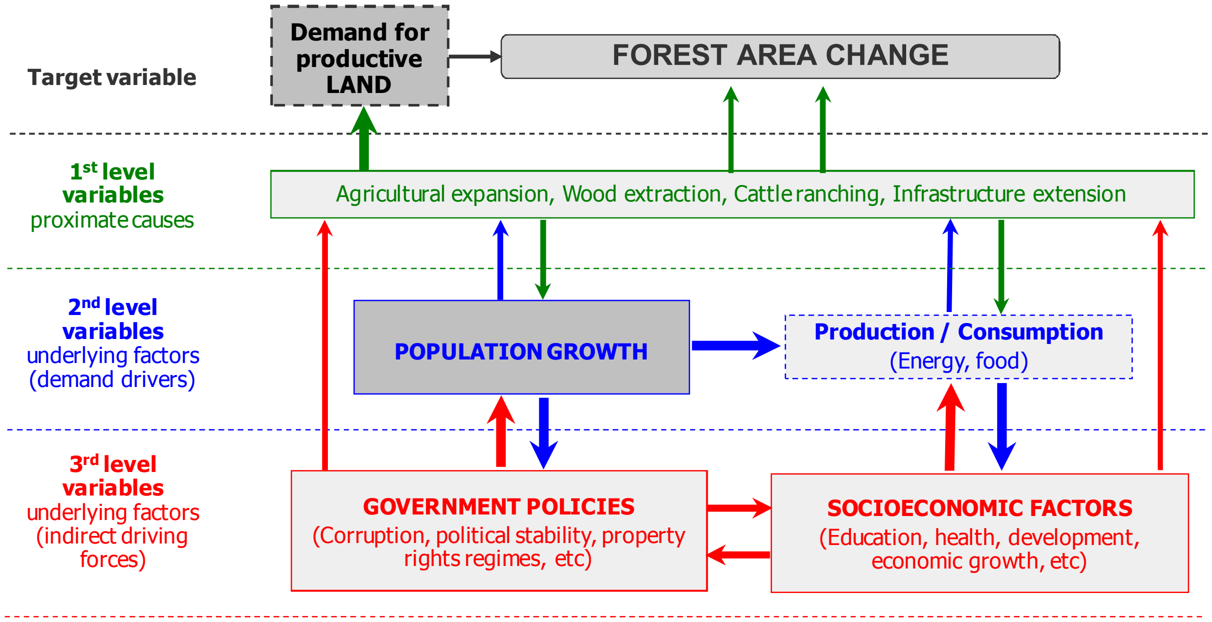
- Clear-cutting for logging and pulpwood
- Forest conversion for permanent commercial agriculture (palm oil plantations, soybean fields)
- Large-scale shifting cultivation (i.e. slash-and-burn) where forest is not permitted to regenerate due to subsequent clearing
- Forest conversion for permanent pasture
- Open pit mining and large-scale mining operations
- Clear-cutting for charcoal production
- Large roads and infrastructure projects
- Dam construction
- Urban expansion
- Oil and gas extraction

Natural causes for deforestation

- Wildfires
- Volcanic eruptions
- Tropical storms

Besides these direct or proximate causes listed above, there are underlying factors such as population growth, government policy, institutional or socioeconomic factors that influence the proximate causes as shown in Figure 18 where three levels of variables have been distinguished.

Figure 18 Overview on direct and indirect deforestation drivers



Indirect driving forces include areas, such as fiscal and development policies, land access and land tenure, weak government institutions and corruption, or social factors such as education or the lack a "forest culture", an appreciation by the population of the value of forests to their society and a tradition of managing the resource for the collective benefit of all.

6.2 Quantitative relationships between drivers and tropical deforestation

A large amount of national and local case studies on deforestation drivers has been conducted in the past. However, regional and global analyses of deforestation remain limited. Geist and Lambin (2002) conclude in a study on deforestation drivers that “tropical forest decline is determined by different combinations of various proximate causes and underlying driving forces in varying geographical and historical contexts.” Especially underlying driving forces of deforestation such as national- to global-scale economic opportunities and policies often react in a combined way and depend on several variables, which may be hard to predict.

Kaimowitz and Angelsen (1998) reviewed different deforestation models. They conclude that “most researchers agreed that more roads, higher agricultural prices, lower wages and a shortage of off-farm employment generally led to more deforestation, but that the effects of agricultural input prices, household income levels, tenure security, population growth, poverty reduction, national income, economic growth, and foreign debt were unclear”. They also pointed out the difficulty of using global regression models, since the data limitation and poor quality make it hard to distinguish between correlation and causality. Even if statistical relationships are found, they do not need to be attributed as causes of deforestation. Correlations need to be evaluated carefully by testing them against country case studies.

Vanclay (2005) pointed out that a statistical analysis of deforestation might be difficult, since the reliability of deforestation estimates varies by countries. This might increase error ranges and thus limit the significance of results based on global statistics.

Despite many studies that claim the direct effect of population growth on deforestation, Vanclay used FAO FRA 2000 data to show that population density has a negligible effect on deforestation, both in the tropics and world-wide. He admits however, that rapid population growth may contribute to deforestation (Vanclay 2005).

A recent study (Rudel, Coomes et al. 2005) claims a certain reverse dependency of deforestation increase and growth in per-capita income. This is explained by the related creation of enough non-farm jobs leading to a decline of land pressure and subsequently to a regeneration of forests.

Despite the mentioned findings, none of the previous studies could find clear factor relationships for deforestation drivers applicable to predict forest area changes.

In this chapter statistical relationships between national deforestation rates and biophysical / socio-economic as well as governance-related deforestation drivers in the tropics were evaluated to develop criteria for the robustness in deforestation trend predictions.

Historic quantitative data on the selected biophysical, socio-economic and governance-related national deforestation drivers were collected. The study was split into two parts. The first part analysed the interactions of the target variable (i.e. forest area change) with first (i.e. proximate causes) and second (underlying factors) level variables. The second part analysed the interactions between second and third level variables (i.e. underlying, indirect driving forces) such as socio-economics and governance.

Their correlations were investigated using statistical methods such as linear univariate and multivariate regression analysis. The obtained correlations were investigated for their causality through cross-checking with results from general and case-specific literature studies. Furthermore, the statistical correlation between absolute and relative land and forest area changes were investigated using simple statistical correlation methods.

The results of the univariate and multivariate regression analysis have been divided temporarily into periods from 1990-2000 and 2000-2005 and spatially into all tropical countries (see Annex, Table 54 and Table 55) and seven tropical regions (see Annex, Table 52 and Table 53). This section mainly analyses the results for 2000-2005, because of its timeliness and higher number of variables and data points. Furthermore, the results from 1990-2000 were used to cross-check validity. The chart visualizations for the explaining variables for the regressions were illustrated in Figure 28 to Figure 31 (see Annex).

6.2.1 Regression analysis for individual tropical countries

For the period 2000-2005, for all tropical countries the significant univariate correlations with forest area change were with the variables ‘Population Growth’, ‘Total fertility rate’ and ‘Public expenditure for education’. These population and education related variables show only an explaining power of less than 15 percent of deforestation each. The stepwise regression yielded an R^2 of 0.253 with ‘Total fertility rate’ as predicting variable. For 1990-2000 only two variables, ‘Human poverty index’ and ‘Adult illiteracy’ showed significant correlations, with the latter yielding only an R^2 of 0.082 as explaining variable in the stepwise regression.

The socio-economic factors which appear to be relevant for the decline of forests in tropical countries are related to the human poverty, education, and population pressure. By using Pearson’s (R) correlations, the Human Poverty Index was found to be positively correlated with the variables ‘population growth’, ‘probability at birth of not surviving to age 40’, and ‘total fertility rate'. The stepwise regression indicated the last one as the explaining variable (R: 0.848, R2: 0.719, Sig.: 0.000, N: 72). Such result was expected, since the Human Poverty Index is a composite index which includes measures for the variables mentioned above.

The variable 'total fertility rate' has also appeared positively correlated with 'population growth', as well as explaining variable for 'public expenditure on education' (R: 0.430, R2: 0.185, Sig.: 0.029, N: 26).

The results of the regression analysis for all tropical countries revealed that the individual country circumstances are often too different from each other to find similar striking correlations in both periods. However, the results indicate that population-related indicators play an important role in explaining deforestation. Furthermore, for both times series the importance of education is clearly visible. While represented by the explaining variable 'Adult illiteracy' for the stepwise regression 1990-2000, a similarity in its character can be drawn from the explaining variable 'Public expenditure on education' for the univariate regression 2000-2005. The increase in expenditure for education as well as an increase in literacy rate is expected to qualify a higher portion of the inhabitants of a certain country for secondary and tertiary employment sectors. This would reduce the amount of forest dwellers dependent on agriculture and forestry – leading to a lower deforestation rate.

Concerning the governance indicator's analysis, by using Spearman's (Rho) coefficients, the variable 'public expenditure on education' has shown positive correlation with 'regulation of credit, labour, and business' and with 'control of corruption', since the first indicator was the explaining variable after the stepwise regression (Rho: 0.649, R2: 0.421, Sig.: 0.002, N: 22).

Other correlations were also found, although they are not straight related to the applied dependent variables, for instance, 'per capita gross domestic product' had positive relationships with both 'corruption perception index' and 'legal structure and security of property rights'. After the stepwise regression, the last variable emerged as explaining variable (Rho: 0.534, R2: 0.285, Sig.: 0.005, N: 56).

Additionally, the security of property rights can be considered a positive incentive to improve countries' economic performance. A government without the mechanisms to correctly enforce property rights gives room for innumerous types of illegal activities related to concessions and forest use. According to Amacher (2006), every year a great amount of forest products deriving from illegal exploitation is commercialized in tropical regions, especially Latin America and Asia. As a result, the legal structure and security of property rights make a substantial contribution not only to preserve and sustainably manage natural resources, but also to generate additional income for local population.

6.2.2 Regression analysis for regions

In the period of 2000-2005, in the univariate regression analysis the 'Human poverty index' appeared as explaining variable for the Caribbean, Northern Africa and South and Central America – similar for the period 1990-2000. It also had the highest explanatory power in the stepwise regression for South and Central America for both time series. Also population-related indicators such as 'Probability at birth of not surviving to age 40', 'Population Growth' and 'Total fertility rate' showed importance for the regions of the Caribbean, Northern Africa, Eastern and Southern Africa and South and Central America, whose importance can partly be confirmed in the stepwise regression. These trends for uni- and multivariate regressions cannot be found for the 1990-2000 correlations, however we did not have data for 'Probability at birth of not surviving to age 40' and 'Total fertility rate (births per woman)' for this period. Furthermore – like for the period 1990-2000 – the production, export and import for different agricultural and forestry commodities shows significant correlations for every region, except the Caribbean, Northern Africa and Oceania.

While the 'Public expenditure on education' parameter only shows significance for the univariate regression for all tropical countries for 2000-2005, education seems to have a major correlation with deforestation in the previous period. Here, 'Adult illiteracy' even displays an explaining variable for the stepwise regression for Eastern and Southern Africa, Northern Africa (and South + Central America).

The Human poverty index is calculated not by income, but as composite index including measures for a long and healthy life, knowledge and a decent standard of living. Thus, no parallel correlation with the 'Average Annual GDP Growth per Capita' can be explained.

For the respective regions of the Caribbean, Northern Africa and South and Central America it is expected that the lack of opportunity under increased poverty leads to the (over)use of natural resources, since no alternatives exist to fulfil their basic needs for food and other resources.

The high correlations of deforestation and population-related variables for the Caribbean, Northern Africa, Eastern and Southern Africa and South and Central America can be interpreted in different ways. In the univariate regression results for the Caribbean, North Africa as well as Central and Southern America the lower the mortality rate in countries of these regions, the higher the forest growth rate. It is not expected that a higher population would lead to the same results, since the increase in population growth and fertility rate contributes to deforestation at the same time. It is rather assumed that mortality acts as a proxy indicator for life quality, including the provision of health services and income.

While the import and export correlations often show a low explanatory power this might partly be related to the limited data available and region-internal market movements. Thus, it is recommended to obtain national time-series of this data to draw valid conclusions about their influence on deforestation.

While the lack of correlations with 'Adult illiteracy' for 2000-2005 might partly be related to data limitations, it is worth considering this variable due to its dominant position for the period 1990-2000 for all tropical countries as well as for regions. The forest area change correlating with 'Adult illiteracy' for 1990-2000` showed that the lower the illiteracy rate, the higher the deforestation. Another explanation was already given in the analysis of the correlations for all tropical countries above.

For the **Caribbean** the explaining correlation between decrease in mortality rate and deforestation was already explained above.

For the region of **Eastern and Southern Africa** countries with a high plantation growth rate have low deforestation, which might be explained by a decreased pressure through timber generation outside forests.

Northern Africa features low-forested countries, and the pressure on these resources is high, especially when population growth and poverty are high. This pressure on the resources is confirmed by the explaining variable in 1990-2000 being increase in permanent crop areas leading to higher deforestation. This can easily be attributed to the higher land demand for an increasing amount of people.

Variables for the region of **Oceania** contain too few cases to establish valid correlations.

In **South and Central America** human poverty acts as strong driver of deforestation for both periods, since poor people often depend on agriculture to meet their basic needs. While the import of cattle meat seems to increase deforestation, this can be attributed to the internal trade in the region. Big countries like Brazil export cattle meat have a relatively small deforestation rate (due to the size of the forest left). Small countries like Guatemala or Nicaragua import cattle meat while having a low absolute forest area, where changes result in a high relative deforestation rate. An increase in the production of palm oil (and sugarcane) also leads to higher deforestation, as well partly visible for 1990-2000. Here the explanation is much more obvious, since a higher production is often associated with a higher demand in land.

While ‘energy consumption’ is the explaining variable in **South and South-East Asia** for the stepwise regression analysis, its data sets are rather coarse. Nevertheless, better country data on these issues is crucial to improve the results. Since there are no variable similarities to 1990-2000, this might also be interpreted as a fast change of dominant deforestation drivers in this region.

For the **Western and Central Africa** region there was not enough data to run a stepwise regression. The best single explaining variable was ‘production of cattle meat’. Since the general growth rate of cattle production was not in any positive correlation to deforestation, it is assumed that the increase in livestock intensity decreases deforestation. An explanation would be that a higher income share from cattle production weakens the economic dependency of forest-related income.

In general, the amount of cases in the regional study is very limited by the data quantity and quality for variables, which makes the results rather tentative.

Concerning the increase of poverty, the results of the socio-economic regression analysis for different regions were not different compared to the outcome for tropical countries as a whole. In all regions (except in Oceania, due to a lack o data) population growth, fertility and mortality rates, and adult illiteracy were pointed out as the main causes of poverty. The low expectancy of life in some regions can also be related to deficient health assistance, especially in rural and poorest areas.

All results concerning population dynamics and poverty in the Caribbean and in South and Southeast Asia lead to the lack of legal structure and security of property rights. Considering that people have no right of land tenure, they consequently have no incentives to use land efficiently (or make any decision concerning its utilization), meaning that in a situation where the property rights are inadequately defined the private cost of deforestation is practically zero.

A stable and effective government is crucial for the education improvement in regions like Eastern and Southern Africa and South and Southeast Asia. The lack of law enforcement and weak policies for the protection of citizens (including the protection of private property) are factors that promote the inequality of wealth and opportunities.

Indubitably, this chain of causation concerning governance and deforestation is fundamental to the elaboration of policies intended to curb forests reduction. To be successful and sustainable, any mechanism (including RED) has to aim not only to decrease the deforestation rate in these countries, but also to develop and implement policies that improve governance and the enhancement of human development at the same time.

6.2.3 Uncertainties of the assessment

All correlations are based on forest area change data from the FRA 2005 (FAO 2006) and international datasets on socio-economic and governance indicators. Since forest assessments are very expensive, most countries only provided heterogeneous timelines and assessment methods to report their forest covers. To determine the forest area change for 1990, 2000 and 2005 the FAO often had to use linear extrapolations and interpolations of different time series for several countries. In minor cases, the FRA also used assumptions that no change would happen or model-based methods to streamline the data. However, it can be assumed that these data adjustments are not distorting the validity of the shown correlations, since these are build on robust trends for whole regions instead of single countries. The remote sensing survey carried out by the FAO in 2000 mainly confirmed the consistency with the Forest Resource Assessment for America and Asia. An exception is Africa, where the FAO remote sensing survey calculated a net annual loss of -2.2 million hectares. The FRA 2005, which is instead mostly based on national reports including expert judgements, calculated a net annual loss of 4.3 million hectares for Africa. Although this figure is very likely overestimated, the remote sensing survey might also have underestimated the deforestation quantity. Since the satellite survey was rather coarse, the often occurring small-scale deforestation patches were probably not detected. Therefore correlations for African regions have to be used with special caution and do – at least so far – not allow a precise determination of deforestation driver influences.

Besides the data inaccuracy mentioned above, the calculation of deforestation trends due to factor (variable) changes involved some inherent uncertainties and complex interactions, which could not be dealt with in this study. Nevertheless, they are outlined to illustrate current shortcomings and future improvement potential.

- Lack of data: A list of missing or insufficiently represented variables is shown in Table 51 (see Annex 1). Illegal logging, which might comprise up to 80 % of exported timber for countries like Indonesia (Greenpeace 2003) cannot be considered in this analysis, since no consistent data on country level exists and most probably never will. Other factor data, such as agricultural imports/exports and production, road density, forest functions, agriculture prices, ownership or data on socio-political processes show large gaps for many countries and /or do not provide sufficient data over time.
- Unquantifiable factors: Political decision-making is expected to strongly influence deforestation and related factors. However, it cannot simply be explained by empiric changes over time. Rather, political and economic decision-making, which influences deforestation directly or indirectly, depends on the policy and market context as well as individual circumstances. These do not need to follow strict logical pathways. The unknown variables cannot be quantified by themselves, but can only be derived as proxies from explainable variable combinations. But since this involves limitations and the discussed uncertainties, the approach seems questionable.

- Factors outside national statistics: the deforestation rate of a country might be driven by external international demands, which themselves can hardly be traced back, since they might origin from several countries at the same time. Although we have the ability to indicate their effect through the export / import rates, we can only quantify the effect of the underlying demand.
- Assumptions: For the statistical analysis several assumptions had to be made to work with the data: Forest Area change is assumed to represent roughly the rate of deforestation. Consequently, also natural forest area changes (revegetation, forest fires, calamities, etc.) are thus implied, when the term deforestation is used. In the correct definition of the word, we do not have data on deforestation but only on net forest area change. For the agriculture and forestry exports and imports as well as the plantation area lacking data was expected to describe zero values.
- Lack of interaction calculations: Interactions among variables might lead to the amplification or the mitigation of other variables or deforestation directly. They could not be fully considered using these statistical methods.
- System complexity: Factors leading to deforestation might act with time delay possibly involving other subsequent factor changes, which contribute in different ways to forest area change. Their analysis would require a complex model.

6.3 Conclusions and recommendations

Even the data set established is not able to provide a complete picture of deforestation drivers and underlying factors, the results constitute an important tool to asses the robustness of prediction claims.

A high human poverty index is a good indication for deforestation in the regions of the Caribbean, Northern Africa and South and Central America. Consequently, any national deforestation trend prediction should use the given information on its expected development. Furthermore, this result sheds light on the fact that deforestation can only be reduced, if poverty alleviation is improved.

Also, population-related indicators like a decrease in mortality rate as well as an increase in fertility (and partly also the population growth) rates contribute to deforestation in the same regions. It is expected that the underlying reason for their influence is the higher resource requirement putting pressure on forest areas through agricultural demands. Again, better national data on agricultural area change rates is necessary to verify these claims.

Education is the third outstanding variable with a high explanatory power for deforestation. Especially the adult illiteracy rate reveals the importance of education, which would enable people to choose alternative income sources to forest-depleting land use activities.

These results cannot fully confirm previous case studies. However, the assumed importance of human poverty related to the income level and education determining the opportunity for off-farm employment are also found in the previous statistical analysis mentioned (Vanclay and Nichols 2005).

Despite the promising results, due to the mentioned uncertainties forest area change can hardly be explained by simple regression functions which assign an influential weight to every factor in the equation. Rather, deforestation analysis requires a complex empirical causal model with several time and space scales, recognizing the feedback and interaction character of many factors. Additionally, such a model should include decision scenarios for several policy pathways to complement the empirical analysis.

To allow a more sophisticated deforestation trend analysis, the quantity and quality of variable data needs tremendous improvements. Especially, the information on forest area change provided by FAO (and most drivers) is still much too coarse to establish national correlations.

Deforestation drivers might bear importance in determining the deforestation trend in the future and might thus be of great value for any RED mechanism. However, to rely on such projections, the drivers have to be determined on the national and sub-national level and satellite techniques needs to be used to quantify forest area changes.

Annual or biannual change rates are recommended to investigate the influence of most biophysical and socio-economic drivers on deforestation. We recommend the collection of additional data for the drivers and conditions of deforestation, which are listed in Table 51 (see Annex 1). A better data basis will not only help to predict trends of forest area changes but also to understand the drivers of deforestation much better. These results might be used to curb the deforestation rate and are thus of double interest for countries joining the RED mechanism.

7 Future GHG emissions from tropical deforestation

7.1 Future trends in tropical deforestation

Chapter 5.1 showed that there are large uncertainties related to the estimates of GHG emissions from past and current tropical deforestation. Projections of future emissions from deforestation are even more uncertain and there are not so many recent sources that quantified the emissions from ongoing future deforestation.

Houghton provided updated projections of future emissions from deforestation in 2005. If today's deforestation rates continue, Houghton et al. (2005) project that another 87 to 130 Pg C will be released from deforestation in the tropics over the next 100 years and that annual C emissions from tropical deforestation will remain at a level of 2.1 Pg C/yr until 2012. The largest forest declines in this long-term projection result from the near elimination of forests in Asia (Myanmar, Indonesia and Malaysia), Latin America (Peru), and Africa (Benin, Ivory Coast, Nigeria, and Zambia) (Houghton et al. 2005).

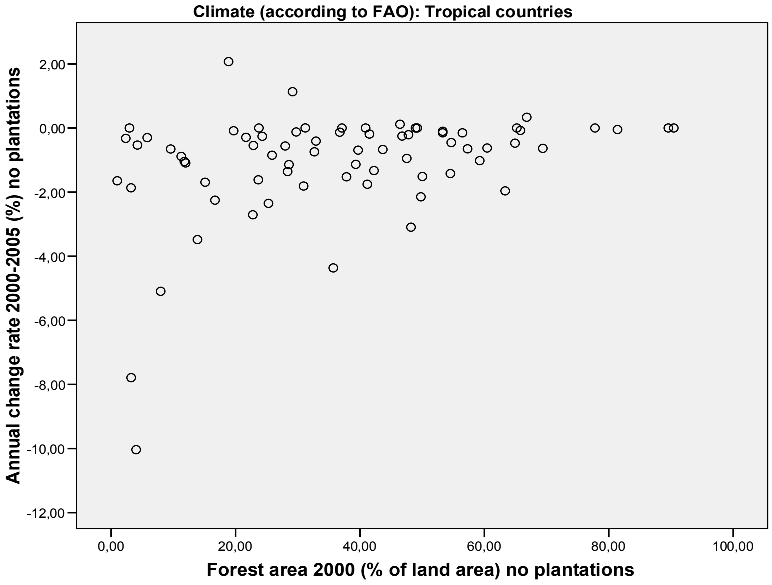
Another recent approach to predict the global deforestation trend has been released by IIASA (Kindermann et al. 2006). The IIASA baseline scenario shows that close to 200 Mio. ha or around 5% of actual forest area will be lost between 2006 and 2025 resulting in a release of additional 17.5 Pg C. Within the next 100 years, today's forest cover will shrink by around 500 Mio. hectares, which is 1/8 of the current forest cover. The accumulated carbon release during the next 100 years amounts to 45 Pg C, which is 15% of the total carbon stored in forests today. Thus, the IIASA long-term estimate is only about half of Houghton's low estimate, indicating the considerable uncertainties for such projections. However, even the lower estimate indicates that urgent action is necessary to avoid the release of such huge amounts of emissions.

7.1.1 Methodological issues related to the assumptions used for projected emissions from deforestation

The estimate of Houghton et al. (2005) is based on FAO data, the assumption of a continuation of current deforestation rates and the arbitrary assumption that deforestation stops when only 15% of a country's forest will remain. The limitations and uncertainties of FAO data are already described in section 5.1.1.1 of this report.

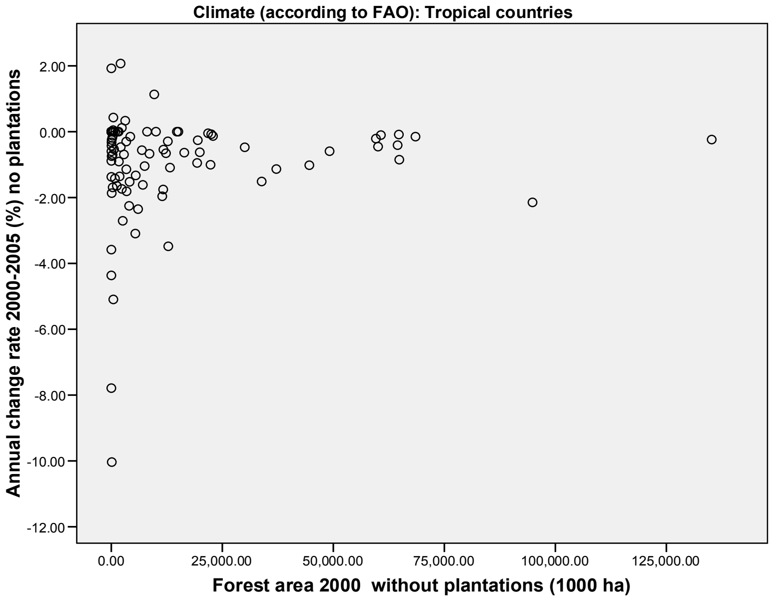
From Figure 19 to Figure 20 it can be concluded that a small relative rate change in deforestation in large countries might have a much higher absolute emission relevance than a high relative rate change in a small country or a country with a low absolute forest cover. Opposite to Houghton's assumption a high deforestation rate might even occur, if a country reaches less than 15 percent of its forest cover. Both figures revealed that deforestation drivers cannot simply be collected per land area, since the effects of a high forestation of a country might have a completely different effect than the low forestation of a country. Therefore, in the future such drivers might be weighted using the forest / total land area relation or they need to be reported in a spatially explicit manner. However, the analysis of relations between absolute and relative forest area change illuminated the necessity not to assume national deforestation threshold, as done by Houghton. Although possible under specific country circumstances, our results show that this behaviour cannot be generalized for all tropical countries.

Figure 19 *Relation between deforestation rate and relative forest cover, based on FAO (2006)*



Source: MPI, BGC

Figure 20 *Relation between deforestation rate and absolute forest cover based on FAO (2006)*



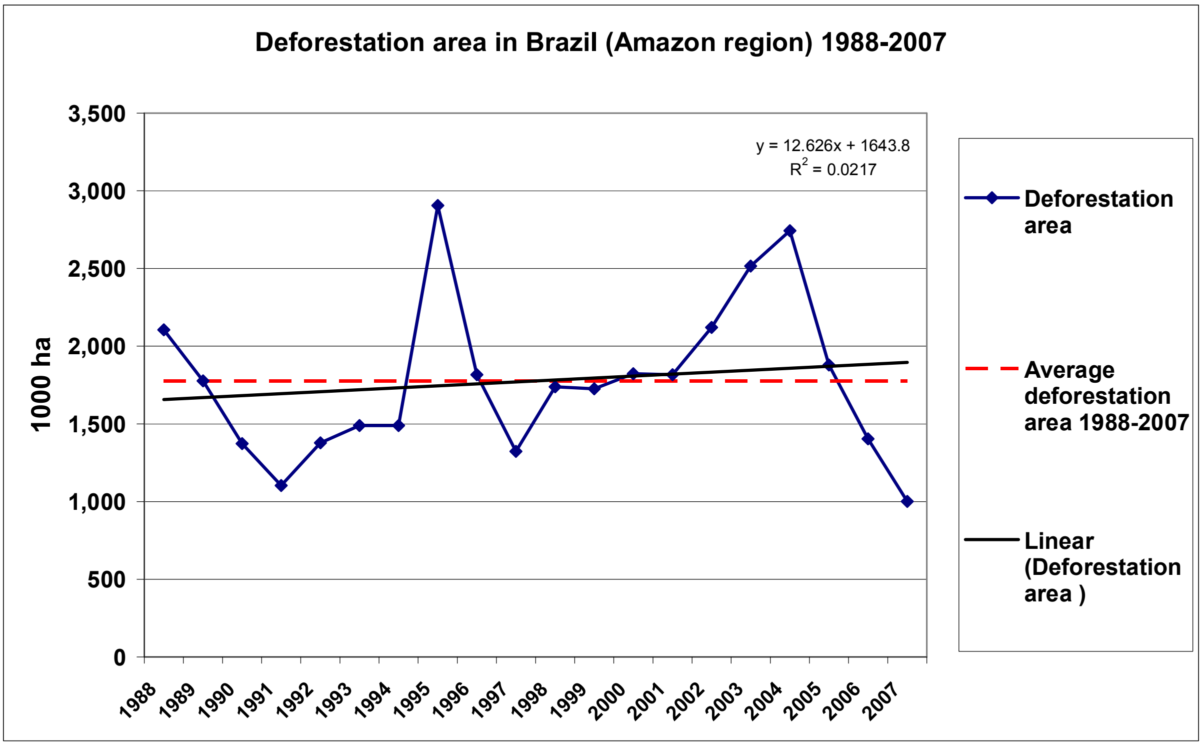
Note: *Brazil was excluded, since its x-value (487,934,000 ha) was unsuitable for this illustration. Mind the scale of x-achsis. Forest areas with rather large differences in magnitude are included in this illustration, therefore small forest areas (e.g. Tuvalu 1,000 ha) seem to be zero.*

Source: MPI, BGC

Chapter 5.1 showed that currently there is no consistent set of time-series data for forest cover change available for tropical countries. Results from satellite images are limited to either global datasets or individual countries or regions within countries and mostly do not cover a time-series. FAO data is covering two years 1990 and 2000 at country level, with considerable uncertainties for some countries. Any extrapolation of deforestation trends at country level would be based on two points in time which is not sufficient for a reliable extrapolation.

Over the last two decades rates of tropical deforestation have increased in some regions and decreased in others. In cases where annual data is available, this shows that annual deforestation areas show a considerable annual variability (see Figure 21). This variability can be explained by climate variations as well as socioeconomic and political drivers such as the start of policies to develop forest areas to agricultural areas, the granting of logging concessions or prices on international markets for cash crops or timber.

Figure 21 Times series of deforestation area in Brazilian Amazon

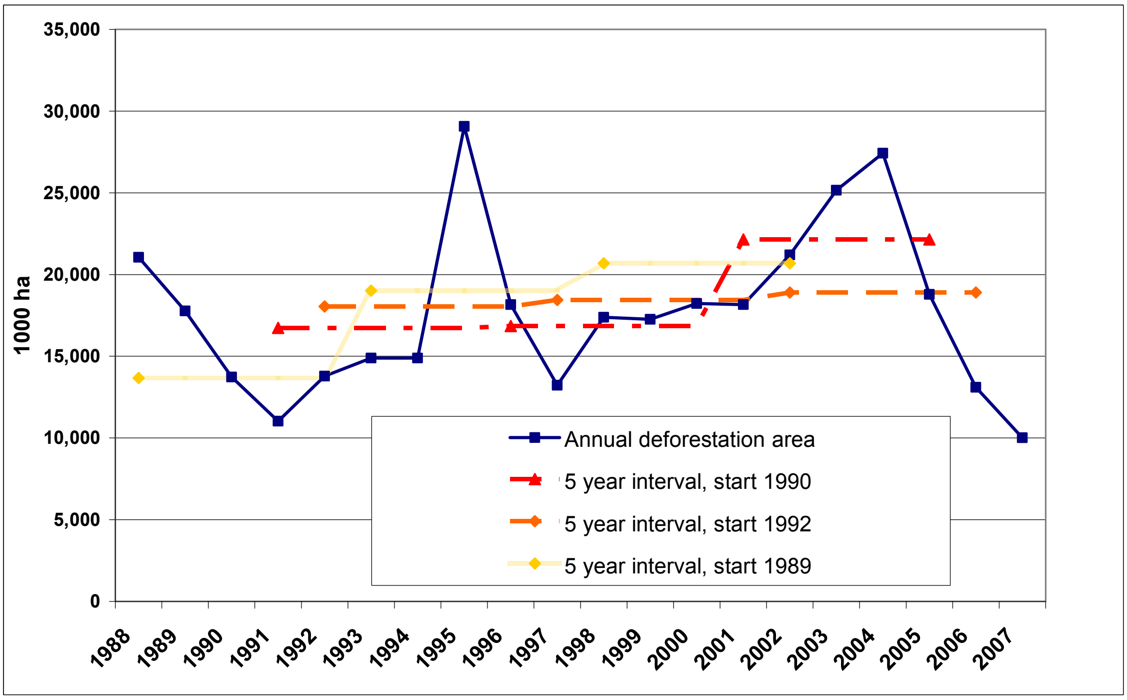


Source: Prodes data from INPE

7.1.2 Uncertainties in trend extrapolation for deforestation projections

The Brazilian dataset – as it is the only annual dataset currently available – was used to analyse the impacts of annual variability of deforestation on the choice of monitoring periods for deforestation areas.

Figure 22 Comparison of annual deforestation area and average deforestation areas from different historic 5-year intervals for the Brazilian Amazon region



Source: Prodes data from INPE, calculations Öko-Institut

Figure 22 shows the annual deforestation areas (blue line) for the Brazilian Amazon for the period 1988 to 2007. The other cases depicted in this Figure assume that forest area data was only collected every 5 years instead of the annual frequency. For this exercise, different historic time 5 year intervals have been averaged as presented in Table 37.

The comparison of the real trend in deforestation area with the results of the 5 year monitoring data in Figure 22 shows that the graphs constructed from 5 year periods give considerably different indications on the deforestation trend over time (see column general trend in Table 37). The real trend shows an increase from 1991 to 2004 with an exceptional high deforestation area in 1995 and 2004 and a decrease after 1995 and 2004. One of the 5-year periods shows an almost constant deforestation area over time, another period a rather constant situation up to 2000 and a strong recent increase whereas a third period would show a continuous strong increase which was more pronounced before 2000. This shows that data from assessments in 5-year periodic intervals would provide contradictory information on the past trend dependent on the choice of the period. Thus, data gathered only at longer time intervals, would not be a useful basis for the extrapolation of future trends.

Table 37 Comparison of different cases assuming non-annual monitoring of forest areas in Brazilian Amazon

Cases	**Monitoring dates**	**General trend**	**Average deforestation area per year, 15 year period [km^2]**	**Average deforestation area per year, most recent 5 year period [km^2]**
Blue line	Annually 1988-2007	Increasing deforestation area from 1991 to 2004, decline thereafter, exceptional high deforestation in 2005	18,042	18,754
Case 1: Red line	1990, 1995, 2000, 2005	Constant deforestation until 2000, strong recent increase in deforestation area after 2000	18,578	22,149
Case 2: Orange line	1992, 1997, 2002, 2007	Almost constant deforestation area across the period	18,464	18,897
Case 3: Yellow line	1989, 1994, 1999, 2004	Continuous increase of deforestation area, increase more pronounced before 2000	17,791	22,035

Source: Prodes data fom INPE, calculations Öko-Institut

The forest area data monitored periodically represent the cumulative deforestation that happened during the period covered, therefore the difference in the average deforestation area from an annual or a period monitoring scheme over 15 years is rather close. However, when average deforestation rates of different recent 5 year intervals are compared, the results differ by up to 18% from the real recent 5 year average, because the intervals include different years.

Consequently, the information derived on average deforestation areas in a country over a certain time period from periodic forest area monitoring is rather reliable, but the longer intervals provides very uncertain information on the deforestation trend. The trend captured with 5-yearly monitoring may strongly differ from the real trend observed with annual data.

7.2 Country-specific modelling of future deforestation

Much research has been invested in the past in developing models that are able to predict future deforestation based on quantitative relationships with driving forces, but without much success because each country has its own specific national situation and combination of drivers. Lambin et al. (2001) point out that to much emphasis has been placed on population pressure and economic activity. Instead they suggest that the relative importance of each driver of deforestation varies from country to country and even on a regional basis within countries, depending on the economy and needs of the population.

A recent study by Brown et al. (2005) found that there were large differences between the predicted levels of deforestation using the same information but different models. As shown in chapter 5.1, time-series data for forest area changes is often not available a fact creating problems for models and their reliability. Bird (2006) lists the following constraints for predictive models even though the drivers of deforestation have been identified:

- the strength of drivers is not well understood;
- the influence of drivers is highly variable over
- time and space; and
- the interrelationship between drivers may be significant.

This leads to a situation in which it seems easier to develop a general qualitative statement about future deforestation for individual countries, but it is very difficult to develop general models that produce reliable quantitative projections for emissions from deforestation for a wide range of countries because the types, strength and interrelationship of drivers are different in different countries. At country or regional level specific studies have produced better prediction results, however also such models cannot predict policy-dependent drivers.

7.3 Future deforestation trends for focus countries

7.3.1 Congo (-Brazzaville)

The Republic of Congo (Brazzaville) is second only to the Democratic Republic of Congo in terms of tropical rainforest coverage among African countries. Congo's forests are highly threatened by logging and colonization of forest lands (http://rainforests.mongabay.com/20congo.htm). Industrial logging has accelerated since the government privatized the timber industry, and much of the new exploitation is taking place in the relatively untouched forests of northern Congo, not in the easily accessible southern region where timber harvesting has historically taken place.

The Republic of Congo was once one of Africa's largest petroleum producers, but with declining production it may increasingly look towards its forests as a source of revenue.

While the government of Congo claims that it has a sustainable forest policy and has introduced legislation to limit what species can be extracted from its forests, reports from the ground indicate that logging companies may largely ignore these regulations and log intensely. Further, illegal logging is a well-documented problem, and corruption undermines even the most basic enforcement efforts.

For these reasons, Congo-Brazzaville is also considered to continue with significant deforestation rates in the future.

7.3.2 Brazil

Brazil holds about one-third of the world's remaining rainforests, including a majority of the Amazon rainforest. Brazil has experienced an exceptional extent of forest loss over the past two generations—an area almost certainly exceeding 600,000 km^2, or about 15 percent of its total surface area of 4,005,082 km^2, has been cleared in the Amazon since 1970. In Brazil only about one-third of recent deforestation can be linked to "shifted" cultivators. A large portion of deforestation in Brazil can be attributed to land clearing for pastureland by commercial and speculative interests, misguided government policies, and commercial exploitation of forest resources.

Most recent data seems to indicate that deforestation areas in Brazil declined considerably since 2004. Preliminary estimates from Brazil's INPE show that deforestation fell 31% for the 2006-2007 year, compared with the previous period (Butler 2007) and by > 60% since 2004. However the present decline is still within the range of past fluctuations and preliminary data in the past had been corrected later. The Brazilian government attributes the decrease in deforestation to successful forestry policies and improved law enforcement and the extension of protected areas.

It seems likely that deforestation will continue in the Brazil Amazon for the foreseeable future, but deforestation may be slower than in the recent past, if the more recent trend continues.

7.3.3 Indonesia

Today just under half of Indonesia is forested, representing a significant decline in its original forest cover. Between 1990 and 2005 the country lost more than 28 million hectares of forest, including 21.7 million hectares of virgin forest. Its loss of biologically rich primary forest was second only to Brazil during that period, and since the close of the 1990s, deforestation rates of primary forest cover have climbed 26 percent. Today Indonesia's forests are some of the most threatened on the planet. Indonesia's forests are being degraded and destroyed by logging, mining operations, large-scale agricultural plantations, colonization, and subsistence activities like shifting agriculture and cutting for fuelwood. Rainforest cover has steadily declined since the 1960s. Legal timber harvesting affects 700,000-850,000 hectares of forest per year in Indonesia, but widespread illegal logging boosts the overall logged area to at least 1.2-1.4 million hectares and possibly much higher. As in Indonesia practically all drivers for deforestation act in a combined way, deforestation is expected to continue in the future.

7.3.4 Madagascar

Due to the unresolved socio-economic problems described in chapter 5.1.2.4, it is expected that deforestation continues in the future in Madagascar. The economic development of the growing population will largely influence the deforestation rates.

7.3.5 Papua New Guinea

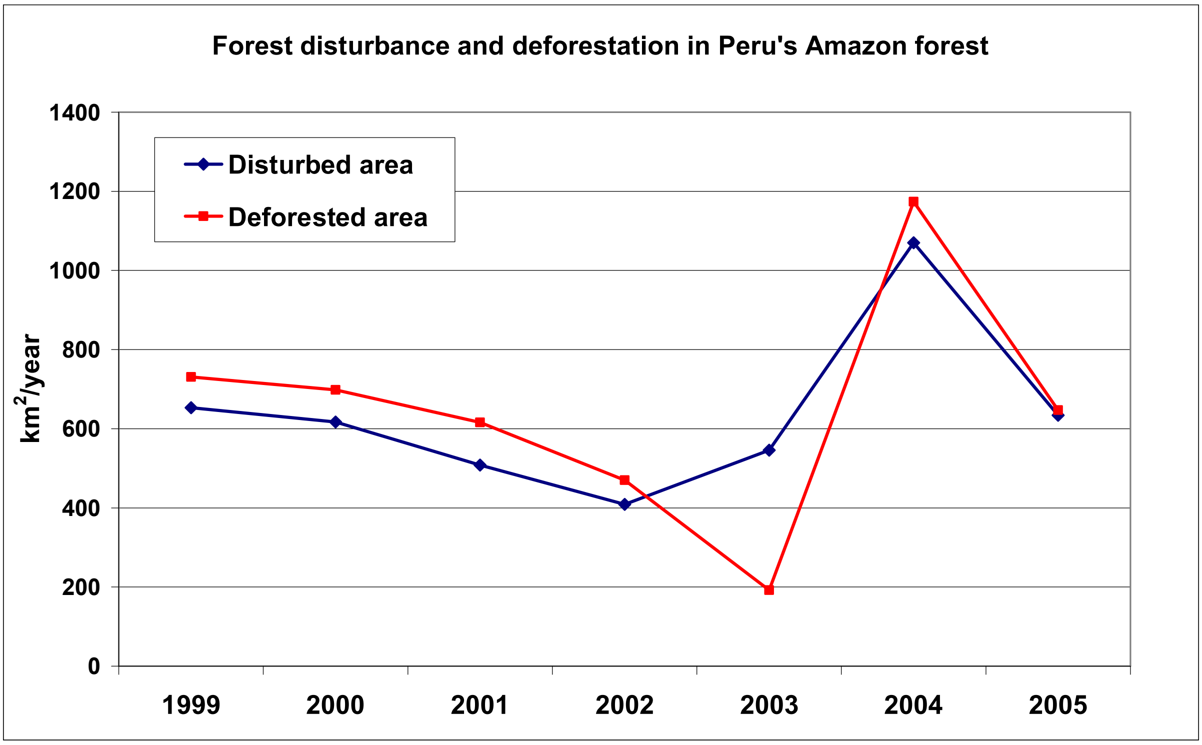
It is very difficult to predict future deforestation trends for PNG, the doubts are mainly related to the unique social structure system of this country where land tenure rights are hold by tribes (in PNG there are more than one thousand tribes) and where often traditional conducts prevail over state organization. In recent years, after 2000, the country experienced a slow down of the deforestation processes, but there are no clear explanations for that. One element could be the recent law enforcement process, Logging Code of Practice 1996 and the Environment Act 2000, but it is difficult to understand how these tools could really prevent land use conversions. On the one hand there are no economic incentives to keep forests and on the other hand the State control of land is very weak. In the last years in PNG forests are a central argument in the political and social debate. Indeed from one side the opportunity costs for land conversion (mainly conversion to oil palm) are considerably increasing and now they represent a real good opportunity for economic incomes. Thus the presence of forests is considered a barrier to a rapid economic development and recently many tribes have officially requested to central administrations to convert part of their forest land in plantations. But from the other side the PNG Government has promoted the UNFCCC negotiations on RED and that is well known in any social contexts as this issue is often reported on national newspapers. The main message that have been passed in PNG society, beside the real negotiation complexity, is that there will be chance to receive concrete international financial support once forest land conservation or sustainable management will be ensured. Thus as the expectations on forest land are so high, the future deforestation trends will highly depend from the conclusion on RED negotiation process and from the capacity of the central government to provide a subsidies system that will convince tribes in keeping their forests. The country is now in a “limbo” waiting for clear signs, if favourable international and in country conditions will be soon in place than it will be not so difficult to predict a substantial decrease of deforestation as large part of it now is not related to strong social or economic processes; while if international or in country conditions will not guarantee an economic convenience in keeping forests, than most likely the deforestation trends will increase considerably and the most plausible scenario will be the extension to all PNG territory of what has already occurred in New Britain, the second largest island where more than 50% of the lowland forest have been already converted to oil palm plantations.

7.3.6 Peru

Peru has about 661,000 km^2 of tropical forests--an area a little larger than France. In 2001, the Peruvian government placed 31% of the managed forests into "permanent resource production." By 2005, a region about the size of Honduras (about 104,970 km^2), was put into long-term commercial timber production. In recent years, the rain forests have been experiencing increased human impacts, as they have in neighbouring Amazon countries. The paving of the Inter-Oceanic Highway and the spreading road network throughout the Pucallpa region have brought migrants mostly from the Peruvian Andes. However, in recent years the Peruvian government has also established or extended large natural protected areas and indigenous territories in the Peruvian Amazon.

A new regional study (Oliveria et al. 2007) using high resolution satellite data showed recent increases in forest disturbances and deforestation rates and leakage into forests surrounding concession areas (see Figure 23). However, only 1-2% of deforestation occurred within natural protected areas between 1999 and 2005 and comparable few (9% of deforestation and 11% of disturbance occurred in indigenous territories.

Figure 23 Recent forest disturbance and deforestation in Peru's Amazon forest



Source: Oliveira et al. 2007

Oliveira at al (2007) concluded that land-use policies in Peru have been key to tempering rain forest degradation and destruction. The scientists found that the government's program of designating specific regions for legal logging, combined with protection of other forests, and the establishment of territories for indigenous peoples helped keep large-scale rain forest damage in check between the years 1999 and 2005. However, the research also showed an increase in forest disturbance over the last couple of years of the study, primarily in two areas where the forests are accessible by roads.

Due to the designation of commercial timber concessions to large new areas and the improvement of road infrastructure to forests, deforestation in Peru is expected to continue in the future with rates that may be similar as those analysed by Oliveira et al (2007) in the recent past.

7.4 Matrix on deforestation drivers, forest resources and forest policies

At a qualitative level, it is easier to categorize individual countries regarding the drivers for deforestation and past deforestation rates, forest resources, the current and past forest policies, the general political and economic framework. Such qualitative overview provides important insights into the possible future development of deforestation. Therefore a matrix was developed that includes such information for each country in a searchable way. The matrix can serve as a tool to get a quick overview on national circumstances, to select countries with similar deforestation drivers, forest areas or deforestation rates. This matrix was provided as a separate tool to Umweltbundesamt.

7.5 Conclusions and recommendations

Over the last two decades rates of tropical deforestation have increased in some regions and decreased in others. In cases where annual data is available, this shows that annual deforestation areas show a considerable annual variability. This variability has natural reasons, such as the draught in 2005 for Brazil and a spread of fires in this particular year as well as socio-economic and political drivers such as the start of policies to develop forest areas to agricultural areas, the granting of logging concessions or prices on international markets for cash crops or timber. The significant annual variability requires annual data over a rather long historic time series to derive a reliable trend extrapolation. Chapter 5.1 showed that currently there is no consistent set of time-series data for forest cover change available for tropical countries. Results from satellite images are limited to either global datasets or individual countries or regions within countries and mostly do not cover a time-series. FAO data is covering two years 1990 and 2000 at country level, with considerable uncertainties for some countries. Any extrapolation of deforestation trends at country level would be based on two points in time which is not sufficient for a reliable extrapolation, in particular when the large annual variability is taken into account. Therefore no projections based on trend extrapolation were derived in this report.

A recent study by Brown et al. (2005) found that there were large differences between the predicted levels of deforestation using the same information but different models. Bird (2006) lists the following constraints for predictive models even though the drivers of deforestation have been identified:

- the strength of drivers is not well understood;
- the influence of drivers is highly variable over
- time and space; and
- the interrelationship between drivers may be significant.

This means that the relationships of drivers of deforestation rates are too complex to be modelled in a reliable way and the drivers themselves are also extremely difficult to predict. This leads to a situation in which it seems easier to develop a general qualitative statement about future deforestation for individual countries, but where it seems largely impossible to develop reliable quantitative projections.

At a qualitative level, it is easier to categorize individual countries regarding the drivers for deforestation and past deforestation rates, forest resources, the current and past forest policies, the general political and economic framework. Such qualitative overview provides important insights into the possible future development of deforestation. Therefore a matrix was developed that includes such information for each country in a searchable way which is added as a separate Addendum to this report.

8 Reducing tropical deforestation as part of a global policy framework to reduce greenhouse gas emissions

8.1 Possible magnitude of credits from a RED mechanism

As illustrated by Table 38, substantial emission reductions are necessary to achieve the different stabilisation goals. Annex I countries would have to reduce emissions by 25 % to 45 % in 2020 and 70 % to 95 % in 2050 below 1990 levels in order to reach a stabilisation of GHG concentrations at 450 ppmv CO_2eq. For a stabilisation of CO_2 concentrations at a level of 550 ppmv CO_2eq., the necessary emission reductions for Annex I Parties would have to be between 15 % to 30 % below 1990 levels in 2020 and 55 % to 90 % in 2050. Global emissions can still increase by 10 % in the 450 and 30 % in the 550 ppmv stabilization scenario respectively, but have to peak soon after in order to reach the necessary emission reductions of 40 % (for 450 ppmv) or 10 % (for 550 ppmv) of 1990 levels. Therefore, none of the mentioned stabilisation levels can be reached without significant emission reductions in Non-Annex I countries in the long term. Since global deforestation accounts for a significant share of the annual anthropogenic GHG emissions (Gullison et al. 2007, IPCC WG 1 2007), forest conservation offers a considerable potential for emission reductions in developing countries.

Table 38 Range of required emission reductions as percentage change relative to 1990 levels to reach the 450 and 550 ppmv CO_2eq stabilization scenarios based on a variety of approaches to share the reduction effort between countries

		2020	**2050**
450 ppmv CO_2eq.	Global *	+10%	-40%
	Annex I	-45% to -25%	-95% to -70%
550 ppmv CO_2eq.	Global *	+30%	-10%
	Annex I	-30% to -15%	-90% to -55%
650 ppmv CO_2eq.	Global *	+50%	+45%

Note: Global reduction values are chosen to represent one possible path towards the given stabilisation level. Other global emission levels in 2020 and 2050 would be possible to reach the same stabilisation levels, and their choice would influence the necessary reductions for the country groups.

Source: Höhne et al. 2007

In order to explore the magnitude of this potential, we developed scenarios representing potential pathways of emission reductions achieved by reducing deforestation in developing countries. These potentials of emission reductions through RED were compared to the emission reductions necessary in other sectors to achieve certain stabilization levels in a post-2012 emission reduction framework.

8.1.1 Scenario assumptions

In this chapter, we show the order of magnitude of future net changes in forest area and associated changes in CO_2 emissions based on simple trajectories of area changes and a range of estimates of C stock densities of forest biomass. For this purpose we made simple assumptions as data about past deforestation trends are too scarce for many countries (see Chapter 7) to make robust projections of deforestation rates at national to continental level.

Forest area projection until 2020

For area changes, we used FAO data on national forest area. Where possible, we deduced the area of plantations and calculated forest area changes only for non-plantation forests.[4] We used the average deforestation rate between 1990 and 2000 for the past deforestation, and the rate 2000-2005 for deforestation after 2000. The projections were initialized with forest area reported for the year 2005. We focused on tropical regions and developing countries with actually high deforestation. For the scenarios, we considered a selection of countries, including:

- Brazil,
- Indonesia,
- Papua New Guinea and
- Democratic Republic of Congo.

Brazil and Indonesia are the two most important countries with regard to deforestation. Papua New Guinea was selected because of its active role in the discussion on RED in the UNFCCC, and DR Congo is chosen as one of the potential African countries with relevant potentials to reduce deforestation. Congo-Brazzaville, one of the focus countries of this study, was not included in the scenarios because due to its small size, its quantitative relevance is rather negligible for the assessment of the magnitude of emissions reductions that may be achieved through a RED mechanism. For this set of countries, we calculated three scenarios:

- **Scenario 1**: constant deforestation rate as in the period 2000-2005
- **Scenario 2:** deforestation rate decreases by 5% annually after 2008: deforestation is reduced by 50% within a decade
- **Scenario 3:** deforestation rate decreases by 10% annually after 2008: deforestation is reduced by 50% within 5 years

The first scenario could be interpreted as business-as-usual without any changes in deforestation drivers since the year 2000. It has to be noted that such a scenario implies that less emissions are occurring from deforestation as compared to the past because the constant rate of deforestation refers to a shrinking forest area. Countries could therefore reduce their

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[4] The exclusion of plantations is justified because plantations typically consist of fast-growing trees for timber or energy with short rotation times and average carbon stocks in the tree biomass are often an order of magnitude lower than in other forests. Therefore, plantations may not be mixed with other forests when a default C stock value for biomass is used. Second, the plantation area tends to grow in many tropical countries while the area of other forests tends to decrease. Separating plantations from other forests increases the accuracy of area changes used to calculate emissions from deforestation.

absolute emissions even without a change in the rate of deforestation. For a discussion of this issue with regard to setting targets, see section 8.2.3

The second and third scenarios imply efforts for reducing deforestation at two levels of ambition. The scenarios do not consider drivers for deforestation nor changes of the drivers. For instance, past deforestation rates in the Congo basin were low, but with stabilizing political conditions it is very likely that deforestation increases in this region. Therefore, special incentives to maintain the carbon stocks are needed for countries with low deforestation rates in the past (see Section 8.2.6). Changes in policies and political frame conditions relevant for deforestation are unforeseeable and vary among regions and countries and cannot be considered here. The estimation of future development of emissions and removals by projections of net forest area change is expected to underestimate emissions from deforestation. This is due to the fact that reductions or growth in carbon stocks on the remaining forest areas may occur which are not taken into account in the scenarios.

Carbon emissions from deforestation

The biomass C stocks estimates as developed and described in chapter 5.2 were used for the scenario calculations. Carbon emissions were calculated by multiplying the area deforested with the various values for average C stocks per hectare elaborated in chapter 5.2.

8.1.2 Scenario results

On the basis of the simple assumptions described above, emissions from deforestation for the three scenarios were calculated. Figure 24 illustrates the CO_2 emissions from deforestation in the three scenarios for Brazil, Indonesia, Papua New Guinea and the Democratic Republic of Congo (for average biomass stock values).

Thus, emissions from deforestation in 2020 could be reduced from 2,278 Mt CO_2 to 1,217 Mt CO_2 or to 620 Mt CO_2 if the deforestation rate would be reduced by 5 % (scenario 1) or 10% (scenario 3) respectively per year as compared to scenario 1 (using average biomass carbon stock values). This is equivalent to an emission reduction of 1,061 Mt CO_2 (if the deforestation rate is reduced by 5 % annually) and 1,658 Mt CO_2 (if the deforestation rate is reduced 10 % annually) in 2020 (compared to scentario 1). These amounts of emissions reductions due to reduced deforestation (1,061 Mt CO_2 – 1,658 Mt CO_2) for the four countries only would be equivalent to 25-40% of total EU-15 GHG emissions in 2005 or 15-23% of total US emissions in 2005.

The absolute emission reductions due to reducing deforestation in 2020 (difference of scenario 2 and 3 as compared to scenario 1) and their error bars (due to different biomass C stock values used) are represented by the two right bars in Figure 25. If not average values, but the full range (minimum and maximum values) of biomass C stock values are used, then the emission reductions vary from 703 to 1,562 Mt CO_2 for scenario 2 and 1,101 Mt CO_2 to 2,441 Mt CO_2 for scenario 3 (the year 2020 is compared to 1990 levels). Using these wider ranges, the potential amount of emission reductions due to RED could represent around 16-58 % of total EU-15 emissions and 10-34 % of total US emission in 2005[5].

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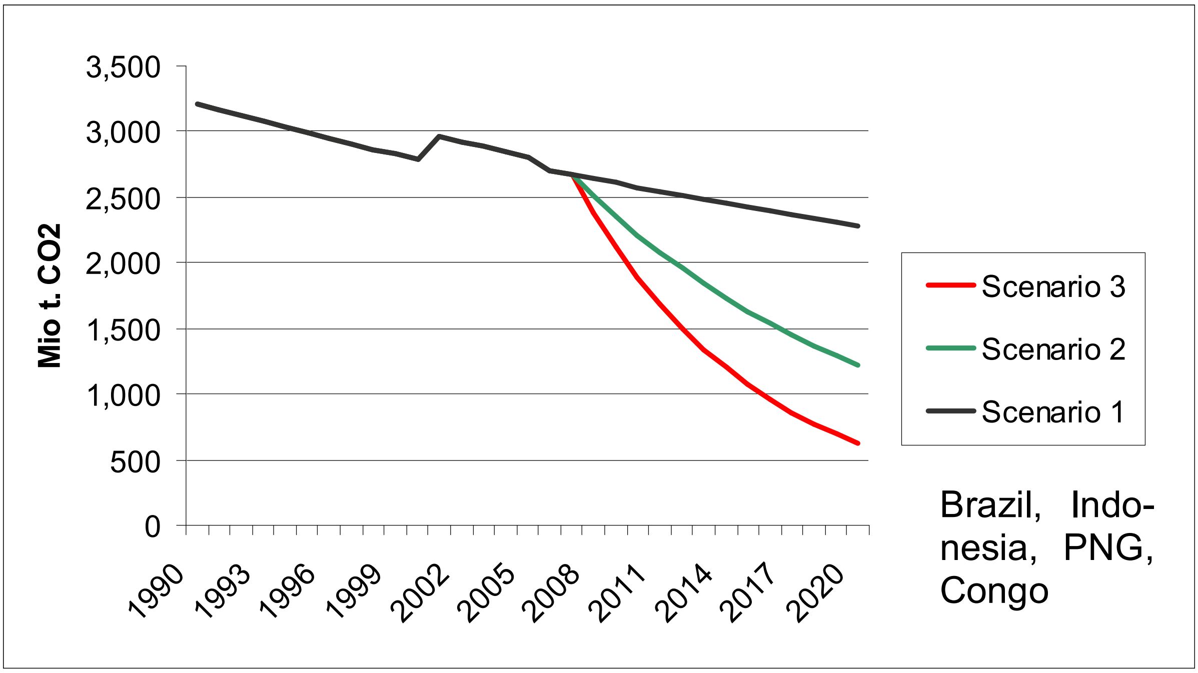
[5] Without LULUCF

Figure 24 *CO_2 emissions from deforestation for the three scenarios for the countries Brazil, Indonesia, Papua New Guinea and Congo*



Note: *Scenario 1 = constant deforestation rate as in period 2000-2005*
Scenario 2 = deforestation rate reduced by 5% annually after 2008
Scenario 3 = deforestation rate reduced by 10% annually after 2008

Source: calculations MPI-BGC and Ecofys

In the above calculations, area changes have been multiplied with the carbon stock factors elaborated in chapter 5.2 (considering the whole range of pools)[6]. As stressed before, for accounting purposes of a future RED scheme, the final estimate does not necessarily need to be accurate, but consistent over time and conservative. In contrast to our calculations, such an accounting scheme could be limited to the consideration of above-ground biomass instead of all pools which would consequently reduce the overall amount of credits calculated.[7]

In a next step, emission reductions due to RED are compared to the emission reductions necessary to reach certain stabilization levels. As illustrated by the two left columns in Figure 25, emission reductions needed to stabilise the concentration of GHGs in the atmosphere at 450 and 550 ppmv CO_2eq. in 2020 are around 20,000 Mt CO_2eq. and 13,600 Mt CO_2eq. respectively (not considering land use emissions). For stabilising the GHG concentration in the atmosphere at 650 ppmv, emissions can still be increased by almost 2300 Mt CO_2eq.. Error bars represent the uncertainty range due to different reference scenarios.

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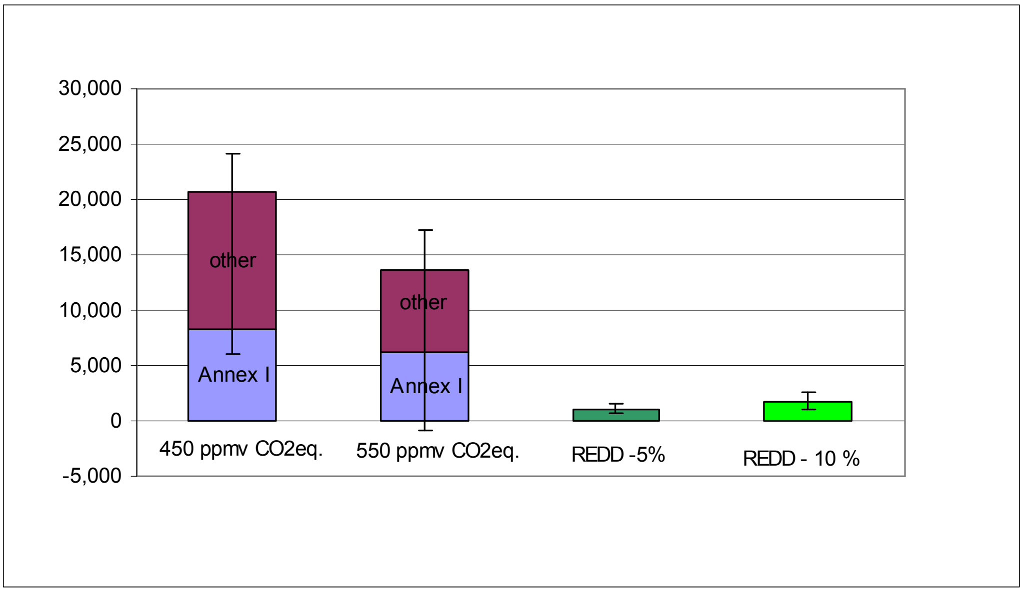
[6] Only 80 % of the total stock of below-ground biomass and 40 % soil organic matter are considered to be released. .

[7] The overall supply of carbon credits could be 30-40 % lower, if only above-ground biomass is considered. For the relation of above-ground biomass to other carbon pools, see 5.2.

Figure 25 Potential emission reductions due to reduced deforestation in Brazil, Indonesia, PNG and Congo compared to emission reductions necessary in other sectors to reach stabilization of CO_2 concentration at 450 and 550 ppmv CO_2eq. for 2020



Source: calculations Ecofys, left bars derived from Höhne et al. 2007

Figure 25 shows the potential reductions due to RED (from Brazil, Indonesia, PNG and Congo) as compared to the global emission reductions (Annex I and Non-Annex I countries) under the 450 ppmv and 550 ppmv scenario. The assumed Annex I GHG reduction target is - 35 % (450 ppmv) and -24 % (550ppmv) as compared to the level of emissions in 1990. If the deforestation rate would be reduced by 5% annually in Brazil, Indonesia, PNG and Congo, emission reductions achieved would represent around 5 % of global emission reductions necessary to reach the stabilization scenario at a level of 450 ppmv CO_2eq. and almost 8 % to reach 550 ppmv level (in case the median reference scenario is chosen). For the scenario in which the deforestation rate is decreased by 10 % annually, RED would be in the range of 8 % to almost 12 % of global emission reductions necessary to reach the respective stabilization levels. Uncertainty ranges of these values are however considerable. Therefore, we advise to interpret these results against the background of the simplified assumptions made.

Considering that our RED potentials are rather underestimated (due to the methodology used for estimating area changes), it has to be taken into account that potential emission reductions from RED (even if only the four selected countries will participate) can represent a significant proportion of the overall emission reductions necessary to reach a stabilisation of GHGs in the atmosphere at 450 or 550 ppmv CO_2eq.. Such a potential supply of credits from a RED mechanism – if fully fungible - could endanger the stability of the carbon market. Our simplistic calculations do support the argument that under current circumstances a market-based approach with fully fungible RED credits is probably not appropriate.

8.2 Measuring the efforts –Reference levels for reduced deforestation in a post-2012 regime

Any RED mechanism in a post-2012 climate regime has to establish a measure to calculate the performance of the participating country in reducing deforestation. For this purpose a reference level is necessary against which the achieved efforts of participating countries are compared and then compensated. A number of proposals for reference emission levels have been put forward in the recent discussion on a RED mechanism and this chapter is providing some further insights on the problems and challenges in the implementation of these proposals.

8.2.1 Reference emission levels and targets

The term reference (emission) level can be used in two different ways in relation to targets for reducing emissions from deforestation:

1. The established reference emission level as such for a country can be considered as an adopted target for reducing deforestation and all emissions reductions achieved beyond the reference level entitle the country for the agreed compensation.
2. The reference emission level is used as a baseline upon which each country adopts a national target, e.g. a certain percentage of deforestation reduction below the baseline and only those emission reductions achieved beyond such target entitle the country for the agreed compensation.

The first approach does not as such reflect any ambition or effort from policies to reduce emissions from deforestation, but would provide incentives for all countries whose emissions are below the historic emissions or projected business-as-usual emissions.

In this report it is assumed that the reference emission level is the basis to establish national level targets for emissions from deforestation that reflect the efforts or ambition of participating countries to reduce deforestations beyond the business-as-usual situation. For this situation reference emission levels do not directly set the line beyond which compensation occurs, but serve more as guidance for policy makers in the establishment of national targets for reducing deforestation.

8.2.2 Criteria for setting reference levels

If reduced deforestation is to be compensated, a mechanism needs to be put in place that correctly reflects the amount of carbon that has been “preserved”. The EU established a number of criteria for a future RED mechanism which are mostly relevant for the establishment of reference emission levels:

- rewarding real and long-term reductions in emissions at the national scale, while respecting the sovereignty of countries;
- rewarding the contribution made to long-term sustainable land and forest management and reducing pressures leading to unsustainable land use or land-use changes;
- recognition of existing commitments under UNFCCC;
- simplicity, flexibility and practicality;

- consistency with and/or evolution from existing monitoring methodologies and accounting rules;
- promoting synergies at national and local levels and appropriate with international initiatives and processes;
- encouragement of early action.

The following sections deal with the two types of information necessary to establish the reference emission level in an accounting mechanism for reducing, first the area changes and secondly the changes in carbon stocks.

8.2.3 Use of historic deforestation areas for the reference emission level

The simplest option for a reference level is the amount of historic deforestation. This seems rather straightforward because historical information is one of the key elements for setting a reference. Historic deforestation rates are proposed by many Parties under the UNFCCC and by proposals from scientific institutions or NGOs (Table 39).

Table 39 Overview of proposals suggesting historic deforestation rates as reference level

Historic deforestation rates	Method	Source
Starting 1980 or later	Satellite images	Santilli et al. 2005
Extrapolation of average annual conversion rates during the 1990 – 2005 period	Earth observation technologies	Archard et al. 2005
Last 10 years	Wall-to-wall, tier 2 method	Brazil, UNFCCC submission
Historic period should be as long as possible, depending on the availability of country specific data, but not shorter than 5 years	Archived satellite remote sensing data	Joint submission Non-Annex I Parties, September 2007
Empiric deforestation level of base year or base reference period		Chile, submission September 2007
Historical emissions from deforestation and should take into account national circumstances		EU submission 2007

Historic forest area losses

A reference level that is based on historic forest conversion rates provides incentives for those countries for which deforestation in the past was high and for which significant forest areas are still left. These countries would either get compensated for future deforestation rates below the historic deforestation or for rates of a national target that is below the historic forest conversion rate.

Only for few tropical countries long time series of historic deforestation based on the same methodologies and the same forest definitions exist. Brazil is one of the few countries for which a time series of annual data is available. INPE in Brazil has presented exceptional good data by using satellite images from Brazilian satellite programmes. For India biannual data on deforestation areas are available. The discussion in section 5.1 showed that major efforts are needed before the current research activities for establishing historic and current forest area changes will be implemented in many tropical countries on a continuous basis. For an international RED mechanism it is not sufficient that international or regional research institutions are able to produce the necessary data on forest area changes for tropical countries. Participating countries have to develop national capacities to implement national monitoring systems on a continuous basis that generate the necessary data for the reference emission levels and for compliance with their national targets. Countries may decide to co-operate with relevant research institutions, but this still requires the establishment of a reliable institutional monitoring framework for deforestation and degradation.

For any emission reduction commitments, it is essential that they refer to consistent time series between the baseline and the commitment period. This means that the methods used to determine historic forest conversion areas should be consistent with the methods used in the future. Any methodology based on rather uncertain historic FAO data for the reference period and high resolution satellite images in the commitment period would not fulfil the requirements for consistent time-series. Therefore it is essential that the future monitoring approach for a RED mechanism is developed in parallel and consistently with the establishment of the historic reference levels. This will automatically exclude those remote sensing methods for a first accounting period that started to produce data rather recently and such methods may only phase in later when they produced longer time series.

In section 5.1.2 a number of technical issues related to the monitoring of forest area changes were addressed.

Choice of historic period

If historic deforestation rates are used for baseline setting, a base year or a base period has to be determined. There are no proposals to use a single base year because deforestation rates are highly variable from year to year. Discussions are ongoing about the length, the beginning and a generic base period. Bolivia for example suggested country-specific base periods, because different regional dynamics on deforestation patterns in tropical countries exist (UNFCCC submission from parties 2006) and a generic base period for all countries could discriminate countries with low deforestation rates in the generic base period. Most authors and countries suggest a base period of at least 5 years to deal with inter-annual variation. Santilli et al. (2005) proposed a base period starting at 1980 or later, based on negotiations, whereas Archard et al. (2005) propose a base period from 1990–2005. The Brazilian proposal (UNFCCC submission by the parties 2006) mentions a base period of 10 years, whereof a minimum of four representative years should be assessed to estimate the reference emission rate. Taking into account the high variability of deforestation rates in Brazil, the choice of representative years from the available historic years seems arbitrary. For credible historic baselines a consistent period across all countries that does not allow picking or dropping individual years is essential.

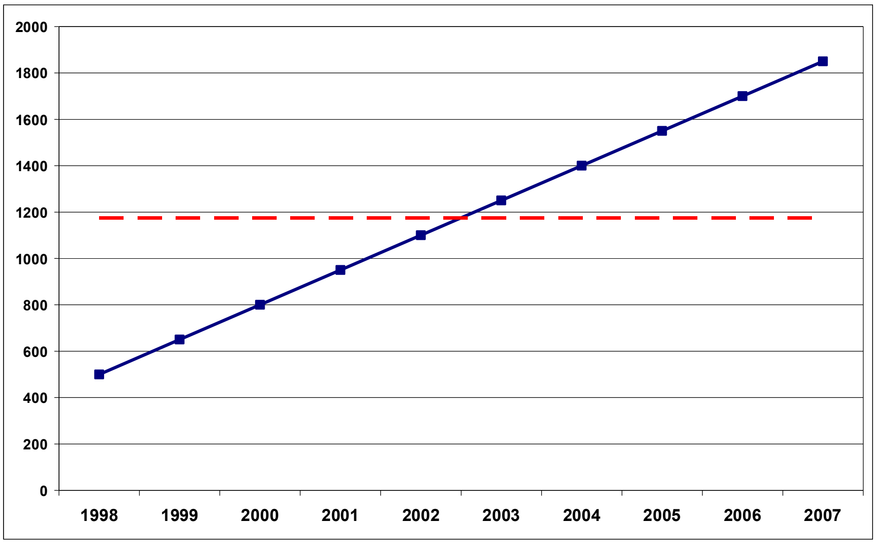
For the choice of the historic periods, time series consistency of methods for the establishment of the reference level and during the commitment period is essential. Therefore it is recommended to start the historic data in 1990 where high resolution Landsat data became available.

The proposals for historic reference levels suggest different historic periods to be chosen for the establishment of the reference level. In theory, there are three different situations for countries with high historic deforestation rates over long historic period such as 10 or 15 years:

- high, but decreasing deforestation rate,
- more or less constant deforestation rate and
- high, but declining deforestation rate.

Figure 26 illustrates a theoretical example of a linearly increasing deforestation area and a reference level equivalent to the average historic deforestation area. The longer the historic period considered for the average historic area, the lower the average gets when deforestation followed an increasing trend over a longer period. If only the past 5 years would be averaged to establish the reference level, this level would be 30% higher than the 10-year average in the theoretical example. Thus, in case of increasing deforestation areas, a conservative approach for the establishment of a historic reference level would be an average over a historic time series that should be as long as possible.

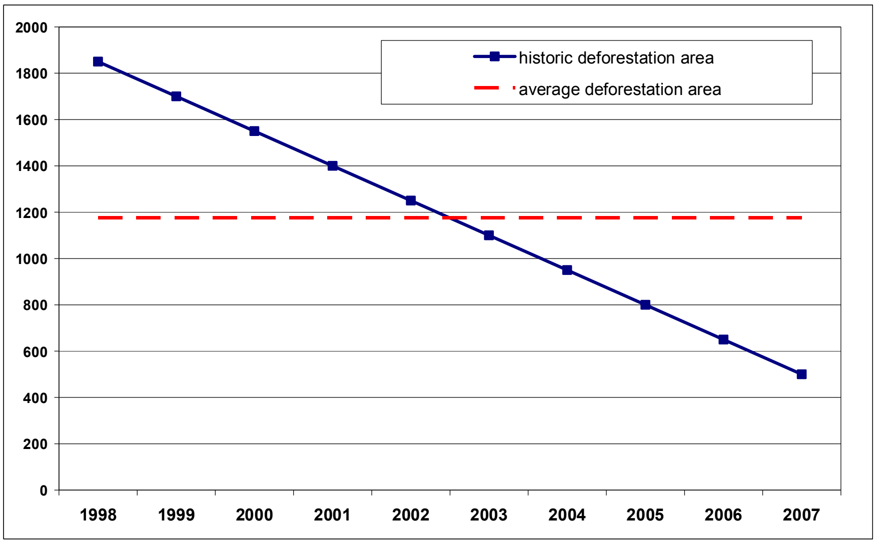
Figure 26 Increasing deforestation area and average area



Note: No units for forest areas are indicated as the example is not based on real data, but only illustrates a theoretical situation.

The opposite situation occurs for a country with a constantly decreasing deforestation area. If the historic average would be chosen as in the previous example (red line) based on a long historic time period, the country would automatically get compensated when it continues with current deforestation rates. In the situation of a constantly decreasing deforestation area, a more conservative approach would be to take the latest available year as reference, because only this reference would necessarily lead to further decreasing deforestation areas in the future.

Figure 27 Decreasing deforestation area



Note: No units for forest areas are indicated as the example is not based on real data, but only illustrates a theoretical situation.

As explained in section 5.1, the practical problem in differentiating such situations may anyway be the fact that no annual historic time series data for forest area losses is available in most countries and the problem that annual fluctuations of deforestation areas are high and that no consistent trends can be derived from the available data.

But even if data over longer periods are available, strong annual fluctuations present a considerable problem for the establishment of conservative reference levels for reduced deforestation. In section 7.1.2, it was shown how the choice of 5-yearly reference periods can impact the average annual deforestation area.

Another issue that needs to be defined is the most recent year that should be included in the historic reference level. The most recent year that enters the reference level should be defined before the countries decide on their participation in a RED mechanism to avoid that the reference can be actively increased by deforesting larger areas.

Updating of historic reference levels

In order to avoid any incentives that a RED mechanism increases deforestation between the start of participation and the monitoring of compliance, the reference level should be related to a historic time in the past. However, such reference levels may fail to take into account significant changes in recent years and maybe overly conservative or not sufficiently conservative in relation to the efforts required by Parties. Therefore it is important that reference levels based on historic data are periodically revised, which is a common element of many proposals for reference levels from Parties, NGOs or research institutions (see Table 40). The revision period should correspond with the commitment period length, this means that the reference can be corrected after the first commitment period for the subsequent period. During one commitment period, the reference level should be fixed.

Table 40 Proposals for updating of reference emission levels

Update of reference period	Country/ organization
Recalculation every 3 years if annual emissions from deforestation fall below reference	Brazil, submission
Revision for each crediting period	Chile, submission September 2007
Reference scenario should be adjusted every 5 years	COMIFAC, submission September 2007

Source: UNFCCC submissions, FCCC/SBSTA/2007/MISC.14

As explained in section 5.1.2, there are sometimes considerable gaps in time (> 3 years) between the deforestation event and the publication of remote sensing data for a country. This situation creates further uncertainty about the current status and the future trend. The point in time when data becomes available should be taken into account for updating or revision of reference levels.

Absolute or relative measure for historic deforestation

Historic forest area changes can be expressed in absolute (ha or km^2 area loss/year) or relative terms (% change/year). Generally, both options are an equivalent way of expressing forest area losses. However, forest area changes in percentage terms are influenced by the remaining forest areas in a country. For example, while Brazil's annual deforestation in absolute terms is highest, Brazil's annual change rate is with -0.5% (1990-2005) rather low and 51 tropical countries have higher percentage losses than Brazil. The top 20 countries on the list of total contribution to tropical deforestation show annual change rates between -0.3 and -2.4%. The global average change rate across all tropical countries is -0.6%. From this point of view it seems preferable to work with absolute area changes for the establishment of reference levels as they are closer related to the emission impacts when comparing different countries.

Table 41 Comparison of absolute and relative change rates for tropical countries with high forest area losses

Country/area	Forest					
	Annual change rate					
	1990-2000		2000-2005		1990-2005	
	1000 ha/yr	%	1000 ha/yr	%	1000 ha/yr	%
Brazil	-2,681	-0.5	-3,103	-0.6	-2821.9	-0.5%
Indonesia	-1,872	-1.7	-1,871	-2.0	-1871.5	-1.6%
Sudan	-589	-0.8	-589	-0.8	-589.0	-0.8%
Myanmar	-466	-1.3	-466	-1.4	-466.5	-1.2%
Democratic Republic of the Congo	-532	-0.4	-319	-0.2	-461.4	-0.3%
Zambia	-445	-0.9	-445	-1.0	-444.8	-0.9%
United Republic of Tanzania	-412	-1.0	-412	-1.1	-412.3	-1.0%
Nigeria	-410	-2.7	-410	-3.3	-409.7	-2.4%
Mexico	-348	-0.5	-260	-0.4	-318.5	-0.5%
Zimbabwe	-313	-1.5	-313	-1.7	-312.9	-1.4%
Venezuela (Bolivarian Republic of)	-288	-0.6	-288	-0.6	-287.5	-0.6%
Bolivia	-270	-0.4	-270	-0.5	-270.3	-0.4%
Philippines	-262	-2.8	-157	-2.1	-227.5	-2.2%
Cameroon	-220	-0.9	-220	-1.0	-220.0	-0.9%
Ecuador	-198	-1.5	-198	-1.7	-197.6	-1.4%
Honduras	-196	-3.0	-156	-3.1	-182.5	-2.5%
Paraguay	-179	-0.9	-179	-0.9	-178.8	-0.8%
Cambodia	-140	-1.1	-219	-2.0	-166.6	-1.3%
Ethiopia	-141	-1.0	-141	-1.1	-140.9	-0.9%
Papua New Guinea	-139	-0.5	-139	-0.5	-139.1	-0.4%

Source: FAO FRA 2005

8.2.4 Carbon estimation for the reference emission level

As a second step in the establishment of reference levels, detected area changes have to be converted into carbon that was saved and not emitted. The carbon content in biomass stocks depends on the forest type concerned, thus depending on the areas where deforestation would have occurred, the amount of carbon that would have been released differs.

Section 5.2 of this report discussed the status of information and the problems in the establishment of carbon stocks for tropical countries. Forest inventories based on field measurement data on biomass stocks and carbon contents for different forest types are often not available for many countries. Research results indicate that technical solutions are available that make it possible to estimate carbon stocks with remote sensing technologies (lidar sounding), but they are currently too expensive and expertise for analysing might be lacking, especially in developing countries (Skutch et al 2006).

The distribution of biomass throughout the tropics is poorly known. A recent comparison found that seven independent estimates of biomass gave totals that varied by more than a factor of two over the Brazilian Amazon (see section 5.2 of this report and Houghton et al., 2001). Uncertainties resulted from limited data on belowground biomass, trees smaller than those routinely sampled, vines, non-tree vegetation, palms, the shape and density of tree boles, and the amount of woody debris on the forest floor. Furthermore, although many individual forest plots have been sampled, extrapolating the results to an entire region is problematic. Many biomass estimates were largely for intact, or undisturbed forests, while both natural disturbances and human activities add variability to the distribution of biomass. The spatial distribution of biomass is important because the emissions of carbon from deforestation are determined by the biomass of the forests actually deforested, not necessarily by the average biomass for a region (Houghton, 2005). Again, in the Brazilian Amazon, independent maps of biomass showed the actual forests deforested to range from 25% higher to 32% lower than the average forest biomass (Houghton et al., 2001). The greatest uncertainty (60%) in the calculated flux of carbon for the region resulted from uncertainty in the biomass of the forests deforested.

However, it is important to note that it may not be essential for the accounting of reduced deforestation that very detailed and accurate data on forest carbon stocks and their spatial distribution in a country are available. On the one hand it is anyway impossible to determine the exact spatial distribution of forests that would have been deforested in the absence of the RED mechanism. This means that the reduced emissions cannot be related to exact spatial areas and default approaches and national reference carbon values have to be developed for the accounting. On the other hand, it is important to develop a conservative accounting approach that uses conservative default factors in countries with poor forest biomass data. For accounting purposes of a future RED mechanism, the final estimate does not necessarily need to be accurate, but it has to be consistent over time and conservative. Consistent means that the reference level and the level during the commitment period should be based on the same methods to avoid that a shift in methods leads to the compliance with targets. Conservative means that the methods should ensure that at least the amount of emissions for which a country is compensated, was really reduced whereas the real emission reduction may be higher. This is an important difference to the task of producing reliable estimates for global, regional or national emissions from deforestation.

From accounting perspective, an approach based on different tiers could be implemented depending on the data availability in the participating countries, similar to current IPCC methods for the estimation of emissions and removals in GHG inventories.

As a simple **default method**, for each country a weighted average of aboveground biomass C stocks across forest types can be established based on IPCC default C stock estimates for forest types and FAO data on spatial distribution of forest types from global forest ecosystem mapping approaches. To make the approach conservative in the absence of national C stock data, the lower value of the range of C stocks for different forest types should be used for the accounting purposes. Forest degradation can be taken into account in the default method with a general assumption that a certain percentage share of the default C stock has to be subtracted, if the country is not able to provide data on the share of intact and degraded forests at national level. Thus a general discounting factor could be implied assuming that the forests that would have been deforested in the absence of a RED mechanism would have been degraded to a certain extent. This assumption is consistent with the real situation that deforestation often occurs to a larger extent after forests have been made accessible through road infrastructure and selective logging. Such default factor would need to be developed based on existing research data on C losses from forest degradation.

Higher tier methods could take into account more country-specific information at different levels. Instead of the IPCC default, a country-specific weighted estimate for aboveground biomass C stocks across all forest types would be an essential component. This country-specific default estimate should be the same for the reference level and during the commitment period. The default assumption related to the share of intact and degraded forests could also be replaced by country-specific data on forest degradation and related carbon stock losses. In case of countries with largely intact forest areas, country-specific biomass inventories can show that forest degradation is not relevant and does not need to be taken into account in the C stock estimation.

In large countries, in particular Brazil, a higher tier method could be based on average regional estimates for C stocks weighted across regional forest types or average estimates based on biome types. However this implies that the historic forest area reference is composed in the same way from regional data or for forest biome types. The national reference emission level would be calculated as the weighted reference emission levels across all regions or biomes.

This approach would not take into account carbon stocks in other forest carbon pools such as belowground biomass, dead wood or soil carbon. This is a reasonable simplification for the accounting of reduced deforestation, because the changes in other pools, in particular soils largely depend on the subsequent land uses to which the deforested areas are converted. The areas where deforestation was reduced can neither be located spatially nor can the subsequent land uses of hypothetical clearings be determined at national level. Therefore the accounting method should only refer to aboveground biomass.

The same arguments apply to the accounting of Non-CO_2 gases. Emissions of non-CO_2 gases are mainly related to the relevance of forest fires for deforestation. It is again hypothetical to determine how areas saved from deforestation would have been cleared. National defaults could be developed based on the role of fires in deforestation and would need to be applied for the historic reference level and the commitment period years. However, the impact of fires faces strong annual variability depending on climate effects in particular years. This means, such national defaults would fluctuate strongly over time. The efforts required to develop a reliable annual and historic national default seem high compared to the benefits of such approach.

In general, the methodological requirements for the accounting of carbon from reduced deforestation are different from the task to establish an accurate estimate for emissions from deforestation in a country and it is possible to use some conservative assumptions for the accounting purposes. Further discussion of these parameters is necessary, but it seems feasible to establish default factors as outlined in the previous section.

8.2.5 Use of projected deforestation for the reference emission level

The 2nd option for a baseline is to establish a more complex projection of the future deforestation based on more sophisticated models combining historic deforestation trends and drivers for deforestation. There are various models already available or under development. Models also mostly rely on historic deforestation patterns but in addition include drivers of deforestation as the most important input variable. Drivers can be e.g. accessibility like closeness to roads, settlements and slope as well as pressure on land like population density, tenure etc. For predicting the area where deforestation is likely to occur, spatial models can be used. Some models that can be applied for predicting future deforestation rates are described in section 6. However modelling future deforestation is time consuming and needs reliable data for the input parameters as well as sufficient knowledge on the quantitative relationship of drivers and deforestation rates. As for most tropical countries no annual time-series data on deforestation areas is currently available, any reference levels that are based on projected trends in deforestation would be highly uncertain. Section 6 showed that it is very difficult to establish clear quantitative relationships between deforestation drivers and deforestation. Most of the drivers (apart from population development) are also difficult to project which is adding considerably uncertainty.

Therefore the option for reference levels based on projected deforestation or emission levels is not recommended due to the high data uncertainties.

8.2.6 Reference level for countries with low deforestation

The approach using historic deforestation levels does not provide significant incentives for the protection of forests for those countries with low deforestation rates in the past and large remaining forest resources. These countries may not be able to decrease deforestation rates below the historic rates or the distance they can achieve to the historic level will remain small, triggering a small compensation. Therefore reference emission levels based on historic deforestation rates cannot provide an incentive for this group of countries. The following two sections present two approaches how reference levels for this group of countries could be established, whereas the third section discusses the rationale for such approach.

8.2.6.1 JRC approach

The Joint Research Centre of the European Commission – IES (JRC) (Archard et al. 2005) proposed an approach distinguishing between countries with high forest conversion rates and countries with low conversion rates and different reference levels are set.

Each baseline is based on:

- the global conversion rate during the baseline period (GCB) = average annual global forest conversion rate (% year^{-1}) at global scale between 1990-2005,
- a national conversion rate during the baseline period (NCB) = average annual national forest conversion rate (% year^{-1}) between 1990-2005 at country level
- a national conversion rate during the commitment period (NCC) = annual national forest conversion rate (% year^{-1}) during the commitment period at country level

50 % of the global conversion rate (GCB) during the base period is used as a global benchmark. A Reduced Conversion Rate (RCR) is calculated by subtracting the national conversion rate measured during the commitment period from the national conversion rate during the baseline period (RCR = NCC-NCB).

Countries with high forest conversion rates above half the global average (> 1/2 GCB) have to reduce their national forest conversion rate to get compensated, whereas countries with lower rates than half the global forest conversion average (< ½ GCB) are credited as long as they do not increase their rates. The reduced conversion rate for the latter countries is calculated as half of the global average conversion rate minus the national conversion rate measured during the commitment period. For the proposed accounting mechanism, reduced conversion rates are then multiplied by the remaining national forest areas and an appropriate carbon preservation factor which is determined prior to the start of the commitment period. Implementing this approach, a number of difficulties have to be resolved which are described in the following section.

Global forest conversion rate

It is not entirely clear which countries should be included in the global conversion rate (GCB). As Archard et al. (2005) address tropical deforestation in their proposal the global average was calculated including all countries in the tropical zone. The tropical zone can be defined either geographically, limited in latitude by the Tropic of Cancer in the northern hemisphere, at approximately 23°30' (23.5°) N latitude, and the Tropic of Capricorn in the southern hemisphere at 23°30' (23.5°) S latitude). Another option for definition would be based on world climate zones, e.g. according to Koeppen's climate classification (http://www.blueplanetbiomes.org/climate.htm), the climate definition of the tropics would comprise less countries, in particular in Africa. Both definitions would exclude China.

The global deforestation rate could also be calculated over the global forest area. However, this would include many countries with increasing forest areas and result in a low global forest conversion rate of -0.2% that is less suitable as a default for tropical countries and that would not provide an incentive to countries with low deforestation rates.

Another option would be calculating a Non-Annex I global average, however it would not be very clear why such political categorization is appropriate for this purpose.

Table 42 was compiled to assess whether regional average forest conversion rates could be used for this purpose, but there are also some problems related to a regional categorization. For Africa, the regional average would work, for Asia it would have to be separated for South and South-East Asia. For PNG the regional approach would not work as it belongs to Oceania for which the regional deforestation rate is dominated by Australia.

Table 42 Regional average forest conversion rates

Country/area	Forest							
	Area		Annual change rate					
	1990	2005	1990-2000		2000-2005		1990-2005	
	1000 ha	1000 ha	1000 ha/yr	%	1000 ha/yr	%	1000 ha/yr	%
Total Eastern and Southern Africa	226,534	226,534	-1,731	-0.7	-1,702	-0.7	0	0.0%
Total Northern Africa	146,093	131,048	-1,013	-0.7	-982	-0.7	-1,003	-0.7%
Total Western and Central Africa	300,914	277,829	-1,631	-0.6	-1,356	-0.5	-1,539	-0.5%
Total Africa	**699,361**	**635,412**	**-4,375**	**-0.6**	**-4,040**	**-0.6**	**-4,263**	**-0.6%**
Total East Asia	208,155	244,862	1,751	0.8	3,840	1.6	2,447	1.2%
Total South and South-east Asia	323,156	283,127	-2,578	-0.8	-2,851	-1.0	-2,669	-0.8%
Total Western and Central Asia	43,176	43,588	34	0.1	14	n.s.	27	0.1%
Total Asia	**574,487**	**571,577**	**-792**	**-0.1**	**1,003**	**0.2**	**-194**	**0.0%**
Total Caribbean	**5,350**	**5,974**	**36**	**0.6**	**54**	**0.9**	**42**	**0.8%**
Total Central America	**27,639**	**22,411**	**-380**	**-1.5**	**-285**	**-1.2**	**-349**	**-1.3%**
Total Oceania	**212,514**	**206,254**	**-448**	**-0.2**	**-356**	**-0.2**	**-417**	**-0.2%**
Total South America	**890,818**	**831,540**	**-3,802**	**-0.4**	**-4,251**	**-0.5**	**-3,952**	**-0.4%**
Total World	**4,077,291**	**3,952,025**	**-8,868**	**-0.2**	**-7,317**	**-0.2**	**-8,351**	**-0.2%**

Source: FAO FRA 2005, (FAO 2006)

For this report, the annual global forest conversion rate between 1990 – 2005 based on FAO FRA 2005 data for tropical forest areas in 1990 and 2005 was determined (including all countries with territories in the geographical tropical zone). This gives a global forest conversion rate of -0.6%, half the global average forest conversion rate would then be -0.3%. Table 43 presents the tropical countries with substantial remaining forest areas (> 1 Mio.) with smaller forest conversion rates than half of the global average. The total forest area of all tropical countries with forest conversion rates below half of the global average comprised about 325,844 kha in 2005.

Table 43 Tropical countries with lower global forest conversion rates smaller than half of the global average and remaining forest areas above 1 Mio. ha

Country/area	Forest								
	Area			Annual change rate					
	1990	2000	2005	1990-2000		2000-2005		1990-2005	
	1000 ha	1000 ha	1000 ha	1000 ha/yr	%	1000 ha/yr	%	1000 ha/yr	%
Peru	70,156	69,213	68,742	-94	-0.1	-94	-0.1	-94.3	-0.1%
Colombia	61,439	60,963	60,728	-48	-0.1	-47	-0.1	-47.4	-0.1%
Angola	60,976	59,728	59,104	-125	-0.2	-125	-0.2	-124.8	-0.2%
Central African Republic	23,203	22,903	22,755	-30	-0.1	-30	-0.1	-29.9	-0.1%
Congo	22,726	22,556	22,471	-17	-0.1	-17	-0.1	-17.0	-0.1%
Gabon	21,927	21,826	21,775	-10	n.s.	-10	n.s.	-10.1	0.0%
Mozambique	20,012	19,512	19,262	-50	-0.3	-50	-0.3	-50.0	-0.2%
Guyana	15,104	15,104	15,104	n.s.	n.s.	0	0	0	0.0%
Suriname	14,776	14,776	14,776	0	0	0	0	0	0.0%
French Guiana	8,091	8,063	8,063	-3	n.s.	0	0	-1.9	0.0%
Panama	4,376	4,307	4,294	-7	-0.2	-3	-0.1	-5.5	-0.1%
Belize	1,653	1,653	1,653	0	0	0	0	0	0.0%
Eritrea	1,621	1,576	1,554	-4	-0.3	-4	-0.3	-4.5	-0.3%
Dominican Republic	1,376	1,376	1,376	0	0	0	0	0	0.0%

Source: FAO FRA 2005, (FAO 2006)

Table 43 also shows that for some of the countries with relatively high remaining forest areas and low forest conversion rates FAO forest area data do not change during the period 1990-2005 (e.g. Guyana, Suriname, French Guiana, Belize, Dominican Republic). This reveals some data problems for the countries with very low deforestation rates. Table 44 provides an overview of the methods used for the compilation of the FAO FRA 2005 for the countries listed in Table 43.

In particular for the African countries with low deforestation rates the FAO data are based on forest area data from the 80s or early 90s. Forest area data for Latin American countries are generally based on more recent data. For four countries, no change in forest area was assumed and therefore the conversion rate is 0, however this may not reflect the real situation. Thus, global forest conversion rates based on FAO data are related to considerably uncertainties, in particular for African countries. Their usefulness to derive reference levels may therefore be limited. The question arises whether all countries independent on the data situation, should be included in the calculation of a global average conversion rate or whether countries with poor and very outdated data should be excluded.

Due to data gaps for many countries and a lack of recent estimates of forest conversion rate for many countries, the determination of the global average conversion rate (GCB) is related to high uncertainties and may therefore not be the preferred method for establishing reference levels for countries with low deforestation rates and large remaining forest areas. It seems preferable to adopt a method where the key parameter is connected with less uncertainties.

Table 44 Methods used fort he compilation of FAO FRA 2005 for the countries listed in Table 43

Country / Area	Most recent data on forest area			Forest Area Time Series	Forest Area Projection
	Field survey/ mapping	Remote sensing	Expert estimate		
Peru		2000		MLT	**LEM**
Colombia		2001		MLT	**LEM**
Angola	**1970**		**1983**	MLT	**LEM**
Central African Republic	**1994**			**SIN**	DEF
Congo	**1993**			MLT	DEF
Gabon			1999	MLT	**LEM**
Mozambique		**1994**		MLT	**LEM**
Guyana			**1999**	**SIN**	**ANC**
Suriname		1998		**SIN**	**ANC**
French Guiana		2000		MLT	**LEM**
Panama		2000		MLT	**LEM**
Belize		2000		**SIN**	**ANC**
Eritrea			1997	**SIN**	DEF
Dominican Republic			1998	**SIN**	**ANC**

Abbreviations:

SIN:	*Reported figures based on data for one point in time*
MLT:	*Reported figures based on data for two or more points in time*
ANC	*Assumed No Change between two or more reference years*
LEM	*Linear interpolation or extrapolation*
DEF	*Separate studies on deforestation or forest area changes used for estimation and forecasting*

Source: FAO FRA 2005, (FAO 2006)

8.2.6.2 Average reduction from participating countries

A new approach for reference levels for countries with low deforestation rates and high remaining forest resources was developed for this report. The objective is to

1. Provide criteria for the selection of countries to which such approach would be applicable
2. Provide a reference for the accounting of credits for compensation for countries with low deforestation rates and large remaining forest areas.

As explained above, the historic national average deforestation is not applicable as a basis for compensating the efforts in keeping the forests for these countries, because almost no deforestation occurred. The use of projections of future deforestation in countries with small past deforestation seems also very difficult because this requires the quantification of the future risk for deforestation. This would produce highly uncertain results and a potential unfair result because the deforestation risk is not applied to the other countries for the establishment of a reference emission level.

Step 1: Selection of countries

When the baseline approach should differentiate between countries with high deforestation rates and countries with large forest areas and low deforestation activities in the past, it is essential to develop criteria for the selection of the latter group of countries.

A straightforward obvious way of separating countries with high deforestation from countries with large natural forests areas that have kept substantial forest resources could be the remaining forest area relative to the total land area of a country. The percentage of forest area is calculated on the basis of FAO data in Table 45 (column on the right). This resulting ranking shows that there are 8 tropical countries with forest areas > 70% that so far largely conserved their national forest resources. However, the total forest area of these 8 countries is with 81 Mio. ha rather small (about the forest area size of Indonesia).

Table 45 Tropical countries with remaining forest areas > 50% of total land area

Country/area	**Forest**	**Forest**						**Forest area/ total land area**
	Area	**Annual change rate**						
	2005	**1990-2000**		**2000-2005**		**1990-2005**		**2005**
	1000 ha	**1000 ha/yr**	**%**	**1000 ha/yr**	**%**	**1000 ha/yr**	**%**	**%**
Suriname	14,776	0	0	0	0	0	0.0%	95%
French Guiana	8,063	-3	n.s.	0	0	-1.9	0.0%	91%
Gabon	21,775	-10	n.s.	-10	n.s.	-10.1	0.0%	85%
Solomon Islands	2,172	-40	-1.5	-40	-1.7	-39.7	-1.4%	78%
Guyana	15,104	n.s.	n.s.	0	0	0	0.0%	77%
Guinea-Bissau	2,072	-10	-0.4	-10	-0.5	-9.6	-0.4%	74%
Belize	1,653	0	0	0	0	0	0.0%	73%
Lao People's Democratic Republic	16,142	-78	-0.5	-78	-0.5	-78.1	-0.5%	70%
Congo	22,471	-17	-0.1	-17	-0.1	-17.0	-0.1%	66%
Papua New Guinea	29,437	-139	-0.5	-139	-0.5	-139.1	-0.4%	65%
Malaysia	20,890	-78	-0.4	-140	-0.7	-99.1	-0.4%	64%
Myanmar	32,222	-466	-1.3	-466	-1.4	-466.5	-1.2%	60%
Cambodia	10,447	-140	-1.1	-219	-2.0	-166.6	-1.3%	59%
Democratic Republic of the Congo	133,610	-532	-0.4	-319	-0.2	-461.4	-0.3%	59%
Colombia	60,728	-48	-0.1	-47	-0.1	-47.4	-0.1%	58%
Equatorial Guinea	1,632	-15	-0.8	-15	-0.9	-15.2	-0.8%	58%
Panama	4,294	-7	-0.2	-3	-0.1	-5.5	-0.1%	58%
Zambia	42,452	-445	-0.9	-445	-1.0	-444.8	-0.9%	57%
Brazil	477,698	-2,681	-0.5	-3,103	-0.6	-2821.9	-0.5%	56%
Bolivia	58,740	-270	-0.4	-270	-0.5	-270.3	-0.4%	54%
Venezuela (Bolivarian Republic of)	47,713	-288	-0.6	-288	-0.6	-287.5	-0.6%	54%
Peru	68,742	-94	-0.1	-94	-0.1	-94.3	-0.1%	54%
Cameroon	21,245	-220	-0.9	-220	-1.0	-220.0	-0.9%	53%

Source: FAO FRA 2005

Below the 70% share of forest area in total land area, the data does not show a clear threshold that would not set an arbitrary threshold. Brazil also appears quite high in this ranking with 56% of forest area to total land area. Therefore the forest area relative to total land area is not applicable as single criterion. Other options for criteria are the annual forest conversion rate in per cent as well as the absolute annual forest area loss. A combination of these parameters can ensure that only the data on forest area change was used to classify those countries for which the historic reference level may not be suitable. For this report the following threshold criteria were established:

- The forest area is decreasing and not increasing
- Annual forest loss rate is less or equal than 0.3%

- Share of forest area to total land area is larger than 30%

An annual forest loss rate of less or equal than 0.3% applied for both period 1990-2000 and 2000-2005 aims at selecting those countries with low deforestation in the past. Brazil's deforestation rate is 0.5% according to FAO data, thus an annual loss rate that aims at selecting countries with low deforestation in the past should be selected below 0.5%.

The criterion of forest area relative to total land area basically excludes all countries with small forest areas due to climate conditions or high past deforestation. Due to the lack of substantial forest areas, deforestation rates are rather low in these countries, thus this criterion ensures that only countries with substantial remaining forest areas are selected.

The countries that would fulfil these criteria according to FAO FRA 2005 data are listed in Table 46.

Table 46 Countries that comply with the criteria for low deforestation in the 1990-2005 period based on FAO data

Country/area	**Forest**							**Forest area/ total land area**
	Area			**Annual change rate**				
	1990	**2000**	**2005**	**1990-2000**		**2000-2005**		**2005**
	1000 ha	**1000 ha**	**1000 ha**	**1000 ha/yr**	**%**	**1000 ha/yr**	**%**	**%**
Democratic Republic of the Congo	140,531	135,207	133,610	-532	-0.4	-319	-0.2	0.59
Peru	70,156	69,213	68,742	-94	-0.1	-94	-0.1	0.54
Colombia	61,439	60,963	60,728	-48	-0.1	-47	-0.1	0.58
Angola	60,976	59,728	59,104	-125	-0.2	-125	-0.2	0.47
Central African Republic	23,203	22,903	22,755	-30	-0.1	-30	-0.1	0.37
Congo	22,726	22,556	22,471	-17	-0.1	-17	-0.1	0.66
Gabon	21,927	21,826	21,775	-10	n.s.	-10	0	0.85
Republic of Korea	6,371	6,300	6,265	-7	-0.1	-7	-0.1	0.63
Panama	4,376	4,307	4,294	-7	-0.2	-3	-0.1	0.58

Source: Data source FAO FRA 2005 (FAO 2006)

The overview in Table 46 shows that with these threshold criteria used, 9 tropical countries would be selected that have large remaining forest areas and low deforestation in the past. The total forest area in 2005 of these countries based on FAO data amounts to 266 Mio. ha.

Step 2: Reference for compensation

Instead of calculating a global forest conversion rate as in the JRC approach, an average reduced forest conversion rate could be calculated based on the data of those countries participating in a RED mechanism. For countries with low deforestation rates the reference level could be based on the achieved average reductions in deforestation by all Parties that join a future RED mechanism.

This approach would have the advantage that only data of countries is included in the calculation that have decided to demonstrate their efforts in reducing deforestation and that have developed consistent datasets for this purpose.

The disadvantage of this approach is that the reference level for the countries with low deforestation can only be determined ex-post when data for the countries with high deforestation has become available. However, it may anyway be preferable to issue compensation for countries with low deforestation ex-post at the end of a commitment period and not up-front before the conservation efforts have been demonstrated.

For the majority of countries that participate in a future RED mechanism, the historic average deforestation rates are applicable as a reference. For these countries the reduced annual conversion rate (RCR) could be calculated as following:

If CR ≥ -0.4% and if FA/TA > 0.3

RCR = RCP/2 - NCC

Where RCP = CACP/TFA

CR = forest conversion rate

FA = total forest area

TA = total land area

NCC = national forest conversion rate during the commitment period (in %/year^{-1}) at country level

RCR = reduced forest area change rate in %

RCP = reduced forest area change rate during commitment period in %

CACP = Area of forest conversion during commitment period of all participating countries in RED mechanism

TFA= total forest area of all participating countries at starting point

This results in a reference level with a hypothetical annual area change from which the national forest area change is subtracted to achieve the hypothetical reduced forest area change rate for countries with low deforestation. Table 47 to Table 49 present some example calculations for this approach.

In the example calculations, FAO default data for C stocks are used which do not differentiate between forest types and degraded or intact forests, thus the resulting emission reductions in Table 49 are overestimated. However, the result still shows that this group of country would still be able to account for a substantial amount of emission reductions per year.

This approach would create an incentive for those countries with low historic deforestation at a level comparable to the other Parties participating in a RED mechanism. In addition, the approach is based on data of comparable quality.

Table 47 *Example calculation for average RCP based on reduced forest area change rate for an arbitrary subset of participating countries assuming that these countries achieved an average reduction of deforestation by either 10% or 20%*

Country	**Forest area**	**Annual forest area change**	**Achieved forest area change during 5 year intervall**		**Reduced forest area change/ total forest area in 2005**	
	2005	**2000-2005**	**assumed reduction (case 1 = 10%, case 2 = 20%) in 1000 ha/yr**		**assumed reduction 10%**	**assumed reduction 20%**
	1000 ha	**1000 ha/yr**	**0.1**	**0.2**	**%**	**%**
	A	**B**	**C**	**D**	**E = C/A**	**F = D/A**
Brazil	477,698	-3,103	-2,793	-2,482	-0.58%	-0.52%
Indonesia	88,495	-1,871	-1,684	-1,497	-1.90%	-1.69%
Papua New Guinea	29,437	-139	-125	-111	-0.42%	-0.38%
United Republic of Tanzania	35,257	-412	-370.8	-330	-1.05%	-0.93%
Mexico	64,238	-260	-234	-208	-0.36%	-0.32%
Philippines	7,162	-157	-141	-126	-1.97%	-1.75%
Bolivia	58,740	-270	-243	-216	-0.41%	-0.37%
Ecuador	10,853	-198	-178	-158	-1.64%	-1.46%
Zambia	42,452	-445	-401	-356	-0.94%	-0.84%
Total	**814,332**	**-6,855**	**-6,170**	**-5,484**	**-0.76%**	**-0.67%**
RCP/2					**-0.38%**	**-0.34%**

Source: FAO FRA 2005, (FAO 2006)

Table 48 *Example calculation for RCR reference level for countries with low deforestation rates based on average reduction for all participating countries*

Country	**Forest area in 2005**	**NCC = Annual forest area change 2000-2005**	**10% assumed reduction**	**20% assumed reduction**	**10% assumed reduction**	**20% assumed reduction**
			Reference level forest area reduction		**RCR**	
	1000 ha	**1000 ha/yr**			**1000 ha/yr**	
Democratic Republic of the Congo	133,610	-319	-506	-450	-187	-131
Peru	68,742	-94	-260	-231	-166	-137
Colombia	60,728	-47	-230	-204	-183	-157
Angola	59,104	-125	-224	-199	-99	-74
Central African Republic	22,755	-30	-86	-77	-56	-47
Congo	22,471	-17	-85	-76	-68	-59
Gabon	21,775	-10	-82	-73	-72	-63
Republic of Korea	6,265	-7	-24	-21	-17	-14
Panama	4,294	-3	-16	-14	-13	-11
Total	**399,744**					

Source: FAO FRA 2005, (FAO 2006)

Table 49 Example calculation of CO_2 emissions reductions for countries with low deforestation rates based on average reduction for all participating countries

Country	default C stock in 2005	10% assumed reduction	20% assumed reduction	10% assumed reduction	20% assumed reduction
		Assumed C conservation		Assumed emission reduction	
	tC/ha	Mt C/ year		Mt CO2/ year	
Democratic Republic of the Congo	140	-26	-18	-96	-67
Peru	85	-14	-12	-52	-43
Colombia	98	-18	-15	-66	-57
Angola	64	-6	-5	-23	-17
Central African Republic	99	-6	-5	-20	-17
Congo	186	-13	-11	-46	-40
Gabon	137	-10	-9	-36	-32
Republic of Korea	31	-1	0	-2	-2
Panama	114	-2	-1	-6	-5
Total				**-348**	**-279**

Source: FAO FRA 2005, (FAO 2006)

8.2.6.3 Is a different approach for countries with low deforestation and high remaining forest areas justified?

An incentive mechanism for reduced deforestation that only addresses tropical countries with high deforestation rates and that does not provide incentives for tropical countries with large remaining forest areas and low deforestation in the past, creates the risk of global leakage, this means that deforestation pressure may be shifted to the latter group of countries for which participation is not interesting. It is also difficult to justify why countries that contributed largely to global emissions in the past through their deforestation activities, receive compensation for conserving their forests while other countries that did not follow this route, should not get compensated. These were the main reasons for developing an approach for different types of reference levels for this group of countries with low past deforestation.

However, such a scheme implies the risk that compensation is disconnected to any efforts necessary for forest conservation at the national level and the compensation received may not be used for forest conservation activities and policies.

When the countries listed in Table 46 are analysed in more detail with regard to the underlying reasons for the low deforestation activity, certain common features can be drawn:

A number of these countries were facing wars, terrorist or guerrilla activities in the period 1990-2005 such as Peru, Colombia, Congo, Angola. Other countries in this list are rich in other natural resources such as oil, gold or diamonds (Congo, Gabon), or have a relatively small population and no significant pressure to increase agricultural areas. Thus, there would be some countries that may be able to use a RED compensation mechanism as free riders, or they may only keep low deforestation rates until the point when civil war will terminate or when other natural resources will be depleted.

8.2.6.4 Compensation for forest conservation activities

To avoid free-rider effects, incentives for forest conservation for countries with low past deforestation should be linked to the implementation of specific national policies and action for forest conservation and the implementation of national forest conservation programmes. If incentives are linked to such action, it may be more useful to develop a compensation approach that takes into account the costs for the conservation of forests and the implementation of appropriate activities instead of basing the compensation on a hypothetical amount of emission reductions achieved. A separate fund addressing these particular countries could be established and compensation could then be based on the proposed forest conservation activities and the related monitoring of such activities. Such approach could better take into account specific national circumstances as well as biodiversity aspects.

8.2.7 Inclusion of forest degradation

There is considerable evidence that the available estimates of carbon emissions from deforestation underestimate total emissions due to the fact that forest degradation is not taken into account. Due to forest degradation carbon stocks in many forests are decreasing without a change in forest area. Practices leading to forest degradation include losses of biomass associated with selective logging, forest fragmentation, fuel wood gathering, ground fires, shifting cultivation, browsing, and grazing (e.g. Barlow et al., 2003; Laurance et al., 1998, 2000; Nepstad et al., 1999). These changes in biomass are generally more difficult to detect with satellite data than changes in forest area and more difficult to document from census data; yet, the changes in carbon may be significant. Estimates of carbon emissions from the degradation of forests (expressed as a percentage of the emissions from deforestation) range from 5% for the world’s humid tropics (Achard et al., 2004) to 25-42% for tropical Asia (Flint and Richards, 1994; Houghton and Hackler, 1999; Iverson et al. 1994) and to 132% for tropical Africa (Gaston et al. 1998).

Differentiating deforestation from degradation is a function of both the mapping scale and basic definitions of forest/non-forest, therefore forest degradation can be addressed in a methodological approach described above for the establishment of a reference emission levels in several ways:

- Firstly the choice of the resolution of the satellite data used for the establishment of changes of forest areas over time will determine the size of clearings that can be identified as deforestation.
- A permanent annual monitoring system based on satellite data can track disturbance events on forest areas and resulting regrowth leading to secondary forests on these areas.
- The choice of forest definition used will determine whether degraded forests areas will be considered as forest areas or as other land uses. An additional definition for forest degradation could also be introduced differentiating primary forests from degraded forests.
- In the estimation of emissions levels, degradation can be addressed by default factors for C stocks in degraded forests or country-specific C stock values for degraded forests. In the absence of information on the status of forests, lower default C stock values for degraded forests could be prescribed to ensure a conservative approach.

Thus, the inclusion of degradation into a RED mechanism can partly be addressed within the detailed methodological guidance for monitoring and accounting.

The approach for reference emission levels described so far would not address the emissions from the conversion of intact, primary forest to secondary forest or different types of non-intact forest. JRC (Mollicone et al. 2006) proposed a differentiation between intact and non-intact forests in their proposal for an accounting approach for reduced deforestation. The inclusion of this source of emissions in a RED mechanism would require the identification of forest areas on which such conversions take place in a consistent way for the past and for commitment period years. The mechanism would then compensate for a reduced conversion of intact to non-intact forest in the commitment period compared to the historic reference.

8.2.8 Forest definition

There is currently no consensus across Parties whether country-specific forest definitions or a generic forest definition should be applied. In their submissions under the UNFCCC some countries suggest the application of the UNFCCC forest definition while others recommend using country-specific forest definitions to include different geographic and climatic conditions. As section 5.1 showed, the precise selection of land cover definitions influences the deforestation rate estimated based on remote sensing and considerable differences in deforestation rates have been related to differences in forest definitions. It is very important that the same forest definition is consistently used for the establishment of the reference emission level and the target as well as during a commitment period.

For a future RED mechanism further analysis is necessary on the consequences of different forest and land use definitions for the unambiguous area detection with remote sensing methods. The most appropriate definition may be less open for selection by countries, but more determined by the detection levels of remote sensing methods.

8.2.9 Adjustment factors for reference emission levels

Some countries suggest the application of adjustment factors to historic reference emission levels. A wide-range of parameters are proposed that should be taken into account in such adjustment factors (see Table 50)

Table 50 Proposals for adjustments to historic emission levels

Adjustments/ changes to historic emissions	**Party**
Taking into account institutional barriers, agents and drivers of deforestation, growth projections, contrasting interests of different economic agents To be determined in national process	Chile, submission September 2007
Development adjustment factor, taking into account low deforestation rates in the past, demographic trends, agriculture, food self-sufficiency, infrastructure development and renewable energies	COMIFAC, submission September 2007

A specific situation addressed as part of the baseline adjustments is the adjustment due to low deforestation rates in the past. This situation was discussed in detail in section 8.2.6 and a quantitative approach was presented and can be tackled by a differentiated approach for the establishment of reference levels and may therefore not require a baseline adjustment.

A number of adjustment reasons proposed are related to drivers for deforestation. Section 6 showed that it is very difficult to establish clear quantitative relationships between drivers of deforestation and deforestation rates. This also implies that the adjustments proposed by Parties cannot be related in an unambiguous quantitative relationship to drivers with available national indicators, because of the variety and complex interactions of drivers for deforestation. The proposals for adjustments of historic emission levels would mean that first a comparable effort would be undertaken to establish historic emission levels on a clear methodological basis. In a second step, these reference levels would be subject to rather arbitrary adjustments. This raises the questions whether a historic reference level has to be established at all in the first step when the final result will most likely depend on the negotiation effectiveness of participating Parties. This approach has a high potential to result in arbitrary reference levels. Compensation for reduced deforestation requires the implementation of national policies that address the drivers of deforestation. Economic incentives via the RED mechanism are provided in order to support countries in the implementation of appropriate national policies. From this conceptual perspective it also does not seem logic why certain drivers for deforestation should lead to higher reference levels. The adjustment would increase the reference deforestation rate compared to the real situation. This would result likely in a situation where continuation of business-as-usual deforestation would be able to get compensated and the effectiveness of a RED mechanism would be reduced.

If the commitments under a RED mechanism should be further differentiated e.g. in relation to economic potentials of participating Parties (e.g. related to least developed countries), it would be preferable to implement such differentiation through the targets to be achieved and not through the historic reference. The use of a historic reference does not automatically imply that all emission reductions below the historic reference level are compensated, but different targets on this basis can be established, e.g. countries could be required to decrease emissions by a certain share below historic levels before the compensation scheme starts.

8.2.10 Reporting, review and verification

An international scheme for financial compensation for reduced deforestation creates the need for a new international process of reporting, review and verification. As a first step reporting requirements under the RED mechanism need to be established. Such reporting requirements would address the reporting of data and information necessary to replicate the estimation of the emission reduction. In addition to such technical estimation information, a second part of reporting requirements should address national forest conservation programmes and national policies for forest conservation implemented by the receiving countries to decrease deforestation. Such reporting would create a transparent link between the financial incentives provided and the forest policies and activities implemented by the receiving countries. The reporting would also promote the exchange on best practice activities across participating countries.

A review of the reported information would check whether the claimed deforestation reductions really occurred and whether the calculation of the associated emissions reductions have been performed in accordance with agreed monitoring and estimation methodologies. Such review could be organized in a similar way as the review of Annex I GHG inventories which are reviewed by international expert review teams in either country visits or in centralized desk reviews at the UNFCCC secretariat. However, the timing of such process would look different as an annual review process does not seem to be necessary. The review of the accounting of emission reductions from reduced deforestation would have two elements, first the review whether the reference emission level was established in accordance with agreed rules and guidance and secondly at the end of the commitment period, the review would check the estimation of the reduced emissions relative to the reference. Such review would mainly check the technical estimation methods.

8.2.11 Conclusions and recommendations

- There is a considerable gap in information on current deforestation trends in many tropical countries and for most countries no annual time series of deforestation areas is available. The lack of data on current deforestation trends automatically leads to high uncertainties for the projection of future deforestation. In addition there are many drivers for deforestation which are interacting in a complex way and which are difficult to predict. Therefore reference levels based on historic deforestation seem to be the only acceptable option for the establishment of national reference levels as projected reference levels are even more uncertain. This situation is reflected in most proposals from Parties and research institutions.
- As for emission reduction commitments of Annex I Parties, time series consistency of methods and data is important to ensure credible and reliable emission reductions. The estimation of forest area changes and related C stocks should follow the same methods for the reference period and the commitment period. The requirement of time-series consistency excludes some of the more recent advances in remote sensing technologies for the first accounting period because such data are not available retrospectively for past deforestation.
- For accounting purposes, the final estimates for reference emission levels and commitment period emissions do not necessarily need to be very accurate, but they need to be consistent over time and they should be conservative. Time-series consistent means that the reference level and the level during the commitment period should be based on the same methods to avoid that a shift in methods leads to the compliance with targets. Conservative means that the methods should ensure that at least the amount of emissions for which a country is compensated, was really reduced whereas the real emission reduction may be higher. This is an important difference to the task of producing reliable estimates for global, regional or national emissions from deforestation.
- The establishment of historic deforestation areas for reference levels requires additional methodological guidance with regard to
  - The monitoring approach to be used, e.g. wall-to-wall assessment of the full country area or adequate sampling size for satellite data;
  - Forest definition and canopy cover rules to be applied for the detection of forest and non-forest areas with remote sensing technologies;
  - Establishment of required resolution and the minimum clearing size that should be identifiable with remote sensing technologies;

  - The determination of the historic period to be used for the establishment of reference emission levels. Time series consistency of methods for the establishment of the reference level and during the commitment period should guide this decision and it is recommended to start the historic data in 1990 where high resolution Landsat data is available. The most recent year that enters the reference level needs to be defined. A recent year should be chosen in the period before the countries decide on their participation in a RED mechanism to avoid that the reference levels can be actively increased by deforesting larger areas.
  - It is recommended to work with absolute area changes for the establishment of reference levels as they are closer related to the emission impacts when comparing different countries.
  - Specification of a tiered approach for the accounting of reduced emissions taking into account different data availability in tropical countries.
  - Establishment of default factors for the estimation of carbon stocks in aboveground biomass saved for those countries without country-specific parameters. Data on default carbon stocks for forest types is available from IPCC 2006 Guidelines or IPCC Good Practice guidance for LULUCF. FAO has provided maps and data on the spatial distribution of forest types at country-level.
  - Establishment of default factors that can be applied to take into account that non-intact forests have lower carbon stocks.
- A different approach for countries with low historic deforestation rates should be implemented because the objective to underpass historic emission levels is not applicable for such countries. It is suggested to develop criteria for the identification of tropical countries with low historic deforestation levels as a first step. If participating countries fulfil these criteria, compensation for continuous low deforestation rates could be calculated on the basis of the reference could be the average reduced annual conversion area calculated on the basis of all countries participating in the RED mechanism.
- Periodic updating of reference emission levels is recommended because the reference levels may fail to take into account significant changes in recent years and maybe overly conservative or not sufficiently conservative in relation to the efforts required by Parties. The revision or updating period should correspond with the commitment period length, this means that the reference can be corrected after the first commitment period for the subsequent period. During one commitment period, the reference level should be fixed.
- It is recommended not to adjust historic reference emission levels to take into account different national circumstances, socio-economic factors or drivers of deforestation. If the commitments should be further differentiated e.g. in relation to economic potentials of parties (e.g. related to least developed countries), it would be preferable to implement such differentiated through the targets to be achieved and not through the historic reference. The use of a historic reference does not automatically imply that all emission reductions below the historic reference level are compensated, but different targets on this basis can be established, e.g. countries need to decrease emissions at least by 10% or 20% below historic levels before the compensation scheme starts.
- At the level of participating countries, the establishment of historic reference levels and the accounting of reduced deforestation require considerable capacity building efforts and

institutional arrangements to establish an institutional system able to continuously monitor deforestation, because such data is currently not analysed on a systematic basis in many tropical countries.

9 Summary of conclusions and recommendations

Forest area data

While monitoring systems are generally available that would satisfy the needs for reporting and accounting of reduced deforestation in an international RED mechanism, considerable future efforts are needed until such monitoring systems will be implemented in all developing countries with large remaining forest areas

- In the past years new high and medium resolution satellite data have become available which have considerably improved the possibilities of monitoring forest area changes in tropical countries and many studies have proven the applicability for the monitoring of deforestation. However, very few Non-Annex I countries have currently implemented permanent national activities and institutions that produce periodic data on forest area and land-use changes based on satellite data. Many satellites have been launched rather recently and few data sources are available for historic periods back to 1990 or earlier. These sources do not produce area change data on an annual basis but for specific periods (1990 and 2000) which are not exactly precise in time (data covers e.g. the year 2000 ± 3 years).
- A stronger focus on consistent time-series data is necessary for a routine application of remote sensing data as part of a future RED mechanism. The past focus has been the improvement of accuracy and resolution for different purposes. Apart from the FAO forest assessments, the provision of consistent time-series of forest area changes over long time periods has not been very important. Only medium resolution satellite data is available on an annual basis, while high resolution data may not be available annually for cloudy regions. Datasets from different sensors with different resolution have to be combined to derive annual time series covering historic and current years. Few research or guidance is available how time-series consistency can be ensured using different satellites and sensors over time.
- There are problems with data availability for high resolution data for the current decade due to the problems with Landsat ETM+ sensor which have to be resolved. Before the new NASA Landsat 8 and Sentinel ESA satellites, which are expected to be launched in 2011 will deliver data, high resolution data will be provided only by the CBERS (China-Brazil), IRS (India) and SPOT (France) satellite constellations.
- Continuous monitoring of land cover changes with remote sensing, which is currently in most developing countries an area of research work (with the exception of Brazil and India), has to be implemented in an permanent national institutional setting on a periodic (annual) basis in all participating countries. This task needs considerable capacity-building activities and substantial financial resources.
- It is necessary to develop further methodological guidance and best practices for the assessment of forest area changes under different national circumstances (e.g. wall-to-wall approach or sampling size, minimum clearing size to be identified, monitoring intervals, harmonized forest classification schemes). Such additional guidance is necessary to ensure comparability and is not yet part of the existing IPCC guidance. As part of this methodological work it is also essential to develop clear, harmonized

and unambiguous definitions for land use cover and forests for the interpretation of satellite images.

Biomass data and related GHG emissions from deforestation

- There exists a very large variation in data structure, quality and availability of data on forest biomass and carbon stocks between the investigated tropical countries. Currently, a large proportion of the uncertainty in estimating carbon stocks and emissions is caused by highly generalized and aggregated values on regional levels which do not allow a reasonable application to national situations. A step towards refining the data resolution at country level is necessary. This would mean e.g., that a set of default forest types, similar to the ones specified in the 2006 IPCC Guidelines (2006), had to be created as reference, where countries would have to report on all of these forest types separately. This would constitute an enormous progress towards more realistic estimates on the magnitude of emissions from deforestation.
- More potential, particularly for refining above-ground biomass estimates, may also lie in a better estimate of intrinsic parameters for biomass estimation, e.g. wood density to be applied to the allometric models (Chave et al. 2006, Nogueira et al. 2006, 2007). Commonly, inventory datasets are fragmentary and/or taxonomical information incomplete. A model approach, currently developed at the MPI-BGC based on PSP data from Papua New Guinea, drawing on Bayesian inference, will soon allow the quantification of errors when compensating for incomplete datasets and can thus assist in characterizing upscaling processes of wood density data to stand, and depending on the inventory data, also to national levels.
- The research for this study also revealed that a wide variety of valuable data on forest inventories exists worldwide. It would be desirable to channel and compile these data and make them publicly available, also beyond intellectual property concerns. First steps have already been undertaken, e.g. online databases on wood density (maintained by ICRAF) or on neotropical rainforest inventories (SALVIAS, ADTN), and this study already profited tremendously from such resources.
- The most uncertain parameter in the calculation of emissions from deforestation is the contribution of emissions released by burning of forests. The uncertainties are related to the area burnt and the amount of fuel load. Satellite measurements are currently limited by cloud cover, coarse satellite grids, and heterogeneous fuel loads, causing the largest uncertainties in global biomass burning estimates on deforestation regions and in areas where peat fires occur. To address these uncertainties, finer resolution satellite measurements and bottom-up modeling (such as CASA (Werf, Randerson et al. 2004)) need to progress[8] (Werf, Randerson et al. 2006). Since only a fraction of the available fuel load burns during a fire, the combustion completeness must be assessed. New satellite-based approaches can detect this through the fire radiative energy to directly estimate emissions (Werf, Randerson et al. 2006). To improve the monitoring and assessment of forest fires and associated emissions, data-collection systems need to be made directly comparable by harmonizing definitions. Systems for sharing information should be developed. It is recommended to combine satellite

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[8] *Or a combination of them.*

data of deforestation area, biomass / vegetation carbon stock data and on-site data on fire intensity) in the future to quantify associated GHG releases.

- Under the current methods the estimation of greenhouse gas emissions from forest fire will remain with a relatively large uncertainty and the distinction between human-induced, human-influenced and natural fire is still beyond current capabilities. Current methods for the estimation of non-CO_2 emission from deforestation need improvement with regard to their country-specific applications.
- An important side-effect of a future RED mechanism is the provision of better data for the participating countries. This information will considerably improve the knowledge on global emissions from deforestation, the understanding of the role of emissions from deforestation at the global and regional level and it will reduce the uncertainties of current estimates.

Drivers for deforestation

- Despite the promising results from correlations of deforestation areas and drivers of deforestation presented in this report, forest area change can hardly be explained by simple regression functions which assign an influential weight to every factor in the equation. Rather, deforestation analysis requires a complex empirical causal model with several time and space scales, recognizing the feedback and interaction character of many factors. Additionally, such a model should include decision scenarios for several policy pathways to complement the empirical analysis. To allow a more sophisticated deforestation trend analysis, the quantity and quality of variable data needs tremendous improvements. Especially, the information on forest area change provided by FAO (and most drivers) is still much too coarse to establish national correlations.
- Deforestation drivers might bear importance in determining the deforestation trend in the future and might thus be of great value for any RED mechanism. However, to rely on such projections, the drivers have to be determined on the national and sub-national level and satellite techniques need to be used to quantify forest area changes.
- Annual or biannual change rates are recommended to investigate the influence of most biophysical and socio-economic drivers on deforestation. A list of potential deforestation driver data necessary to improve the deforestation trend predictions are not only given in the results of the univariate regressions (see Annex: Table 2-5). We recommend the collection of additional data for the drivers and conditions of deforestation, which are listed in Table 1 (see Annex). A better data basis will not only help to predict trends of forest area changes but also to understand the drivers of deforestation much better. These results might be used to curb the deforestation rate and are thus of double interest for countries joining the RED mechanism.
- The analysis of relations between absolute and relative forest area change illuminated the necessity not to assume national deforestation thresholds, as done by Houghton. Although possible under specific country circumstances, our results show that this behaviour cannot be generalized for all tropical countries.

Reference emission levels

- There is a considerable gap in information on current deforestation trends in most tropical countries and for most countries no annual time series of deforestation areas are available. The lack of data on current deforestation trends automatically leads to high uncertainties for the projection of future deforestation. In addition there are many drivers for deforestation which are acting in a complex way and which are difficult to predict. Therefore reference levels based on historic deforestation seems to be the only acceptable option which is reflected in most proposals from Parties and research institutions.
- As for emission reduction commitments of Annex I Parties, time series consistency of methods and data is important to ensure credible and reliable emission reductions. The estimation of forest area changes and related C stocks should follow the same methods for the reference period and the commitment period. The requirement of time-series consistency excludes some of the more recent advances in remote sensing technologies for the first accounting period because such data are not available retrospectively for past deforestation.
- For accounting purposes, the final estimates for reference emission levels and commitment period emissions do not necessarily need to be extremely accurate, but they need to be consistent over time and they should be conservative. Time-series consistent means that the reference level and the level during the commitment period should be based on the same methods to avoid that a shift in methods leads to the compliance or non-compliance with targets. Conservative means that the methods should ensure that at least the amount of emissions for which a country is compensated, was really reduced whereas the real emission reduction may be higher. This is an important difference to the task of producing reliable estimates for global, regional or national emissions from deforestation.
- The establishment of historic deforestation areas for reference levels requires additional methodological guidance with regard to
  - The monitoring approach to be used, e.g. wall-to-wall assessment of the full country area or adequate sampling size for satellite date;
  - Forest definition and canopy cover rules to be applied for the detection of forest and non-forest areas with remote sensing technologies;.
  - Establishment of required resolution and the minimum clearing size that should be identifiable with remote sensing technologies;
  - The determination of the historic period to be used for the establishment of reference emission levels. Time series consistency of methods for the establishment of the reference level and during the commitment period should guide this decision and it is recommended to start the historic data in 1990 where high resolution Landsat data is available. The most recent year that enters the reference level needs to be defined. A recent year should be chosen in the period before the countries decide on their participation in a RED mechanism to avoid that the reference levels can be actively increased by deforesting larger areas.

  - It is recommended to work with absolute area changes for the establishment of reference levels as they are closer related to the emission impacts when comparing different countries.
  - Specification of a tiered approach for the accounting of reduced emissions is necessary taking into account different data availability in tropical countries.
  - Establishment of default factors for the estimation of carbon stocks in aboveground biomass is necessary for those countries without country-specific parameters. Data on default carbon stocks for forest types is available from IPCC 2006 Guidelines or IPCC Good Practice guidance for LULUCF. FAO has provided maps and data on the spatial distribution of forest types at country-level.
  - Default factors should be established that take into account that non-intact forests that are cleared have lower carbon stocks. Thus in the estimation of emission reductions from deforestation, a correct representation of degraded or non-intact forests at national level needs to be ensured. Emission reductions from reduced deforestation will be overestimated when this is not considered.

- A different approach for the establishment of reference emission levels should be implemented for countries with low historic deforestation rates because the objective to underpass historic emission levels is not applicable for such countries. It is suggested to develop criteria for the identification of tropical countries with low historic deforestation levels as a first step. If participating countries fulfil these criteria, compensation for continuous low deforestation rates could be calculated on the basis of the average reduced annual conversion area calculated for all countries participating in the RED mechanism.
- Periodic updating of reference emission levels is recommended because the reference levels may fail to take into account significant changes in recent years and maybe overly conservative or not sufficiently conservative in relation to the efforts required by Parties. The revision or updating period should correspond with the commitment period length, this means that the reference should be corrected after the first commitment period for the subsequent period. During one commitment period, the reference level should be fixed.
- It is recommended not to adjust historic reference emission levels to take into account different national circumstances, socio-economic factors or drivers of deforestation. If the commitments should be further differentiated e.g. in relation to economic potentials of Parties (e.g. related to least developed countries), it would be preferable to implement such differentiation through the targets to be achieved and not through the historic reference. The use of a historic reference does not automatically imply that all emission reductions below the historic reference level are compensated, but different targets on this basis can be established, e.g. countries need to decrease emissions at least by 10% or 20% below historic levels before the compensation scheme starts.
- At the level of participating countries, the establishment of historic reference levels and the accounting of reduced deforestation requires considerable capacity building efforts and institutional arrangements to establish an institutional system able to continuously monitor deforestation, because such data is currently not analysed on a systematic basis in many tropical countries.

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11 Annexes

11.1 Annex 1: Additional information in relation to section 6.2 "Quantitative relationships between drivers and tropical deforestation"

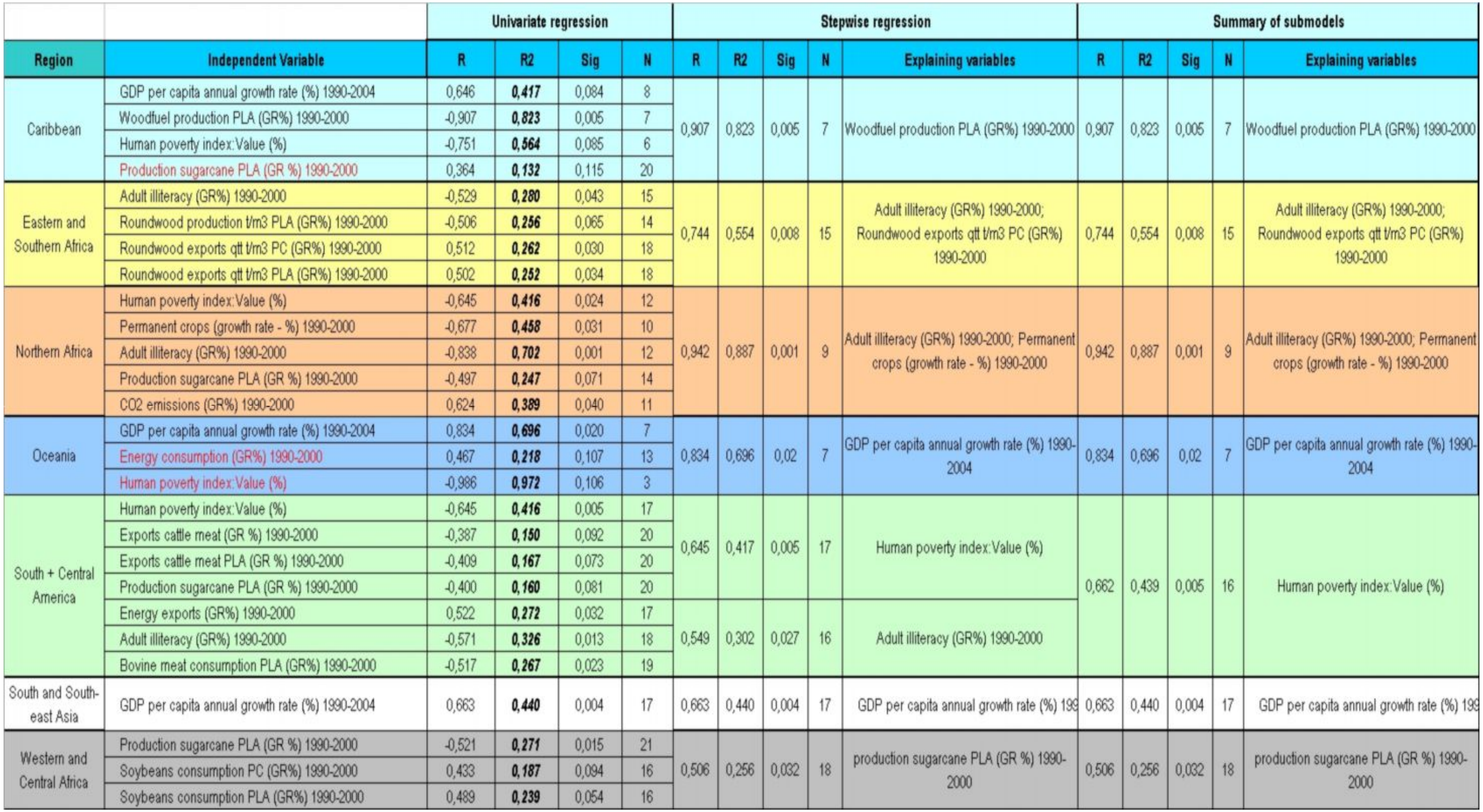
Table 51 *Missing or insufficiently represented variable data*

Type	Indicator	Unit	Source	Current time series availability
Forestry	Fire occurrence	area burned (1000 ha)	FRA	2000
	Forest functions	% of forest area	FRA	2005
	Woodfuel removal	(1000 m3)	FRA	2005
	Industrial roundwood removal	(1000 m3)	FRA	2005
	Industrial roundwood Price	(in $1000)	FRA	2005
	NWFP Price	(in $1000)	FRA	2005
	Illegal logging	?	?	?
	Forests under concession	(1000 m3)	?	?
	Woodfuel Price	(in $1000)	FRA	2005
Socio-Economics (Employment)	Unemployment rate	% of labour force	UNDP, IMF	2005
	Employment in forestry	% of labour market	FRA	1990, 2000
	Employment in agriculture	% of labour market	UNDP	2003
	Employment in industry	% of labour market	UNDP	2003
	Employment in services	% of labour market	UNDP	2003
Socio-Economics (HDI+health)	Life expectancy	years	WB	2001-2005
	People undernourished	% of total population	UNDP	2001
	Public health expenditure	% of GDP	UNDP	2003
	Private health expenditure	% of GDP	UNDP	2003
Socio-Economics (Infraestructure)	Roads paved	% of total roads	WB	2001-2004
	Access to improved water source	% of population	WB	1990, 2004
	Access to improved sanitation	% of population	WB	1990, 2004
Socio-Economics	Public ownership	% of forest area	FRA	2000
	Private ownership	% of forest area	FRA	2000

Type	Indicator	Unit	Source	Current time series availability
(Ownership)	Other ownership	% of forest area	FRA	2000
Economy	Inequality	Share of income (%)	UNDP	2000
	Share of income or expenditure (%)	% (current US$)	WB	2004-2005
Agriculture	Agricultural area	(000 ha)	WB	1990, 2000-2005
	Permanent crops area	(000 ha)	FAO	1990, 2000-2005
	Permanent pasture area	(000 ha)	FAO	1990, 2000-2005
	Exports of cattle meat	(tonnes)	FAO	1990, 2000-2005
	Exports of palm oil	(tonnes)	FAO	1990, 2000-2005
	Exports of soybeans	(tonnes)	FAO	1990, 2000-2005
	Exports of sugar cane	(tonnes)	FAO	1990, 2000-2005
	Imports of cattle meat	(tonnes)	FAO	1990, 2000-2005
	Imports of palm oil	(tonnes)	FAO	1990, 2000-2005
	Imports of soybeans	(tonnes)	FAO	1990, 2000-2005
	Imports of sugar cane	(tonnes)	FAO	1990, 2000-2005
	Producer price of cattle meat	(US$ / tonne)	FAO	1990, 2000-2005
	Producer price of palm oil	(US$ / tonne)	FAO	1990, 2000-2005
	Producer price of soybeans	(US$ / tonne)	FAO	1990, 2000-2005
	Producer price of sugar cane	(US$ / tonne)	FAO	1990, 2000-2005

Type	Indicator	Unit	Source	Current time series availability
	Production of cattle meat	(tonnes)	FAO	1990, 2000-2005
	Production of palm oil	(tonnes)	FAO	1990, 2000-2005
	Production of soybeans	(tonnes)	FAO	1990, 2000-2005
	Production of sugar cane	(tonnes)	FAO	1990, 2000-2005

Table 52 *Univariate and multivariate regression results for 1990-2000 (regions)*



		Univariate regression				**Stepwise regression**					**Summary of submodels**				
Region	**Independent Variable**	**R**	**R2**	**Sig**	**N**	**R**	**R2**	**Sig**	**N**	**Explaining variables**	**R**	**R2**	**Sig**	**N**	**Explaining variables**
Caribbean	GDP per capita annual growth rate (%) 1990-2004	0,646	***0,417***	0,084	8	0,907	0,823	0,005	7	Woodfuel production PLA (GR%) 1990-2000	0,907	0,823	0,005	7	Woodfuel production PLA (GR%) 1990-2000
	Woodfuel production PLA (GR%) 1990-2000	-0,907	***0,823***	0,005	7										
	Human poverty index:Value (%)	-0,751	***0,564***	0,085	6										
	Production sugarcane PLA (GR %) 1990-2000	0,364	***0,132***	0,115	20										
Eastern and Southern Africa	Adult illiteracy (GR%) 1990-2000	-0,529	***0,280***	0,043	15	0,744	0,554	0,008	15	Adult illiteracy (GR%) 1990-2000; Roundwood exports qtt t/m3 PC (GR%) 1990-2000	0,744	0,554	0,008	15	Adult illiteracy (GR%) 1990-2000; Roundwood exports qtt t/m3 PC (GR%) 1990-2000
	Roundwood production t/m3 PLA (GR%) 1990-2000	-0,506	***0,256***	0,065	14										
	Roundwood exports qtt t/m3 PC (GR%) 1990-2000	0,512	***0,262***	0,030	18										
	Roundwood exports qtt t/m3 PLA (GR%) 1990-2000	0,502	***0,252***	0,034	18										
Northern Africa	Human poverty index:Value (%)	-0,645	***0,416***	0,024	12	0,942	0,887	0,001	9	Adult illiteracy (GR%) 1990-2000; Permanent crops (growth rate - %) 1990-2000	0,942	0,887	0,001	9	Adult illiteracy (GR%) 1990-2000; Permanent crops (growth rate - %) 1990-2000
	Permanent crops (growth rate - %) 1990-2000	-0,677	***0,458***	0,031	10										
	Adult illiteracy (GR%) 1990-2000	-0,838	***0,702***	0,001	12										
	Production sugarcane PLA (GR %) 1990-2000	-0,497	***0,247***	0,071	14										
	CO2 emissions (GR%) 1990-2000	0,624	***0,389***	0,040	11										
Oceania	GDP per capita annual growth rate (%) 1990-2004	0,834	***0,696***	0,020	7	0,834	0,696	0,02	7	GDP per capita annual growth rate (%) 1990-2004	0,834	0,696	0,02	7	GDP per capita annual growth rate (%) 1990-2004
	Energy consumption (GR%) 1990-2000	0,467	***0,218***	0,107	13										
	Human poverty index:Value (%)	-0,986	***0,972***	0,106	3										
South + Central America	Human poverty index:Value (%)	-0,645	***0,416***	0,005	17	0,645	0,417	0,005	17	Human poverty index:Value (%)	0,662	0,439	0,005	16	Human poverty index:Value (%)
	Exports cattle meat (GR %) 1990-2000	-0,387	***0,150***	0,092	20										
	Exports cattle meat PLA (GR %) 1990-2000	-0,409	***0,167***	0,073	20										
	Production sugarcane PLA (GR %) 1990-2000	-0,400	***0,160***	0,081	20										
	Energy exports (GR%) 1990-2000	0,522	***0,272***	0,032	17	0,549	0,302	0,027	16	Adult illiteracy (GR%) 1990-2000					
	Adult illiteracy (GR%) 1990-2000	-0,571	***0,326***	0,013	18										
	Bovine meat consumption PLA (GR%) 1990-2000	-0,517	***0,267***	0,023	19										
South and South-east Asia	GDP per capita annual growth rate (%) 1990-2004	0,663	***0,440***	0,004	17	0,663	0,440	0,004	17	GDP per capita annual growth rate (%) 199	0,663	0,440	0,004	17	GDP per capita annual growth rate (%) 199
Western and Central Africa	Production sugarcane PLA (GR %) 1990-2000	-0,521	***0,271***	0,015	21	0,506	0,256	0,032	18	production sugarcane PLA (GR %) 1990-2000	0,506	0,256	0,032	18	production sugarcane PLA (GR %) 1990-2000
	Soybeans consumption PC (GR%) 1990-2000	0,433	***0,187***	0,094	16										
	Soybeans consumption PLA (GR%) 1990-2000	0,489	***0,239***	0,054	16										

Table 53 Univariate and multivariate regression results for 2000-2005 (regions)

		Correlation 1990-2000	Univariate regression				Stepwise regression					Summary of submodels				
Region	**Independent Variable**		**R**	**R2**	**Sig**	**N**	**R**	**R2**	**Sig**	**N**	**Explaining variables**	**R**	**R2**	**Sig**	**N**	**Explaining variables**
Caribbean	Human poverty index: Value	x	-0,805	**0,648**	0,053	6	0,869	0,755	0,025	6	Probability at birth of not surviving to age 40 (% of cohort) 2000-05	0,869	0,755	0,025	6	Probability at birth of not surviving to age 40 (% of cohort) 2000-05
	Probability at birth of not surviving to age 40 2000-05	o	-0,869	**0,755**	0,011	7										
	Total fertility rate 2000-2005	o	-0,744	**0,554**	0,055	7										
Eastern and Southern Africa	Plantation Annual change rate 2000-2005		0,618	**0,382**	0,011	16	0,666	0,444	0,013	13	Plantation Annual change rate 2000-2005	0,618	0,382	0,011	16	Plantation Annual change rate 2000-2005
	Agriculture value added 2001-2005		-0,426	**0,181**	0,100	16										
	Probability at birth of not surviving to age 40 2000-05	o	0,532	**0,283**	0,041	15										
	Population Growth 2000-2005		-0,543	**0,295**	0,020	18	0,542	0,294	0,025	17	Population Growth 2000-2005 (in % / yr)					
	Imports cattle meat 2000-2005		0,451	**0,204**	0,060	18										
	Official Development Assistance 2001-2005		0,437	**0,191**	0,080	17										
Northern Africa	Human poverty index:Value	x	-0,781	**0,610**	0,008	10	0,801	0,641	0,01	9	Total fertility rate (births per woman) 2000-2005	0,801	0,641	0,01	9	Total fertility rate (births per woman) 2000-2005
	Probability at birth of not surviving to age 40 2000-05	o	-0,804	**0,646**	0,005	10										
	Total fertility rate 2000-2005	o	-0,801	**0,642**	0,010	9										
	Population Growth 2000-2005		-0,648	**0,420**	0,023	12										
Oceania	x	x	x	**x**	x	x	x	x	x	x	x	x	x	x	x	x
South + Central America	Human poverty index:Value	x	-0,667	**0,445**	0,003	17	0,666	0,444	0,005	16	Human poverty index:Value (%)	0,777	0,603	0,002	17	Human poverty index:Value (%) , production palm oil PLA (GR %) 2000-2005
	Probability at birth of not surviving to age 40 2000-05	o	-0,393	**0,154**	0,096	19										
	Total fertility rate 2000-2005	o	-0,541	**0,293**	0,020	18										
	Population Growth 2000-2005		-0,383	**0,146**	0,096	20										
	Imports cattle meat PLA 2000-2005		-0,526	**0,277**	0,017	20	0,564	0,318	0,01	20	production palm oil PLA (GR %) 2000-2005					
	Imports palm oil PLA 2000-2005		0,433	**0,188**	0,057	20										
	production sugarcane PLA 2000-2005	x	-0,382	**0,146**	0,097	20										
	production palm oil PLA 2000-2005		-0,564	**0,318**	0,010	20										
	energy consumption 2000-2003		-0,521	**0,271**	0,018	20	0,796	0,633	0,001	14	Imports cattle meat (GR %) 2000-2005					
	CO2 emissions 2000-2003		-0,472	**0,223**	0,036	20										
	Roundwood imports qtt t/m3 PC 2000-2004		-0,481	**0,231**	0,082	14										
	Imports cattle meat 2000-2005		-0,450	**0,203**	0,047	20										
South and South-east Asia	Imports cattle meat 2000-2005		0,436	**0,190**	0,043	22	0,58	0,336	0,019	16	electric power consumption PLA (GR %) 2001-2004	0,67	0,45	0,004	16	energy consumption (GR%) 2000-2003
	electric power consumption PLA 2001-2004		0,419	**0,175**	0,094	17										
	energy consumption 2000-2003		0,505	**0,255**	0,017	22	0,51	0,26	0,017	22	energy consumption (GR%) 2000-2003					
	Roundwood imports qtt t/m3 PLA 2000-2004		0,392	**0,154**	0,119	17										
	Plantation Annual change rate 2000-2005		0,371	**0,137**	0,118	19										
	CO2 emissions 2000-2003		0,405	**0,164**	0,061	22										
Western and Central Africa	production cattle meat PLA 2000-2005		0,571	**0,326**	0,007	21	x	x	x	x	x					
	Roundwood imports qtt t/m3 PC 2000-2004		0,634	**0,402**	0,126	7										
	Roundwood imports qtt t/m3 PLA 2000-2004		0,623	**0,388**	0,135	7										

Table 54 Univariate regression results for 1990-2000 (tropical countries)

	Independent variables	
Dependent variable: Annual change rate 1990-2000 no plantations	**Human poverty index: Value (%)**	**Adult illiteracy (GR%) 1990-2000**
Pearson Correlation	-0,241	-0,298
R2	***0,058***	***0,089***
Sig. (2-tailed)	0,041	0,009
N	72	75

Table 55 Univariate regression results for 2000-2005 (tropical countries)

	Independent variables		
Dependent variable: Annual change rate 2000-2005 (%) no plantations	**Total fertility rate (births per woman) 2000-2005**	**Population Growth 2000-2005 (in % / yr)**	**Public expend education GNI (GR %) 2000-2004**
Pearson Correlation	-0,317	-0,369	-0,384
R2	***0,100***	***0,136***	***0,147***
Sig. (2-tailed)	0,005	0,000	0,040
N	76	109	29

Figure 28 Tropical countries - Visual regression curves – Explaining variables for the multivariate regression results 1990-2000

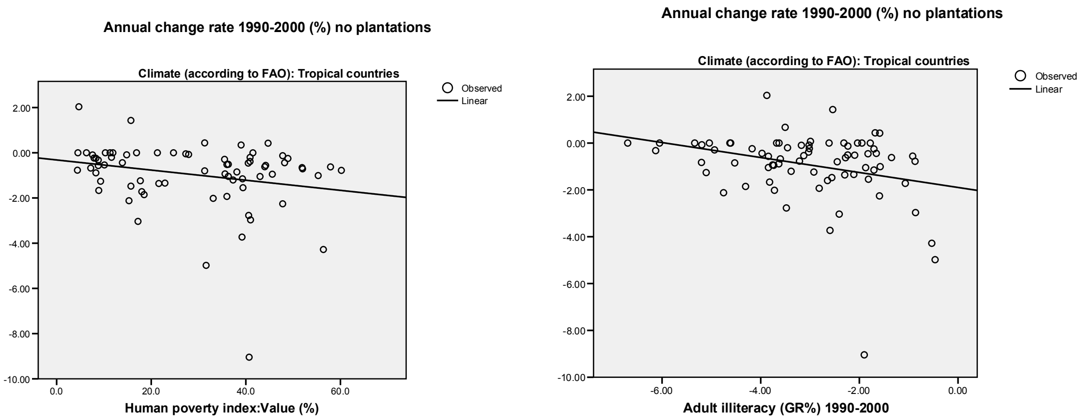


Figure 29 Tropical countries - Visual regression curves - Explaining variables for the multivariate regression results 2000-2005

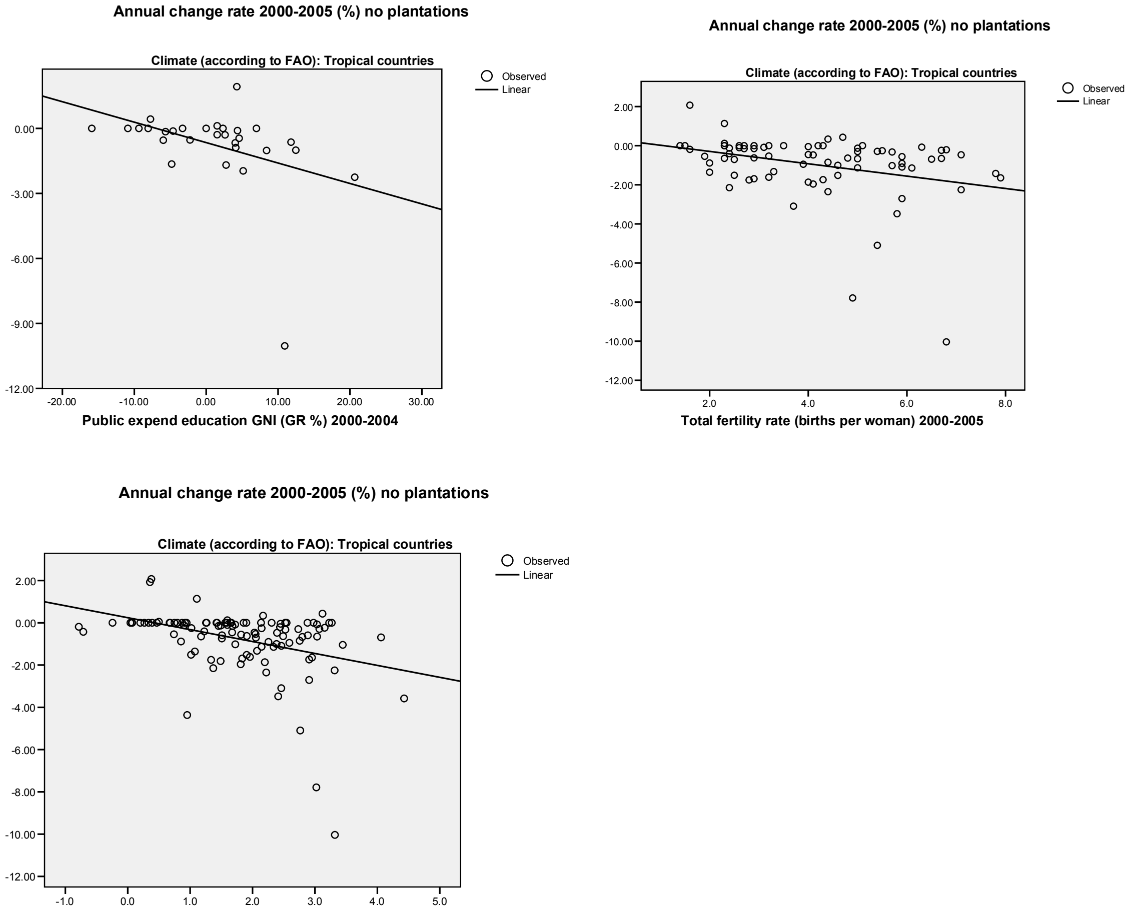
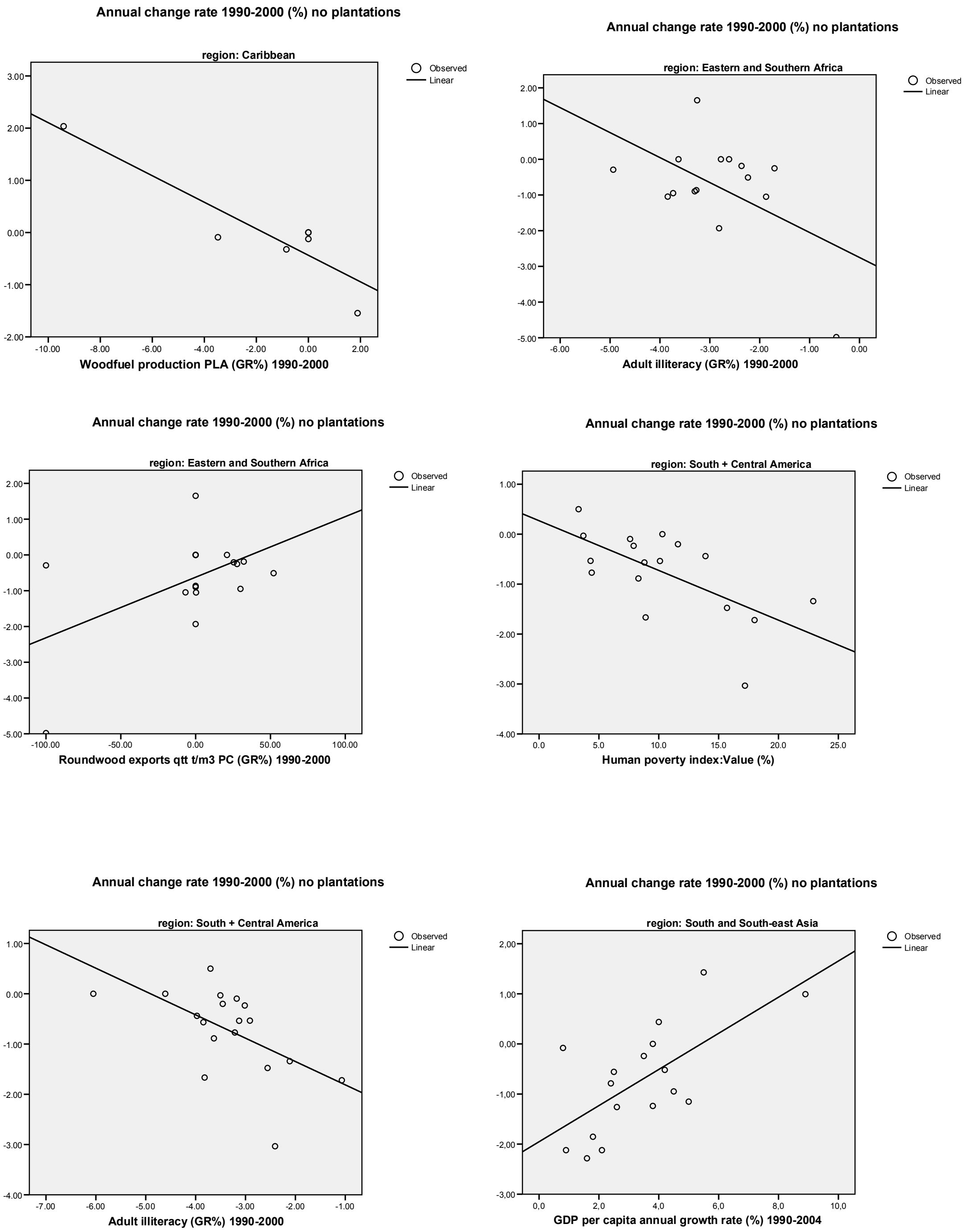


Figure 30 *Regions - Visual regression curves – Explaining variables for the multivariate regression results 1990-2000*



Western and Central Africa:

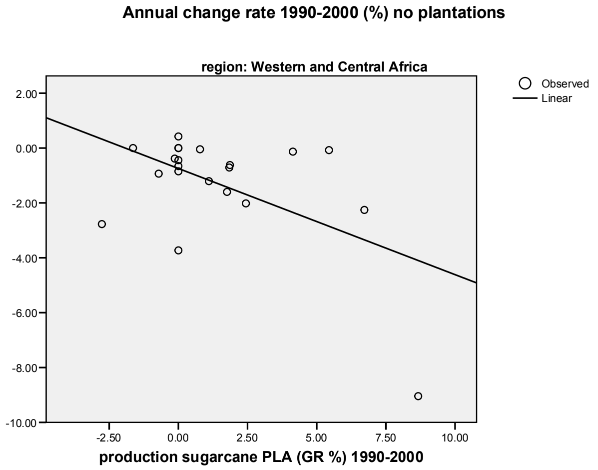
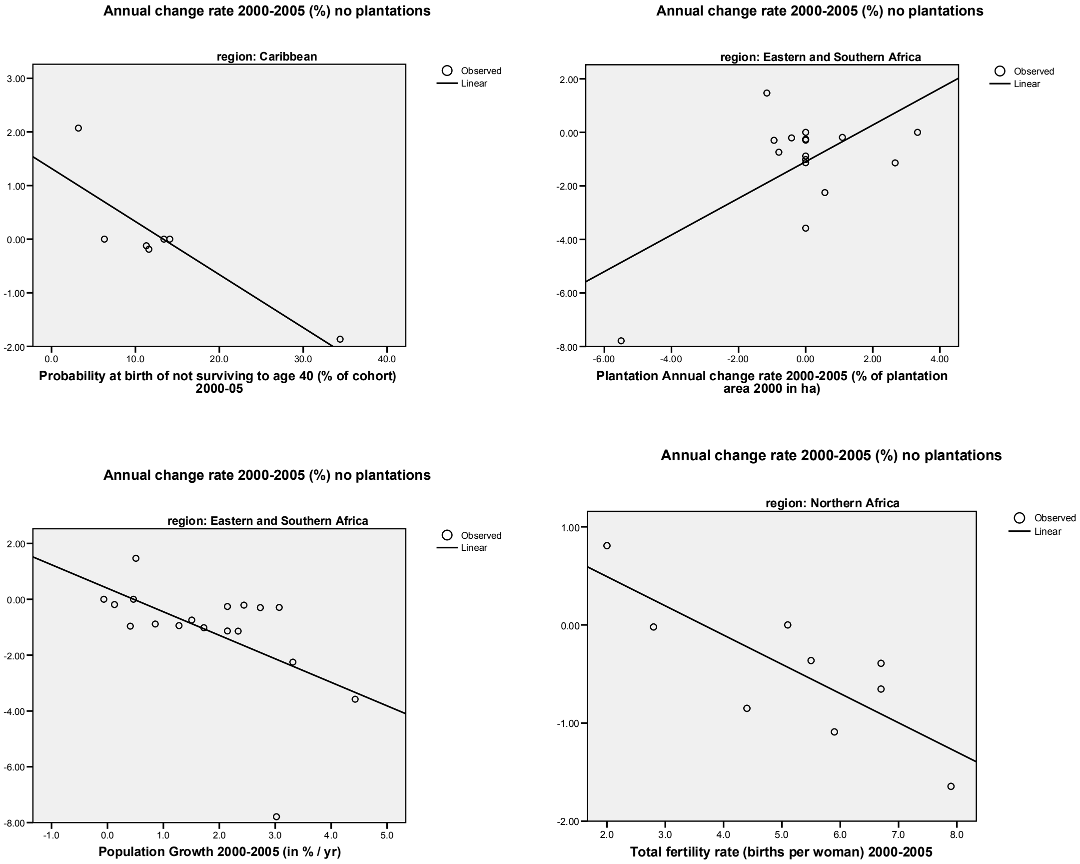
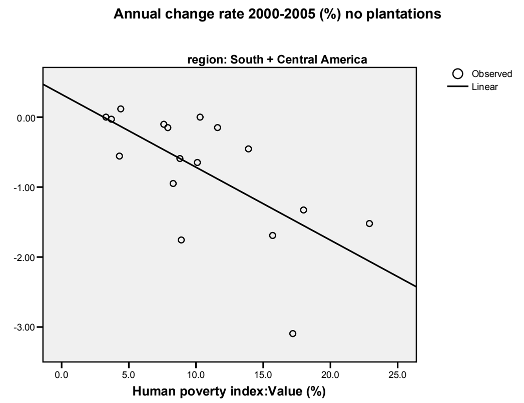
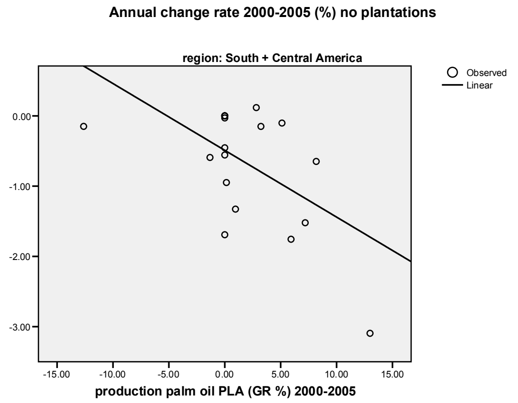
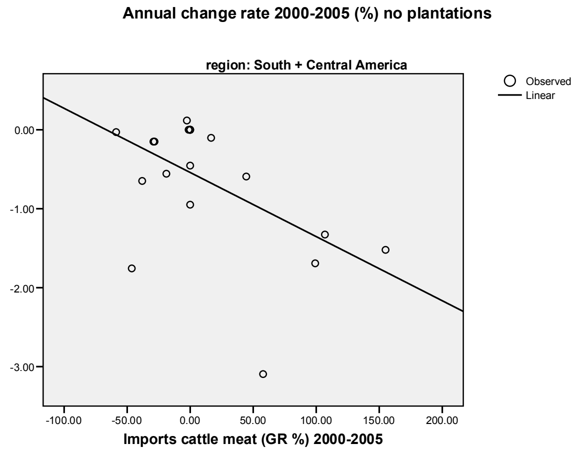


Figure 31 Regions -Visual regression curves – Explaining variables for the multivariate regression results 2000-2005




Annual change rate 2000-2005 (%) no plantations
region: South + Central America
Observed
Linear
0.00
-1.00
-2.00
-3.00
0.0
5.0
10.0
15.0
20.0
25.0
Human poverty index:Value (%)


Annual change rate 2000-2005 (%) no plantations
region: South + Central America
Observed
Linear
0.00
-1.00
-2.00
-3.00
-15.00
-10.00
-5.00
0.00
5.00
10.00
15.00
production palm oil PLA (GR %) 2000-2005


Annual change rate 2000-2005 (%) no plantations
region: South + Central America
Observed
Linear
0.00
-1.00
-2.00
-3.00
-100.00
-50.00
0.00
50.00
100.00
150.00
200.00
Imports cattle meat (GR %) 2000-2005

11.2 Annex 2 Methods for calculating GHG emissions from tropical forest fires

The 2006 IPCC Guidelines (IPCC 2006), Volume for Agriculture, Forestry and other Land Use (AFOLU), provide a comprehensive three-tier approach for estimating carbon stock changes and non-CO_2 emissions resulting from fire on forest land, including those resulting from forest conversion. Data limitations required calculating those emissions based on IPCC default values under Tier 1.

According to the 2006 IPCC Guidelines, data needed to calculate the non-CO_2 emissions from fire are the area burnt, the mass of fuel available for combustion , the fire intensity represented as combustion factor as well as an emission factor (both using an IPCC default value). 2006 IPCC Guidelines use the following equation to estimate the emissions of individual greenhouse gases for any type of fire:

Equation 1 $$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc.
A = area burnt, ha
M_B = mass of fuel available for combustion, tonnes ha^{-1}.
C_f = combustion factor, dimensionless
G_{ef} = emission factor, g kg^{-1} dry matter burnt

2006 IPCC Guidelines recommend the development of country-specific methods to determine G_{ef}, M_B and $C_{f.}$ If no specific country or ecosystem information for G_{ef}, M_B and C_f are available, the 2006 IPCC Guidelines provide default values under Tier 1, which will also be used in the calculation example in chapter 5.3.

Summary of steps for calculating greenhouse gas emissions from biomass burning:

Step 1: Using guidance from AFOLU Volume of 2006 IPCC Guidelines, Chapter 3 (approaches in representing land-use areas), categorize the area of *Forest Land Remaining Forest Land* into forest types of different climatic or ecological zones. Obtain estimates of A (area burnt) from global database or from national sources.

Step 2: Estimate the mass of fuel (M_B) available for combustion, in tonnes/ha, which includes biomass, litter and dead wood (e.g. from inventory or satellite data, if available).

Step 3: Select combustion factor C_f (default values are in 2006 IPCC Guidelines, AFOLU volume, Table 2.6, Chapter 2).

Step 4: Multiply M_B and C_f to provide an estimate of the amount of fuel combusted. If M_B or C_f is unknown, defaults for the product of M_B and C_f are given in 2006 IPCC Guidelines, AFOLU volume, Table 2.4.

Step 5: Select emission factors G_{ef} (default factors are in 2006 IPCC Guidelines, AFOLU volume,Table 2.5, Chapter 2).

Step 6: Multiply parameters A, M_B, C_f and G_{ef} to obtain the quantity of greenhouse gas emission from biomass burning. Repeat the steps for each greenhouse gas.

Source: from (IPCC 2006)

The data for the area burnt was derived from the FAO FRA (FAO 2006). The emission and carbon stock values were obtained in two scenarios i) from the FAO FRA and ii) from the IPCC, using a minimum and maximum value. The uncertainty range for IPCC default values of emission factors and fuel load was provided from table 2.4-2.5 of the IPCC GPG (Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories).

11.3 Annex 3 Methods for calculating GHG emissions from tropical peatland fires

Peatfire emission detection is mainly based on case studies related to the Indonesian forest and peatland fires from 1997-98. The calculations in chapter 5.4 are based on such case studies from Levine ((Levine 2000), cited in (Langmann and Heil 2004)) for Indonesia. To calculate peatland emissions, Levine (Levine 2000) developed a simple approach, which is shown in equations 2-4.

Total biomass consumed by burning (M in tons):

Equation 2 $\mathbf{M = A_B * B * E}$

M = total mass of vegetation or peat consumed by burning (in tons)
A_B = area burnt (in km^2)
B = biomass load in tons/km^2
E = burning efficiency, dimensionless

CO_2 emissions released from burning:

Equation 3 $\mathbf{CO_2\_E = M * C * CE}$

CO_2_E = Gaseous emissions of CO_2 (in tons of carbon)
C = emission factor, g kg^{-1} dry matter burnt
CE = combustion efficiency, dimensionless

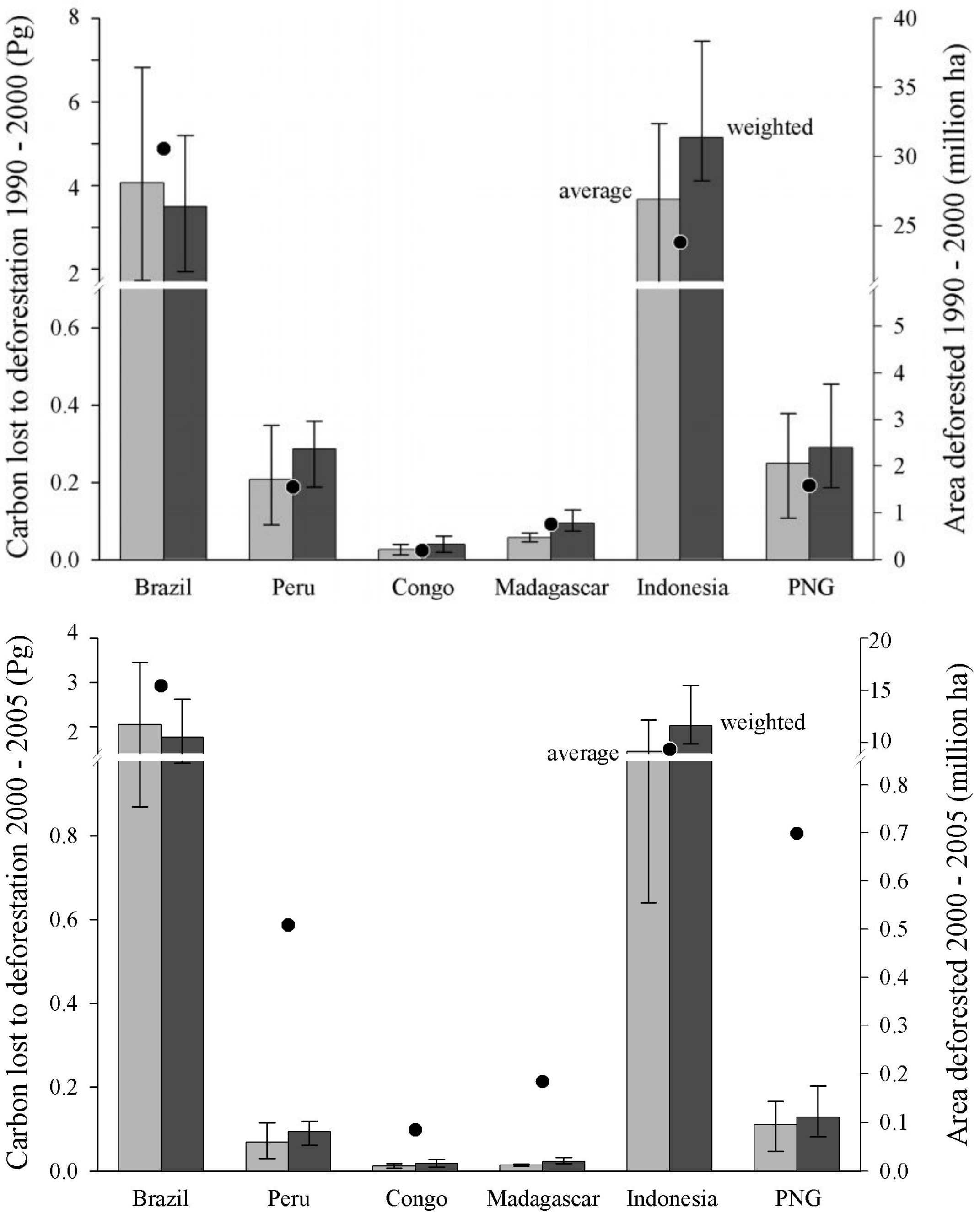
Non-CO_2 emissions released from burning:

Equation 4 $$X\_E = CO_2\_E * ER$$

X_E = Emissions of non-CO_2 gases, notably CO or CH_4 (in tons of carbon)
ER = CO_2-normalised species emission ratio.

11.4 Annex 4 Figures and tables of carbon losses distinguished for the periods between 1990 – 2000 and 2000 - 2005

Figure 32 *Carbon losses through deforestation in the pilot countries during 1990 – 2000 and 2000 – 2005 based on the deforested area and considering default values from 2006 IPCC Guidelines as regional arithmetic mean or weighted mean per country including biomass C stock data from analyses of this study.*



Note: *Black dots indicate the forest area lost during that period.*

Source: calculations, MPI-BGC, J. Dietz

Table 56 *Carbon lost from above-ground biomass (AGB) and all pools (Total) between 1990 - 2000 and 2000 - 2005 through deforestation estimated using different carbon stock values*

		Carbon lost to deforestation 1990 - 2000 (Tg)							Carbon lost to deforestation 2000 - 2005 (Tg)						
		FAO (2006) average of all forest	Arithmetic mean of IPCC default values for all relevant tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types			FAO (2006) average of all forest	Arithmetic mean of IPCC default values for all relevant tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types		
			mean	min	max	mean	min	max		mean	min	max	mean	min	max
Brazil	AGB	3194	2865	899	5197	2463	1109	3930	1612	1446	453	2622	1243	560	1983
	Total*	*n.d.*	4058	1720	6826	3496	1928	5189	*n.d.*	2049	870	3445	1766	975	2620
Peru	AGB	190	145	46	264	219	134	282	62	48	15	86	72	44	92
	Total*	*n.d.*	208	90	348	287	188	359	*n.d.*	68	29	114	94	62	118
Congo	AGB	20	18	7	29	29	12	48	9	8	3	13	13	6	22
	Total*	*n.d.*	26	13	39	39	19	60	*n.d.*	12	6	18	18	9	27
Madagascar	AGB	73	36	27	46	70	52	101	18	9	6	11	17	13	25
	Total*	*n.d.*	57	45	68	93	73	129	*n.d.*	14	11	17	23	18	31
Indonesia	AGB	1619	2531	817	4060	3964	3059	5999	637	995	321	1596	1559	1203	2359
	Total*	*n.d.*	3666	1628	5481	5151	4110	7459	*n.d.*	1441	640	2155	2025	1616	2933
Papua New Guinea	AGB	46	169	54	271	210	126	346	20	74	24	119	93	55	153
	Total*	*n.d.*	249	107	378	290	187	455	*n.d.*	109	47	166	128	82	201

Source: calculations, MPI-BGC, J. Dietz

Table 57 *Carbon lost in the tropics on the regional scale from above-ground biomass (AGB) between 1990 - 2000 through deforestation estimated using two different carbon stock values*

	Carbon lost from above-ground biomass due to deforestation 1990 - 2000 (Tg)						
	FAO (2006) average of all forest	Arithmetic mean of IPCC default values over all tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types		
		mean	min	max	mean	min	max
Caribbean	-45	-68	-23	-88	-93	-53	-124
South & Central America	8373	7869	2493	13565	9242	6267	13962
Northern Africa	242	894	711	1077	1255	1255	1255
Western & Central Africa	2700	2966	1117	4807	3765	2027	5954
Eastern & Southern Africa	1452	2176	1218	3132	2597	1846	3927
South & Southeast Asia	4358	5396	2257	8355	6237	3695	8225
Oceania	840	918	296	1472	1361	1057	2012
Tropical countries Total	17988	20196	8075	32412	24369	16098	35183

Source: calculations, MPI-BGC, J. Dietz

Table 58 *Carbon lost in the tropics on the regional scale from above-ground biomass (AGB) between 2000 - 2005 through deforestation estimated using two different carbon stock values*

	Carbon lost from above-ground biomass due to deforestation 2000 - 2005 (Tg)						
	FAO (2006) average of all forest	Arithmetic mean of IPCC default values over all tropical and subtropical forest types per continent			Weighted mean of IPCC default values for all relevant forest types		
		mean	min	max	mean	min	max
Caribbean	-34	-51	-17	-66	-70	-40	-94
South & Central America	4541	4268	1352	7357	5012	3399	7572
Northern Africa	117	433	345	522	608	608	608
Western & Central Africa	1122	1233	464	1999	1565	843	2475
Eastern & Southern Africa	714	1070	599	1541	1277	908	1932
South & Southeast Asia	2410	2984	1248	4620	3449	2043	4548
Oceania	334	365	118	585	541	420	799
Tropical countries Total	9136	10257	4102	16462	12377	8176	17869

Source: calculations, MPI-BGC, J. Dietz

Table 59 *Greenhouse gases released in the period 1990 - 2000 under the assumption that all forest lost during that time would have been lost due to burning activities (high GHG scenario)*

		Greenhouse gases released from all forest lost in the period 1990 - 2000, if burnt								
		Carbon Dioxide (CO_2)			Methane (CH_4)			Nitrous Oxide (N_2O)		
		mean[a]	min[b]	max[c]	mean[a]	min[b]	max[c]	mean[a]	min[b]	max[c]
Brazil	AGB[d]	8123	3589	13126	12.4	3.9	24.0	5.4	1.7	10.4
	Total[e]	14405	6382	28270	15.2	4.8	33.5	6.4	2.0	14.1
Peru	AGB[d]	724	433	940	1.1	0.5	1.7	0.5	0.2	0.7
	Total[e]	1140	650	2034	1.3	0.6	2.4	0.6	0.2	1.0
Congo	AGB[d]	96	39	160	0.1	0.0	0.3	0.1	0.0	0.1
	Total[e]	155	65	319	0.2	0.1	0.4	0.1	0.0	0.2
Madagascar	AGB[d]	229	169	337	0.4	0.2	0.6	0.2	0.1	0.3
	Total[e]	377	254	712	0.4	0.2	0.8	0.2	0.1	0.4
Indonesia	AGB[d]	13073	9902	20041	20.0	10.6	36.7	8.7	4.6	15.9
	Total[e]	20472	14371	40220	23.9	12.7	49.9	10.1	5.4	21.1
Papua New Guinea	AGB[d]	692	408	1155	1.1	0.4	2.1	0.5	0.2	0.9
	Total[e]	1170	639	2414	1.3	0.5	3.1	0.6	0.2	1.3

Source: calculations, MPI-BGC, J. Dietz

Notes: *Only natural forest cover considered, excluding plantations.*

[a] calculated with 51 % of all carbon lost through fire (Kauffman et al. 1995).

[b] calculated with 42 % of all carbon lost through fire (Fearnside et al. 1999, 2007).

[c] calculated with 29 % of all carbon lost through fire (Fearnside et al. 2001).

[d] Lost completely through flaming combustion using the high trace gas scenario of Fearnside (2000).

[e] Combines the loss of 100 % above-ground biomass through flaming combustion, 80 % below-ground biomass through decay, 100 % litter through smoldering combustion, 100 % dead wood through smoldering combustion, 40 % soil organic carbon through decay (Fearnside 2000).

Source: calculations, MPI-BGC, J. Dietz

Table 60 *Greenhouse gases released in the period 2000 - 2005 under the assumption that all forest lost during that time would have been lost due to burning activities (high GHG scenario)*

		Greenhouse gases released from all forest lost in the period 2000 - 2005, if burnt								
		Carbon Dioxide (CO_2)			Methane (CH_4)			Nitrous Oxide (N_2O)		
		mean[a]	min[b]	max[c]	mean[a]	min[b]	max[c]	mean[a]	min[b]	max[c]
Brazil	AGB[d]	4099	1811	6623	6.3	1.9	12.1	2.7	0.8	5.3
	Total[e]	7281	3225	14280	7.7	2.4	16.9	3.2	1.0	7.1
Peru	AGB[d]	237	142	308	0.4	0.2	0.6	0.2	0.1	0.2
	Total[e]	373	213	666	0.4	0.2	0.8	0.2	0.1	0.3
Congo	AGB[d]	43	18	72	0.1	0.0	0.1	0.0	0.0	0.1
	Total[e]	70	29	144	0.1	0.0	0.2	0.0	0.0	0.1
Madagascar	AGB[d]	56	41	82	0.1	0.0	0.2	0.0	0.0	0.1
	Total[e]	92	62	173	0.1	0.1	0.2	0.0	0.0	0.1
Indonesia	AGB[d]	5140	3893	7880	7.9	4.2	14.4	3.4	1.8	6.3
	Total[e]	8050	5650	15814	9.4	5.0	19.6	4.0	2.1	8.3
Papua New Guinea	AGB[d]	306	179	512	0.5	0.2	0.9	0.2	0.1	0.4
	Total[e]	516	281	1068	0.6	0.2	1.4	0.2	0.1	0.6

Notes: *Only natural forest cover considered, excluding plantations.*

[a] calculated with 51 % of all carbon lost through fire (Kauffman et al. 1995).

[b] calculated with 42 % of all carbon lost through fire (Fearnside et al. 1999, 2007).

[c] calculated with 29 % of all carbon lost through fire (Fearnside et al. 2001).

[d] Lost completely through flaming combustion using the high trace gas scenario of Fearnside (2000).

[e] Combines the loss of 100 % above-ground biomass through flaming combustion, 80 % below-ground biomass through decay, 100 % litter through smoldering combustion, 100 % dead wood through smoldering combustion, 40 % soil organic carbon through decay (Fearnside 2000).

Source: calculations, MPI-BGC, J. Dietz

Table 61 *Greenhouse gases released in the period 1990 - 2000 under the assumption of no burning activities turning the entire biomass stock into CO_2 with the only non-CO_2 greenhouse gas produced would be methane from the decay of litter and dead wood (low GHG scenario)*

		Greenhouse gases released from all forest lost in the period 1990 - 2000, without fire								
		Carbon Dioxide (CO_2) (Tg)			Methane (CH_4) (Gg)			Nitrous Oxide (N_2O)		
		mean	min	max	mean	min	max	mean	min	max
Brazil	AGB	9031	4066	14408	0.0	0.0	0.0	0	0	0
	Total	12817	7070	19028	3.4	1.7	4.8	0	0	0
Peru	AGB	804	490	1032	0.0	0.0	0.0	0	0	0
	Total	1052	689	1316	0.2	0.1	0.2	0	0	0
Congo	AGB	107	45	176	0.0	0.0	0.0	0	0	0
	Total	142	71	221	0.0	0.0	0.0	0	0	0
Madagascar	AGB	255	192	370	0.0	0.0	0.0	0	0	0
	Total	342	269	474	0.1	0.0	0.1	0	0	0
Indonesia	AGB	14534	11217	21998	0.0	0.0	0.0	0	0	0
	Total	18887	15071	27348	2.6	1.3	3.7	0	0	0
Papua New Guinea	AGB	770	462	1268	0.0	0.0	0.0	0	0	0
	Total	1063	685	1667	0.2	0.1	0.2	0	0	0

Source: calculations, MPI-BGC, J. Dietz

Table 62 *Greenhouse gases released in the period 2000 - 2005 under the assumption of no burning activities turning the entire biomass stock into CO_2 (low GHG scenario)*

		Greenhouse gases released from all forest lost in the period 2000 - 2005, without fire								
		Carbon Dioxide (CO_2) (Tg)			Methane (CH_4) (Gg)			Nitrous Oxide (N_2O)		
		mean	min	max	mean	min	max	mean	min	max
Brazil	AGB	4557	2052	7270	0.0	0.0	0.0	0	0	0
	Total	6474	3575	9607	1.7	0.9	2.4	0	0	0
Peru	AGB	263	161	338	0.0	0.0	0.0	0	0	0
	Total	345	226	431	0.1	0.0	0.1	0	0	0
Congo	AGB	48	20	79	0.0	0.0	0.0	0	0	0
	Total	64	32	100	0.0	0.0	0.0	0	0	0
Madagascar	AGB	62	47	90	0.0	0.0	0.0	0	0	0
	Total	83	65	115	0.0	0.0	0.0	0	0	0
Indonesia	AGB	5715	4411	8650	0.0	0.0	0.0	0	0	0
	Total	7426	5926	10753	1.0	0.5	1.5	0	0	0
Papua New Guinea	AGB	340	203	563	0.0	0.0	0.0	0	0	0
	Total	469	301	738	0.1	0.0	0.1	0	0	0

Source: calculations, MPI-BGC, J. Dietz

Table 63 *Comparison of greenhouse gases as CO_2 equivalents released in the period 1990 – 2000 (left) and 2000 – 2005 (right) under the high and low greenhouse gas scenarios*

		1990 - 2000 (Tg CO_2 equivalents)						2000 - 2005 (Tg CO_2 equivalents)					
		High GHG scenario			Low GHG scenario			High GHG scenario			Low GHG scenario		
		mean[a]	min[b]	max[c]	mean	min	max	mean[a]	min[b]	max[c]	mean	min	max
Brazil	AGB[d]	10051	4189	16862	9031	4066	14408	5072	2114	8508	4557	2052	7270
	Total[e]	16713	7099	33353	12817	7070	19028	8446	3587	16844	6474	3575	9607
Peru	AGB[d]	895	505	1208	804	490	1032	293	165	396	263	161	338
	Total[e]	1343	735	2395	1052	689	1316	440	241	784	345	226	431
Congo	AGB[d]	119	46	205	107	45	176	54	21	93	48	20	79
	Total[e]	182	73	381	142	71	221	82	33	172	64	32	100
Madagascar	AGB[d]	284	197	433	255	192	370	69	48	105	62	47	90
	Total[e]	441	287	841	342	269	474	107	70	205	83	65	115
Indonesia	AGB[d]	16176	11556	25744	14534	11217	21998	6360	4544	10122	5715	4411	8650
	Total[e]	24107	16299	47813	18887	15071	27348	9479	6409	18800	7426	5926	10753
Papua New Guinea	AGB[d]	856	476	1484	770	462	1268	378	209	658	340	203	563
	Total[e]	1371	719	2878	1063	685	1667	604	316	1273	469	301	738

Source: calculations, MPI-BGC, J. Dietz