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Abbreviations

AiC	Action in Context
ASMGHG	Agricultural Sector and Mitigation of Greenhouse Gas
AZE	Alliance for Zero Extinction
BAU	Business As Usual
CER	Certified Emission Reductions
COP	Conference of the Parties
EC	European Commission
EPA	United States Environmental Protection Agency
EPIC	Environmental Policy Integrated Climate
EU	European Union
EU ETS	European Union Emissions Trading Scheme
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Statistical Database of the Food and Agriculture Organization of the United Nations
FLEG	Forest Law Enforcement and Governance
FRA	Global Forests Resource Assessment
GATT	General Agreement on Tariffs and Trade
GDP	Gross domestic product
GGI	Greenhouse Gas Initiative
GHG	Greenhouse Gas
GLOBIOM	Global Biomass Optimization Model
G4M	Global Forest Model
HRU	Homogeneous Response Unit
IAD	Institutional Analysis and Development Framework
IFA	International Fertilizer Industry Association
IFRPI	International Food Policy Research Institute
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
IPTS	Institute for Prospective Technology Studies
JRC	Joint Research Centre
IUCN	International Union for Conservation of Nature
MCPFE	Ministerial Conference on the Protection of Forests in Europe
Mha	Million hectares
MTOE	Million Tonnes Oil Equivalent
NASA	National Space Agency
NGO	Non-governmental organization
NPP	National Protection Plan
PBL	Dutch Planbureau voor de Leefomgeving
POLES	Prospective Outlook on Long-term Energy Systems
PPP	Purchasing power parity

RED	Reducing emissions from deforestation
REDD	Reducing emissions from deforestation and degradation
REDD+	Reducing emissions from deforestation and degradation including conservation, sustainable forest management and sink enhancement
REDD++	Reducing emissions from deforestation and degradation including conservation, sustainable forest management and sink enhancement and afforestation
	SPWP Secondary Processed Wood Product
ITTO	International Tropical Timber Organization
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
WCMC	World Conservation Monitoring Centre
WTO	World Trade Organization
YSSP	Young Scientists Summer Program

6 Annex A: Methodology

In this Annex we shortly introduce the most important methodological tools applied in the driver analysis, the scenario building and the model runs. The geographical scope and timeframe are also described. The objective here is to give an indication rather than an exhaustive scientific justification.

6.1 Driver analysis

In understanding interrelated causes of deforestation and forest degradation, we distinguish between underlying causes and proximate causes. Proximate causes are considered as direct causes, and represent so to speak the visible motivations for forest decline (upper part of Figure 6.1). Underlying causes (drivers) of forest decline are factors of higher causal order that determine the degree of the actual direct pressures on forests (lower part of Figure 6.1), (see Wunder, 2003; Chomitz and Gray, 1996; Geist and Lambin, 2002; Rudel et al., 2005; on these different proximate and underlying drivers and pressures).

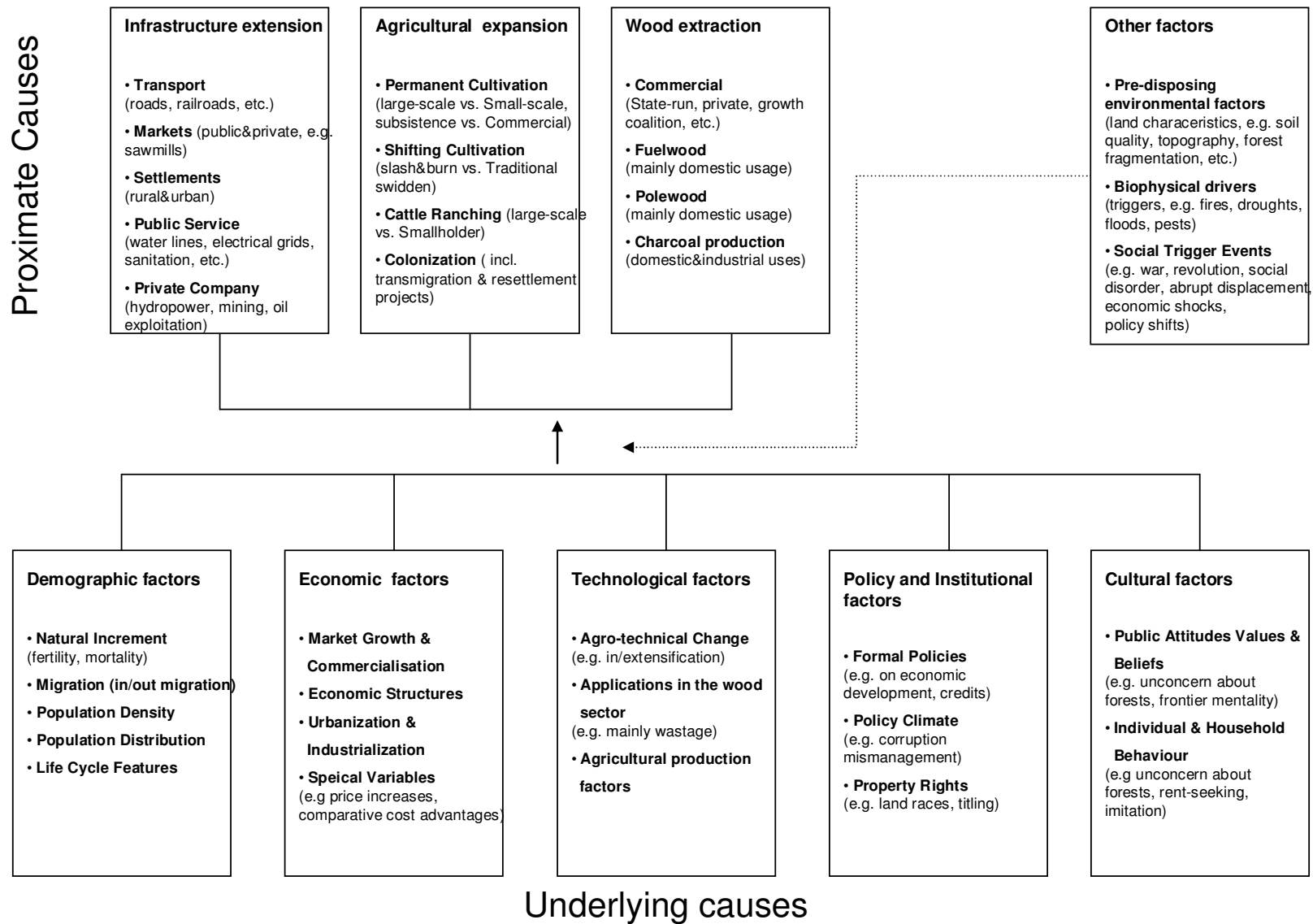
This step in the analysis will identify and select geo-regional drivers and pressures assessments.

Box 6.1 Definition: forest decline versus deforestation

Forest decline, forest degradation and deforestation

We define “forest decline” as the two processes of deforestation and forest degradation, which have both common and specific drivers, and which may or may not be spatially and temporally interrelated and will differ between regions. Deforestation is closely related to the conversion of forestlands to alternative uses with negligible or zero presence of trees. Degradation represents all other forest-decline processes impacting significantly on the integrity of forest functions.

Figure 6.1 Conceptual analysis framework for forest-loss drivers and pressures (Geist and Lambin, 2002).



6.2 Insight into modelling process

This section provides some insights into the framework underlying the modelling process.

This section is based on the draft document “GLOBIOM: Global Biomass Optimization Model” by Petr Havlík^{a*}, Uwe A. Schneider, Erwin Schmid, Rastislav Skalský, and Michael Obersteiner. For variables, functions and parameters, see Annex A.

6.2.1 Simplified GLOBIOM framework

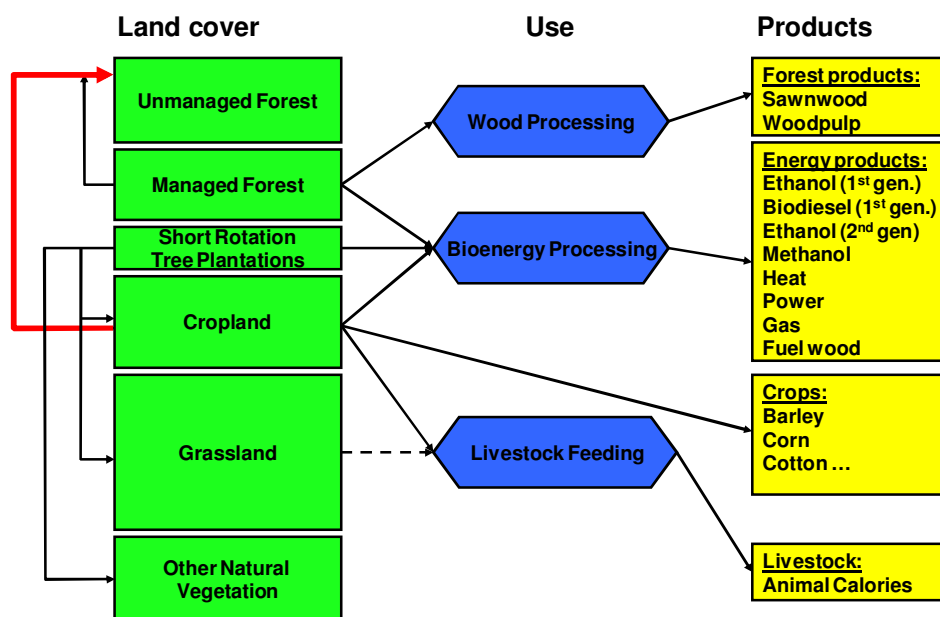
GLOBIOM is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to give policy advice on global issues concerning land use competition between the major land-based production sectors. Concept and structure of GLOBIOM are similar to the US Agricultural Sector and Mitigation of Greenhouse Gas (ASMGHG) model (Schneider, McCarl and Schmid 2007).

The market is represented through product supply functions which are detailed, geographically explicit and mathematically expressed via Leontief production functions. Resource supply is expressed through general supply functions without detailed geographic information used (only water supply is currently represented in this way). Product demand functions are used to represent aggregate consumer behaviour via exogenous demand shifters depending on GDP and population development and price elasticity in order to capture demand changes induced by commodity price changes. In what follows we will present the model along Figure 6.8, where not only the product chains but also the land use change options are represented.

Land and its characteristics are the key element of our modelling approach. In order to enable global bio-physical process modelling of agricultural and forest production, a comprehensive database has been built (Skalsky et al., 2008), which contains geo-spatial data on soil, climate/weather, topography, land cover/use, and crop management (e.g. fertilization, irrigation). The data are available from various research institutes (National Space Agency (NASA), JRC, FAO, United States Department of Agriculture (USDA), International Food Policy Research Institute (IFRPI), etc.) and significantly vary with respect to spatial, temporal, and attribute resolutions, thematic relevance, accuracy, and reliability. Therefore, data were harmonized into several common spatial resolution layers including 5 and 30 arcmin as well as country layers. Consequently, Homogeneous Response Units (HRU) have been delineated by including only those parameters of landscape, which are almost constant over time. At the global scale, we have included five altitude classes, seven slope classes, and five soil classes. In a second step, the HRU layer is merged with a $0.5^\circ \times 0.5^\circ$ grid and with country boundaries, to delineate Simulation Units that contain other relevant information such as global climate data, land category/use data, irrigation data, etc. Each Simulation Unit is simulated with the bio-physical process model EPIC (Environmental Policy Integrated Climate model; Williams 1995, Izaurralde et al. 2006), and is the basis for estimation of land use/management parameters in all other supporting models. Thus the HRU concept assures consistent aggregation of geo-spatially explicit bio-physical impacts in an economic land use

optimisation model such as GLOBIOM. In GLOBIOM, it is possible to choose at which level of resolution to run the model, and aggregate the input consistently. As showed in the Appendix, currently each land related activity and all land resources are indexed by country, altitude, slope and soil class. The information relevant to the $0.5^\circ \times 0.5^\circ$ grid layer has been averaged to keep the model size within reasonable limits.

Figure 6.8 GLOBIOM land use and product structure



[Source: IIASA]

[Note: The dashed arrow means that there is a linkage between grassland and livestock. However, the data quality is very bad and the global livestock products are not fully consistent yet. IIASA, in cooperation with the International Livestock Research Institute, have produced one of the first consistent livestock representations – FAO is very interested in using it further. However, uncertainties are still very large at this point in time.]

The model directly represents production from three major land cover types: cropland, managed forest, and short rotation tree plantations.¹

Cropland, crop production and crop products

Crop production accounts for more than 30 globally most important crops. Yield coefficients, as well as fertilizer and irrigation rates, are simulated with EPIC for 20 of them (80 % of the 2007 harvested area as reported by the FAO). Four management systems are considered (irrigated, high input - rainfed, low input - rainfed and subsistence management systems) corresponding to the IFPRI crop distribution data classification (You and Wood, 2006). For the remaining crops, which will be simulated by EPIC subsequently, national level data provided by the FAO's Statistical Database (FAOSTAT) are used for the crop yield level. And only two management systems are differentiated in their analysis – rainfed and irrigated. Rainfed and irrigated crop yields adjustments, crop specific irrigation water requirements, and costs for five irrigation systems are derived from a variety of sources as described in Sauer et al. (2008). For sake of consistency, also the regional level of EPIC estimated yields is set equal to the FAO data.

¹ Grassland production is so far represented only indirectly without explicit linkage with livestock feed requirements. Work is going on to improve on this aspect in the next version of the model.

Crop supply can enter one of three processing/demand channels: consumption, livestock production or biofuels production. Consumption demand is modelled by constant elasticity functions parameterized using FAOSTAT data on prices and quantities, and own price elasticities as reported by Seale *et al.* 2003. Only a preliminary regional livestock production representation is applied in the present version of the model where a bundle of livestock products (bovine meat, chicken meat, equine meat, pig meat, sheep and goat meat, turkey meat, milk, and eggs) is assimilated to a generic commodity - “animal calories”. Feed requirements have been calculated from the Supply Utilisation Accounts, FAOSTAT. Demand for livestock products is represented through upward sloping demand curves. Biofuels options from crops include first generation technologies for a) ethanol from sugarcane and corn, and b) biodiesel from rapeseed and soybeans. The processing data, conversion coefficients and cost, are based on Hermann and Patel (2007) for ethanol and on Haas *et al.* (2006) for biodiesel.

Primary forest production and forestry products

Primary forest production from traditional managed forests is characterized also at the level of Simulation Units. The most important parameters for the model are mean annual increment, maximum share of sawlogs in the mean annual increment, and harvesting cost. These parameters are shared with the Global Forest Model (G4M) – a successor of the model described by Kindermann *et al.* (2006). More specifically, the mean annual increment for the current management is obtained by down-scaling the biomass stock data given by the Global Forest Resources Assessment (FAO, 2005) from the country level to the $0.5^\circ \times 0.5^\circ$ grid using the method described in Kindermann *et al.* (2008). This downscaled biomass stock data is subsequently used to parameterise the increment curves. Finally, sawlogs share is estimated by the tree size which in turn depends on yield and rotation time. Harvesting cost is adjusted for slope and tree size as well.

Five primary forest products are defined: sawlogs, pulplogs, other industrial logs, wood fuel, and energy biomass.²

Harvesting cost includes logging and timber extraction. The unit cost of harvesting equipment and labour is derived from various datasets for Europe and North America (e.g. Jiroušek *et al.*, 2007; Wang *et al.*, 2004; FPP, 1999; Stokes *et al.*, 1986). Because the productivity of harvesting equipment depends on the terrain conditions, a slope factor (Hartsough *et al.*, 2001) was integrated to estimate the total harvesting cost. The labour

² Sawlogs, pulplogs and energy biomass are further processed. Sawnwood and woodpulp production and demand parameters rely on the 4DSM model described in Rametsteiner *et al.* (2007). FAO data and other secondary sources have been used for quantities and prices of sawnwood and woodpulp. For production cost estimates of these products, for example, mill costs, an internal IIASA database and purchased data were used. The energy biomass can be converted in several processes: combined heat and power production, fermentation for ethanol, heat, power and gas production, and gasification for methanol and heat production. Processing cost and conversion coefficients are obtained from Leduc *et al.* (2008), Hamelinck and Faaij (2001), Sørensen (2005), and Biomass Technology Group (2005). Demand for woody bioenergy production is implemented through minimum quantity constraints, similarly as demand for other industrial logs and for firewood, represented in the Appendix by Equation (2). Woody biomass for bioenergy can be produced also on short rotation tree plantations. To parameterize this land use type, we determined regionally values for plantation maximum mean annual increment from FAO and other various databases (e.g. Alig *et al.*, 2000; Chiba and Nagata, 1987; FAO, 2006; Mitchel, 1999; Stanturf *et al.*, 2002; Uri *et al.*, 2002; Wadsworth, 1997; Webb *et al.*, 1984;). The maximum values have been for each Simulation Unit scaled proportionally to the NPP values given in Cramer *et al.* (1999).

cost, as well as the cost of saplings, is regionally adjusted by the ratio of the purchasing power parity (PPP) over GDP (Heston et al., 2006).

Land cover and land use change

As represented graphically in Figure 6.8, we allow for endogenous change in the land cover/use within the land resources described in our model. Expansion into other land cover/use types is not allowed, and thus the total land endowment remains fix over the whole simulation horizon. When carrying out simulations over several periods, changes made in one period, are transferred into the next period, introducing recursive dynamics into the model. Land use change options are on the one hand limited through general restrictions on conversion from one land use to the other; e.g. cropland expansion into other natural vegetation is not allowed anywhere. On the other hand, land suitability criteria linked to production potentials exclude selectively land use conversion to a particular land use type in a particular Simulation Unit. Land use suitability is taken into account either indirectly through estimated crop and forest productivity, or directly by not only calculating the production potentials but also by explicitly delineating suitable areas. This detailed direct suitability analysis has been for short rotation tree plantations.

GHG accounting

GLOBIOM allows for accounting, and eventually taxing, of the major greenhouse gas emissions/sinks related to agriculture and forestry. The calculation of emission coefficients depends on the emission source. Soil N₂O (Nitrous oxide) emissions from application of synthetic fertilizers are calculated according to the IPCC (1997) guidelines, on the basis of fertilizer use as simulated in EPIC, or for crops which are not yet simulated, using fertilizer application rates derived from the International Fertilizer Industry Association (IFA), 1992, and FAOSTAT. Coefficients for CH₄ (methane) emissions from rice production, and from enteric fermentation and manure management, are derived from the Environmental Protection Agency (EPA), 2006, by recalculating the total values per activity level. CO₂ coefficients for emissions and sinks due to deforestation and new tree plantations respectively are calculated directly from our Simulation Unit specific parameters of the per hectare above ground biomass. A limitation of the model is that GLOBIOM accounts only for above and below ground living biomass. This underestimates emissions from deforestation especially in regions like Southeast Asia where deforestation on peatlands is likely to take place.

Methodology for translating deforested area outputs into costs of avoided deforestation

Shock scenarios are carried out with GLOBIOM model, which considers only drivers of deforestation coming from agriculture or bioenergy production. We consider that the model operates under fixed total land constraint and decides about the land use depending on the profitability of different activities in particular Simulation Units. Deforestation itself is costly and the model would not do it, if it is not profitable (the income which comes from the deforested land must be higher than the cost of deforestation). The cost of avoiding deforestation is so equal to the difference between the cost of deforestation itself and the future income from agricultural production (opportunity cost). Marginal cost is the cost of the last (most costly) unit of deforestation avoided, here expressed in CO₂.

Technically, the marginal cost of reducing CO₂ from deforestation is calculated so that there is a constraint in the model on the quantities of CO₂ that may be emitted – e.g. 50% of the baseline. The marginal cost is then obtained as the dual value of this constraint.

Model calibration

The final model calibration, supposed to correct data imperfections and get the baseline solution close to the observed values, is done by adjusting the cost parameters of selected activities so that for the baseline activity levels, their marginal cost equals to their marginal revenue, as assumed by the microeconomic theory. The controlled activities are Simulation Unit specific crop areas, and regional primary forest products supply and animal calories supply.

6.2.2 The G4M Model – modelling a geographic explicit scenario

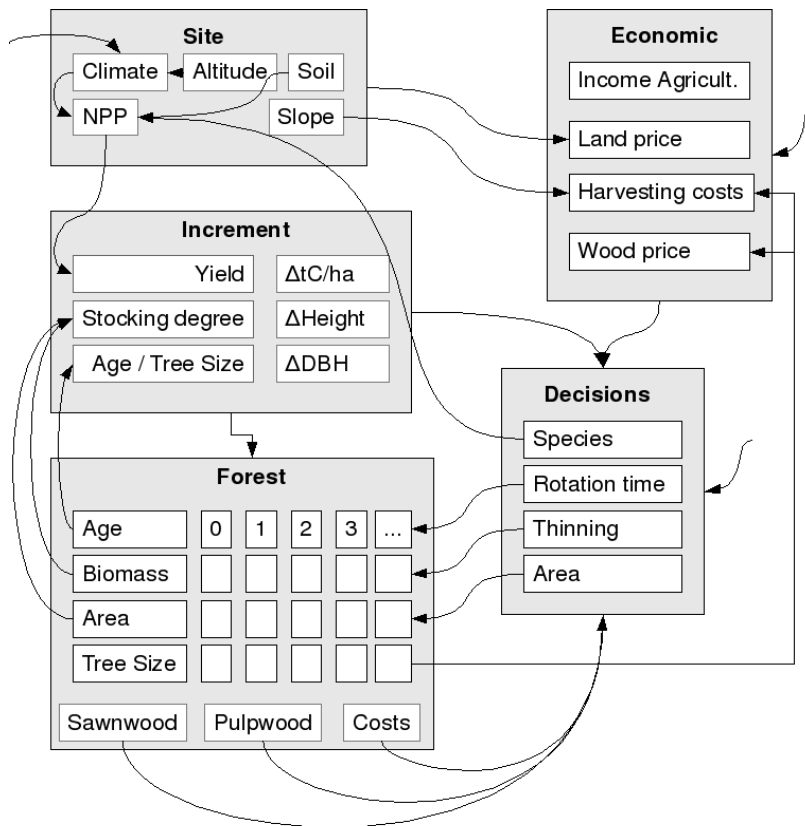
The G4M estimates the annual above ground wood growth and harvesting costs. It keeps track of the above ground forest biomass. By comparing the income of managed forest (difference of wood price and harvesting costs, income by storing carbon in forests) with income by alternative land use at the same location (i.e. agriculture), the decision of afforestation or deforestation is made. As G4M is spatially explicit (currently on a 0.5°x0.5° resolution which is planned to be brought down to 30"x30") the different deforestation pressures at the forest frontier can also be handled.

Growth is determined by a potential National Protection Plan (NPP) map. At present this NPP map is static but can be changed to a dynamic NPP model which reacts to changes of temperature, precipitation, radiation or CO₂ concentration. Main forest management options are species selection, application of thinning and choice of rotation time. G4M does not distinguish between species but a change of species can be emulated by adapting NPP, wood price and harvesting costs. The rotation time can be individually chosen but the model can estimate optimal rotation times to maximize increment, maximize stocking biomass or maximal biomass at harvest time. The model handles age classes with one year width.

Afforestation and disasters cause an uneven age-class distribution over a forest landscape. The model is doing final cuts in a manner, that all age classes have the same area after one rotation time. During this age class harmonization time the standing biomass, increment and amount of harvest is fluctuating due to changes in age-class distribution and afterwards stabilizing.

The model can use external information (like wood prices, prescribed land-use change) from other models or data bases, which guarantee food security and land for urban development or account for disturbances. As outputs, G4M produces forecasts of land-use change, carbon sequestration/emissions in forests, impacts of carbon incentives (e.g., avoided deforestation), and supply of biomass for bio-energy and timber.

Figure 6.9 G4M flowchart



[Source: IIASA]

The major tasks for G4M modelling will comprise:

- Incorporate outputs on drivers and scenario information from Task 1&2. Much of the information generated by Task 1&2 will be of qualitative nature and it will require substantial efforts to incorporate this knowledge in the quantitative modelling. This might require building a specific “translation tool” for the purposes of G4M modelling.
- Adapt the currently existing formulation of a REDD incentive scheme to the richer set specified in Task 2.
- Include transaction costs and monitoring costs.
- Reformulation of calibration procedures according to inputs from Task 1&2 and implementation of different methods to compute reference emission pathways in a consistent manner with GLOBIOM. Country specific calibration information might be used to statistically decompose some of the driver information in Task 1.
- Assimilate new data streams such as GLOBCOVER³ information, carbon stock information.
- Rebuild the afforestation module to produce scenarios on net-deforestation.

³ The European Space Agency is currently creating the most detailed portrait ever of the Earth's land surface via its Envisat environmental satellite. The GLOBCOVER project aims at producing a global land cover map to a resolution three times sharper than any previous satellite map.

- Build a dynamic full carbon accounting scheme.
- Establish a consistent linking scheme to GLOBIOM. This will involve linkages with respect to delivery of basic input data sets to GLOBIOM as well as “down-scaling” of GLOBIOM results in G4M.

6.2.3 POLES model

The POLES (Prospective Outlook for the Long term Energy System) model is a global sectoral simulation model for the development of energy scenarios until 2050. This study uses the most recent update of the POLES model data. The dynamics of the POLES model are based on a year by year simulation process of energy demand and supply with lagged adjustments to prices and a feedback loop through international energy prices.

The model is developed within a hierarchical structure of interconnected modules at the international, regional and national level. It is broken down into sectors and in each sector, energy consumption is calculated both for substitutable fuels and for electricity. Each demand equation contains an activity variable elasticity, price elasticity and captures trends in technology as well as saturation effects when appropriate. All energy prices are determined endogenously in POLES. The main exogenous input parameters of the POLES model are population and economic growth, which are based on the UN’s *World Population Prospects: The 2004 Revision* and data from the French Research Centre for International Economics (CEPII), respectively.

The world is sub-divided into 47 regions. The model delivers detailed energy balances for each of these regions (see next section for more detail). Recent modifications included detailed modules for energy-intensive industries as well as an extension to cover non-CO₂ greenhouse gases.

The most recent POLES baseline scenario describes a ‘business as usual’ development without any additional dedicated energy efficiency or climate change policies and measures. For the EU, a carbon permit price of 5€ per tonne of CO_{2-eq} was assumed for all sectors covered under the EU Emissions Trading Scheme (EU ETS), thus incorporating the impact of already existing policies. This permit price is justified by the experience of permit price volatility since the start of the EU ETS as well as by recent developments on the market for emission permits in the light of the economic and financial crisis. The most recent POLES baseline has been calibrated to reflect the evolutions observed over recent years in terms of energy efficiency improvement, a slow-down of the world economy and a slow catch-up by developing economies.

POLES Baseline Scenario description (provided by Russ *et al*, 2007)

In the baseline scenario energy sector trends of the previous years are projected to continue in the future. Even without further policies, energy consumption per GDP will decline further at a similar rate to the one observed over the past two decades. These improvements, however, will be more than offset through economic growth. As a result, global energy consumption is projected to be 46% above its 2005 levels by 2030.

Consumption is expected to grow at a similar pace among all energy carriers until 2030. The fuel mix will remain more or less stable until 2030. Beyond 2030, low carbon energy carriers, such as renewables, are projected to increase their contribution to total energy consumption from 25% to 35%.

Due to the overall increase in consumption and the continued dominance of fossil fuels imply a steep increase in global greenhouse gas emissions: emissions in 2030 will be 68% higher than in 1990. Emissions will increase particularly fast in developing countries.

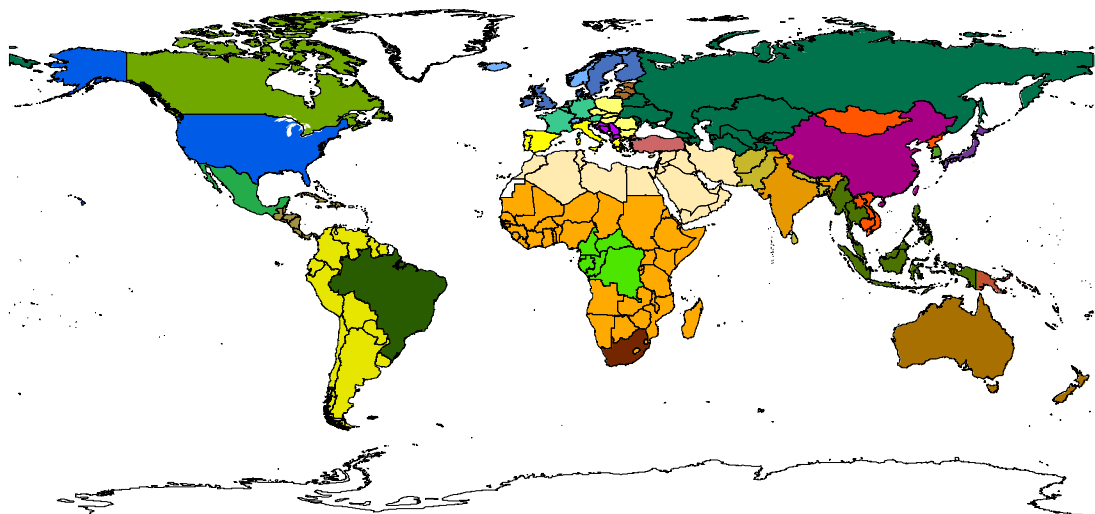
More detailed information on the POLES model and its baseline scenarios is provided in Russ *et al*, 2007.

6.2.4 Regions

The flexible model structure enables to easily change the model resolution; currently two regions definitions are being simultaneously used, either 11 regions corresponding to the IIASA Greenhouse Gas Initiative (GGI) regions definition (IIASA, 2007), or 28 regions, representing a disaggregation of the 11 regions adapted to enable linkage with the POLES model (Criqui *et al*. 1999).

The following figure depicts GLOBIOM's worldwide coverage with its basic resolution of 28 regions.

Figure 6.10 GLOBIOM coverage: the earth / basic resolution: 28 regions



[Source: IIASA]

The following table provides a detailed presentation of all countries per region.

Table 6.1 Overview of regional groupings in GLOBIOM model

Region	Country		
Middle East and North Africa	Algeria	Kuwait	Saudi Arabia
	Bahrain	Lebanon	Syria
	Egypt	Libya	Tunisia
	Iran	Morocco	Turkey
	Iraq	Oman	United Arab Emirates
	Israel	Qatar	Yemen
	Jordan		
Sub-Saharan Africa	Angola	Ethiopia	Niger
	Benin	Gabon	Nigeria
	Botswana	Gambia	Rwanda
	Burkina Faso	Ghana	Sao Tome and Principe
	Burundi	Guinea	Senegal
	Cameroon	Guinea Bissau	Seychelles
	Cape Verde	Kenya	Sierra Leone
	Central African Republic	Lesotho	Somalia
	Chad	Liberia	South Africa
	Comoros	Madagascar	Sudan
	Congo Democratic Republic	Malawi	Swaziland
	Congo Republic	Mali	Tanzania
	Cote d' Ivoire	Martinique	Togo
	Djibouti	Mauritania	Uganda
	Equatorial Guinea	Mozambique	Zambia
	Eritrea	Namibia	Zimbabwe
North America	Canada	USA	
Pacific OECD	Australia	Japan	New Zealand
Former Soviet Union	Armenia	Kazakhstan	Tajikistan
	Azerbaijan	Kyrgyzstan	Turkmenistan
	Belarus	Moldova	Ukraine
	Georgia	Russian Federation	Uzbekistan
Planned Asia China	Cambodia	Korea DPR	Mongolia
	China	Laos	Vietnam
South Asia	Afghanistan	India	Pakistan
	Bangladesh	Maldives	Sri Lanka
	Bhutan	Nepal	
Other Pacific Asia	Brunei Durasallam	Malaysia	Singapore
	Fiji Islands	Myanmar	Solomon Islands
	Indonesia	Papua New Guinea	Thailand

	Kiribati	Philippines	Tonga	
	Korea Republic	Samoa	Vanuatu	
Latin America and the Caribbean	Argentina	Dominica	Neth. Antilles	
	Bahamas	Dominican Republic	Nicaragua	
	Barbados	Ecuador	Panama	
	Belize	El Salvador	Paraguay	
	Bermuda	Grenada	Peru	
	Bolivia	Guatemala	St. Lucia	
	Brazil	Guyana	St. Vincent	
	Chile	Haiti	Suriname	
	Colombia	Honduras	Trinidad and Tobago	
	Costa Rica	Jamaica	Uruguay	
	Cuba	Mexico	Venezuela	
	EU27	Austria	Germany	Netherlands
		Belgium	Greece	Poland
Bulgaria		Hungary	Portugal	
Cyprus		Ireland	Romania	
Czech Republic		Italy	Slovakia	
Denmark		Latvia	Slovenia	
Estonia		Lithuania	Spain	
Finland		Luxembourg	Sweden	
France		Malta	UK	
Rest of Europe		Albania	Gibraltar	Norway
	Bosnia Herzegovina	Iceland	Serbia-Montenegro	
	Croatia	Macedonia	Switzerland	

[Source: IIASA]

Results for this report are given for the three sub-regions with the highest deforestation levels: Latin America and the Caribbean, Sub-Saharan Africa, and Pacific Asia. Geographic explicit results are shown for the Congo Basin.

Table 6.2 Overview of model regions, sub-regions and countries

Region	Sub-Regions	Countries
Latin America & Caribbean	Brazil	Brazil
	Mexico	Mexico
	RCAM	Bahamas, CostaRica, ElSalvador, Honduras, Panama, Barbados, Cuba, Grenada, Jamaica, StLucia, Belize, Dominica, Guatemala, NethAntilles, StVincent, Bermuda, DominicanRp, Haiti, Nicaragua, TrinidadTob
	RSAM	Colombia, Peru, Ecuador, Suriname, Guyana, Uruguay, Paraguay, Venezuela
Sub-Saharan Africa	South Africa	South Africa
	Sub-Saharan Africa	Burkina Faso, Eritrea, Ghana, Lesotho, Mali, Niger, Senegal, Sudan, Uganda, Angola, Burundi, Chad, CotedIvoire, Ethiopia, Guinea, Liberia, Martinique, Nigeria, Seychelles, Swaziland, Zambia, Benin, Comoros, Djibouti, GuineaBissau, Madagascar, Mauritania, Rwanda, SierraLeone, Tanzania, Zimbabwe, Botswana, CapeVerde, Gambia, Kenya, Malawi, Namibia, Mozambique, SaoTomePrn, Somalia, Togo
	Congo Basin	CentAfrRep, CongoRep, Cameroon, Gabon, CongoDemR, EqGuinea
Other Pacific	Pacific Islands	Samoa, FijilIslands, SolomonIs, Kiribati, Tonga, PapuaNGuin, Vanuatu
Asia	RSEA_OPA	Indonesia, Singapore, Malaysia, Thailand, Myanmar, BruneiDarsm, Philippines
	South Korea	South Korea

[Source: GLOBIOM]

6.2.5 Model limitations and constraints

This section provides a summary overview of key model limitations and specific model run constraints. These are also mentioned separately throughout the report.

Model limitations

Deforestation from sustainable forest: The GLOBIOM model considers that the wood from deforestation is not used by the forest industry. Thus, the forest industry is assumed to use only wood from “sustainable” harvests. This means that increased demand for wood will - in GLOBIOM - lead to conversion of unmanaged forest to managed forest, but not to deforestation. Actually increased wood demand adds additional value to managed forests compared to agriculture and thus may rather slow down the deforestation.

Synthetic animal production representation: Animal production is represented through an aggregate of animal calories. The structure of this aggregate is fixed, set equal to the structure observed in the different regions in the base year. Similarly feed ratios are considered fixed, with structure of the forage crops as observed in the base year, differentiated again by region. This means for example that no endogenous substitution of pork by poultry in human diets, or of wheat by corn in animal diets is possible. Therefore we also chose to represent biofuels co-products through fixed substitution ratios. Furthermore, in the current version of the model only demand for forage crops is

represented, hence an increase in livestock production is not linked to increased grassland demand. This link would put additional pressure on deforestation in the meat shock scenarios.

Inclusion of co-products: Due to the nature of the model structure, which does not yet contain a flexible representation of different animal species, but a rather fixed aggregate of animal calories with fixed predefined feed ratios only differentiated by country, we decided to implement an approach similar to the one used for the Gallagher review (Gallagher, E. 2008). This means that the substitution ratios (tonne by product / tonne feedstuff) are defined exogenously to the model and kept constant over the simulations.

The values are taken from CE Delft supporting material to the Gallagher review (Croezen H. and Brouwer, F. 2008). The by-products yields per unit of crop feedstock utilized in biofuels production are displayed in the table below.

Table 6.3 Amounts of co-products per unit of crop feedstock for biofuels production

Crop	Unit of crop
Wheat	0,323
Soy	0,83
Corn	0,30
Palm	0,02
Sorghum	0,02

[Source: IIASA]

The calculation methodology in order to define substitution ratios is also extensively explained in the CE Delft supporting document (Croezen H., Brouwer, F. 2008).

One problem with this approach is that currently the reduced oil production due to substitution of soy cake by other co-products is not taken into account. The Ecofys support document to the Gallagher review assumed that this additionally needed oil would come from palm and thus the net land saving from e.g. rapeseed would be some 15% less than the gross one (Dehue and Hettinga, 2008). This ratio may be even higher for soybeans. Our calculations give from this point of view the gross Land Use Change savings and represent thus the very optimistic end. Hence, the ‘with’ and ‘without’ co-product storylines encompass the spectrum of possible outcomes.

No autonomous yield increase in the baseline: We assume that the yield increase can be split in two parts – i) autonomous (input neutral) technological change, and ii) management change. The figures provided by - for example the FAO - do not enable a split between these two parts, but the IIASA model does. In the conservative baseline scenario we assume that only endogenous yield increase occurs due to management changes (e.g. shifts from a low input to a high input or irrigated crop production system). However, it is assumed that input neutral technological change will be available. This is a conservative assumption motivated by the fact that changes in input neutral technological change are many times, e.g. in India, compensated by soil fertility losses due to erosion and salinisation.

In the alternative baseline analysis, we then test the hypothesis of an input neutral yield growth of 1% per annum. This corresponds to the average projections of the total annual yield growth (input neutral and intensification comprised) and hence represents rather the upper limit on the expected input neutral yield growth. Thus, it is impossible to identify whether the yield growth comes from genetic improvement or from a switch from low-input to high input or even irrigated agriculture. A full stop in the total yield increase is indeed unlikely, but the statistics project a slowdown for the future. On average the total projected yield growth (autonomous and management) is around 1 % per year which is also the value which we use for the sensitivity scenario.

Restriction on trade with biofuels: Because of the multitude of support and trade policies implemented in different ways in different countries to promote biofuels production, it is a trivial task to set up the model in a way that perfectly reproduces them. Especially, since the majority of these measures were put in place only recently, it is impossible to capture them through a usual calibration procedure. Therefore it is necessary to frame the model with exogenous assumptions. We admit that this may be restrictive, and sensitivity analysis could improve the understanding of these parameters. From other scenarios we ran, we know that if trade in ethanol is allowed, the ethanol will come largely from Brazilian sugar cane. This, counter-intuitively, may not lead to increased deforestation in Brazil, if the ethanol production from sugar cane there, is more land efficient than production of ethanol from wheat or corn in the EU.

Of course it is harder to trade the primary product (e.g. grains); however this is possible in the model. Currently the trade of final biofuels products is highly regulated through international trade policies and other sectoral policies, which result in a rather complex domestic market protection structure. This type of protection is possible to be modeled if the model can be calibrated to an observed situation. However, historical trade in biofuels was rather low. From this the no trade scenario would be hardly distinguishable from a small biofuels trade scenario. What we implemented for the trade scenarios was full trade in the feedstock, but not in the final products.

GLOBIOM is very well suited to also include trade and specific trade barriers in trade scenarios. However, performing detailed analyses on these trade issues requires (1) the acquisition of very detailed data, (2) substantial work to include these information into GLOBIOM, which is something we will certainly do in future projects and are willing to share, when ready, with DGENV during 2010.

Cropland expansion in forests only: Indeed, there seems to be high uncertainty about the past and future conversion matrix. For example, Searchinger et al. (2008) based on calculations using mainly FAO data, estimate that about 80 % of the new cropland in Brazil comes from forests. We want to remind that because of the overall biofuels scenarios implemented in the baseline, there is not only pressure on expansion of cropland, but also of short rotation plantations. Short rotation plantations are allowed to expand both in cropland and in grassland. Hence, there is an arbitrage whether short rotation tree plantations will go on current cropland and move it further into forests creating deforestation, or whether the cropland will stay in place, reducing deforestation, and short rotation tree plantations will go in majority to grassland. Hence, there is not a one to one relationship between cropland expansion and deforestation.

Constraints specific to the modelled scenarios

The model and corresponding results are characterised by the following constraints:

- It should be mentioned that shocks on certain drivers will be modelled, holding all other developments equal (as per the baseline scenario);
- Prices and international trade flows are endogenously computed for more or less aggregated world regions;
- Resulting cost estimations do not take into account additional costs, such as implementation and monitoring expenditures, and are therefore likely to be underestimated;
- Finally, the model focuses to great extent on agricultural pressures which cause deforestation but neglects other pressures, such as industrial expansion, illegal logging, ranching and urbanisation/settlements.

6.2.6 Timeframe

The time horizon for analysis will focus on 2020 / 2030 to ensure consistency with EU goals around these dates. Some scenarios could go beyond this horizon, if appropriate.

6.3 Establishing the global baseline

Changes of socio-economic drivers and societal trends

There are a number of existing quantitative and qualitative driver scenarios in the literature and available in respective databases. IIASA has created geographical explicit driver scenarios for population and gross domestic product (GDP). Energy demand developments have been down-scaled. The geographic explicit information on these developments has been considered for the quantification of impacts throughout the modelling section of this report. The socio-economic and societal trends scenarios have been developed in consistency with those developed and used by the Institute for Prospective Technology Studies (IPTS), an Institute belonging to the Joint Research Centre (JRC) of the European Commission (EC) for the Prospective Outlook on Long-term Energy Systems (POLES) model; in particular, scenarios on population, GDP and on energy price changes due to energy security policies and climate change policies.

Exogenous drivers: population growth, GDP and food demand

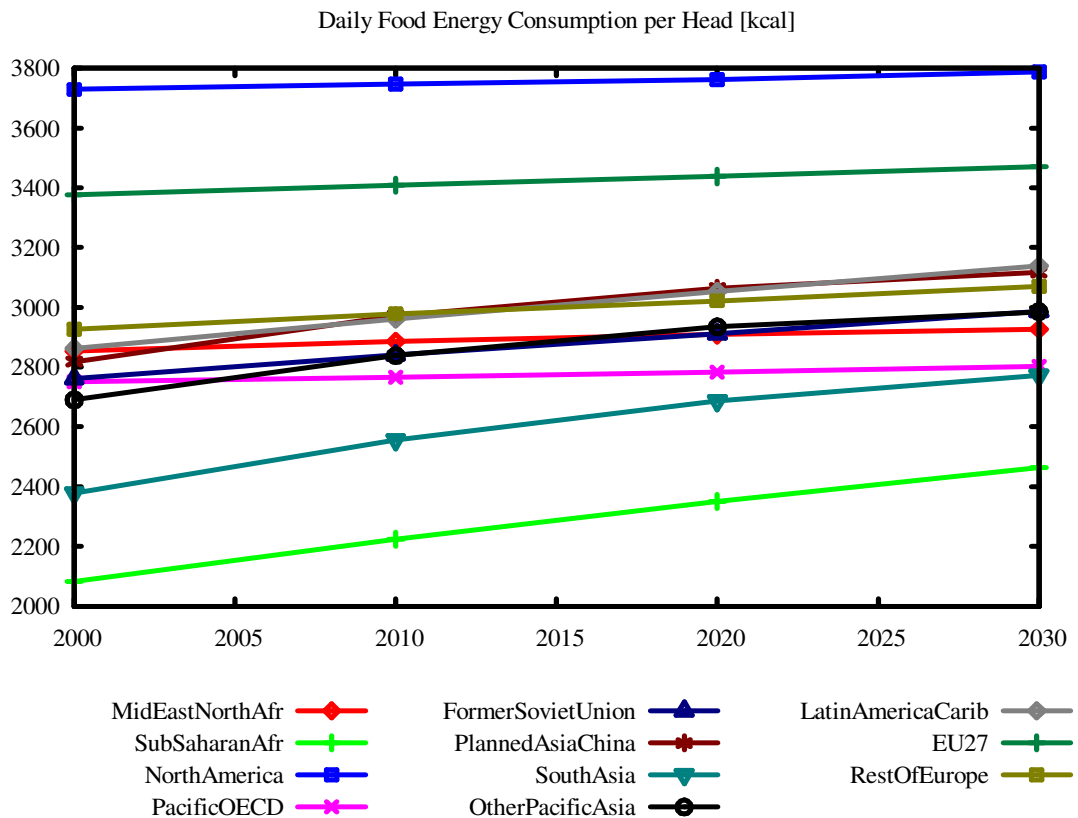
As GLOBIOM operates in partial equilibrium, several parameters enter the 2030 projections as exogenous drivers. Food demand is driven by GDP and population changes. In addition, food demand must meet minimum per capita calorie intake criteria, which are differentiated with respect to the source between crop and livestock calories.

Demand is calculated for the different regions on the basis of projections presented in FAO (2006). Figure 6.2 provides an overview of the daily food energy consumption per head in kcal as a proxy for GDP growth under the baseline scenario. As mentioned above,

the data and geographical categorization is based on the latest POLES used for the background analysis of the Copenhagen Communication⁴.

At first sight it becomes obvious that the population in all POLES regions will experience an increase in daily food energy consumption. However, the increase is very little in developed regions such as North America and EU-27 (which already experience the highest daily food energy intake of all regions) as well as in the Pacific OECD and the Middle East/North Africa. The former Soviet Union region, planned Asia and China, other Pacific Asia, Latin America and the Caribbean as well as the rest of Europe are all foreseen to experience a steady increasing daily food energy intake under the baseline, although still far behind the consumption of North America and the EU-27. The most striking development under this baseline parameter is however the enormous increase of daily food energy consumption in Sub-Saharan Africa and South Asia. These regions, although remaining behind all other regions with regard to total consumption, are foreseen to experience the largest increases until 2030. This development appears reasonable, considering the very low level of daily food energy consumption most of the population faces in these regions.

Figure 6.2 Baseline scenario for daily food energy consumption per head (proxy for GDP growth)

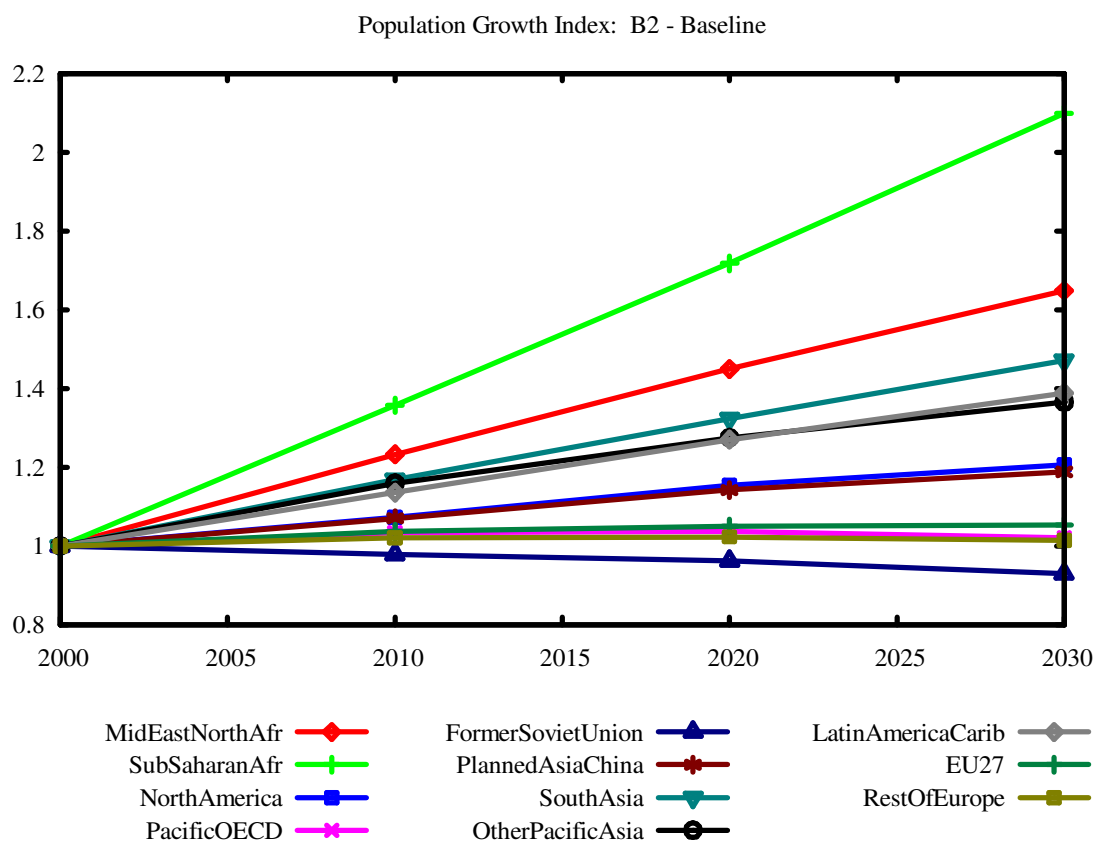


[Note: for an overview of all countries per region, we refer to Table 6.2.]
 [Source: IIASA based on POLES scenario (Oct. 2008)]

⁴ COM (2009)39, SEC (2009)101, Russ et. al, 2009

The figure below displays the region-specific baseline scenario development with regard to population growth. The first observation which can be easily made is a decreasing population within the region of the former Soviet Union until 2030. In the EU-27, the remaining Europe and the Pacific OECD region, the population will remain more or less at current levels by 2030, having the potential for slight population increases. Besides these regions experiencing a declining or stagnating population, all other POLES regions will experience continuous population growth until 2030. Especially striking are the population growth projection lines for Sub-Saharan Africa, the Middle East and North Africa as well as South Asia, in order of indexed population growth. All these regions will experience a substantial population growth.

Figure 6.3 Baseline scenario for population growth



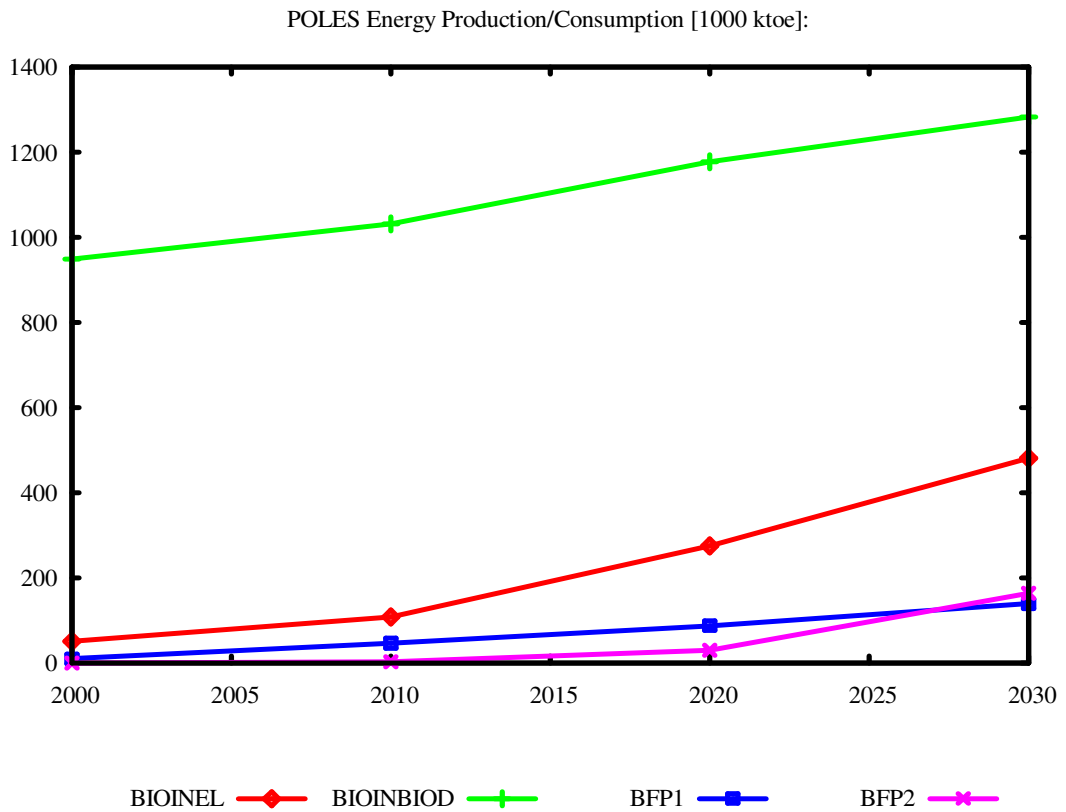
[Source: IIASA]

Biofuels baseline

The baseline scenario for the biofuels development will be coherent with the existing POLES scenario as delivered for the Copenhagen communication. This baseline scenario foresees a gradual increase in energy demand for transport. Figure 6.4 depicts the foreseen increases in global energy consumption from four types of biofuels. It is obvious that the already largest share of produced energy from biomass, biomass for domestic consumption (fuelwood), will also contribute the largest share until 2030, maintaining its overall share compared to the other three biofuels considered. The second most important use of biomass, with regards to market share, currently is and will be until 2030 the electricity generation. First generation biofuels will experience some growth until 2030. However, by 2025 the first generation fuels are foreseen to be surpassed, with regards to

market share, by second generation biofuels which will start to play a visible role under the biofuels baseline from 2015 onwards. Furthermore it can be stated that the baseline, with regard to biofuels, also foresees an increasing demand in biofuels use for transportation from the year 2000 through to 2050.

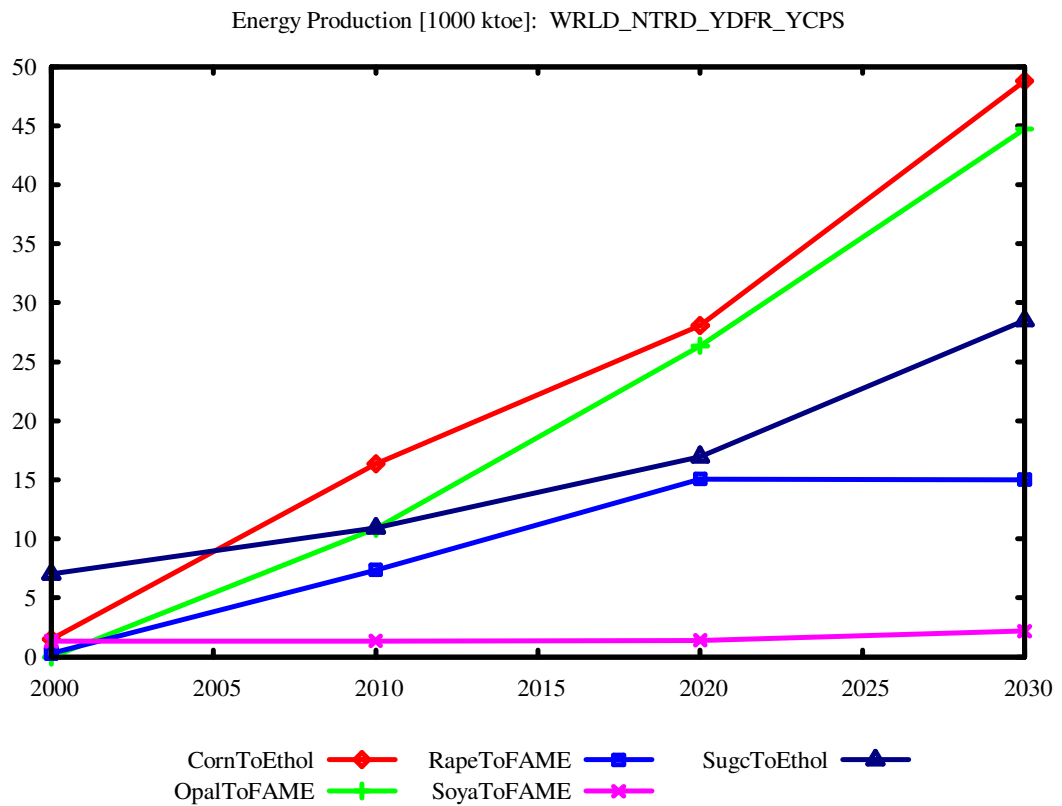
Figure 6.4 Baseline scenario for global energy /consumption of different biofuels



[Legend: BIOINEL – Biomass for electricity production
 BIOINBIOD – Biomass for domestic consumption (fuelwood)
 BFP1 – Biofuel first generation
 BFP2 – Biofuel second generation]
 [Source: IIASA based on POLES scenario (Oct. 2008)]

Figure 6.5 presents the foreseen baseline developments with regard to energy production by biofuels type. The figure differentiates between the production of biodiesel and ethanol from various crops. No general observation can be made with regard to general developments of ethanol and biodiesel as it is important to take the natural product of which these fuels are made off into consideration. The most obvious elements of the figure are the tremendously increasing production graphs for ethanol produced from corn and for biodiesel produced from palm oil until 2030. These two types of fuel are foreseen to supply the largest part of the market. In addition, the ethanol production from sugar is also foreseen to experience substantial increases until 2030 under the baseline. The picture differs a little for the production of biodiesel from rape which is considered to experience growth until 2025 and stagnate afterwards as the potential of rape will be totally utilized by 2025. The biodiesel production from soya will remain more or less stable in terms of production growth rates and in comparison with the shares of the other mentioned ethanol and biofuels production methods.

Figure 6.5 Energy production baseline, by biofuels type



[Legend: Opal - Oil Palm
FAME – Technical word for Biodiesel]
[Source: IIASA]

The share of biofuels in total transport energy is foreseen to increase from ca. 4% in 2020 to approximately 8% in 2030 under the baseline. Table 6.1 below presents the stated forecasts.

Table 6.1 Forecasted share of biofuels in total transport energy

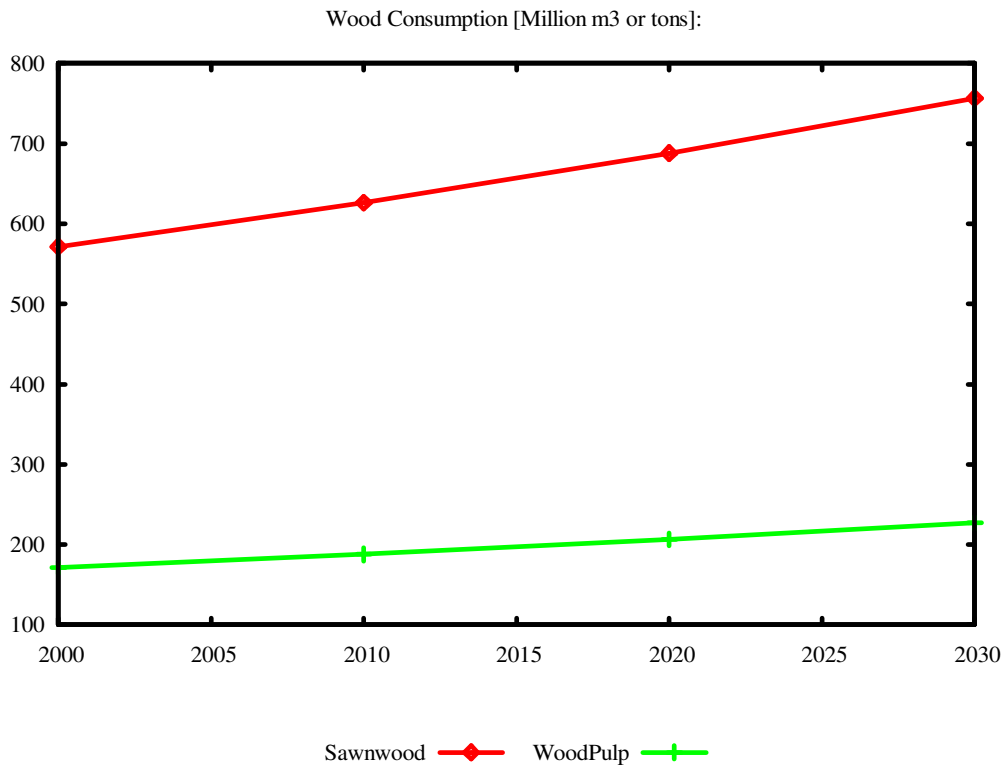
Year	2000	2010	2020	2030	2040	2050
Energy demand for Transportation	100%	116%	129%	132%	133%	132%
Share of biofuels in total transport energy	0,20%	2,04%	4,17%	8,43%	13,08%	17,56%

[Source: Latest POLES Input Data]

Wood demand baseline

The baseline for wood demand is made up of the total global demand for sawnwood and pulp products and is based on the same types of baseline assumptions as for the above-described biofuels forecast. Figure 6.6 therefore only displays the projected developments of demand for sawnwood and pulp products. Until 2030, the baseline demand forecasts for sawnwood display a steady increase. Although the same can be said for the graph depicting the pulp product demand, it is clear that the demand will not grow with as high rates as the sawnwood demand.

Figure 6.6 Baseline scenario for wood consumption



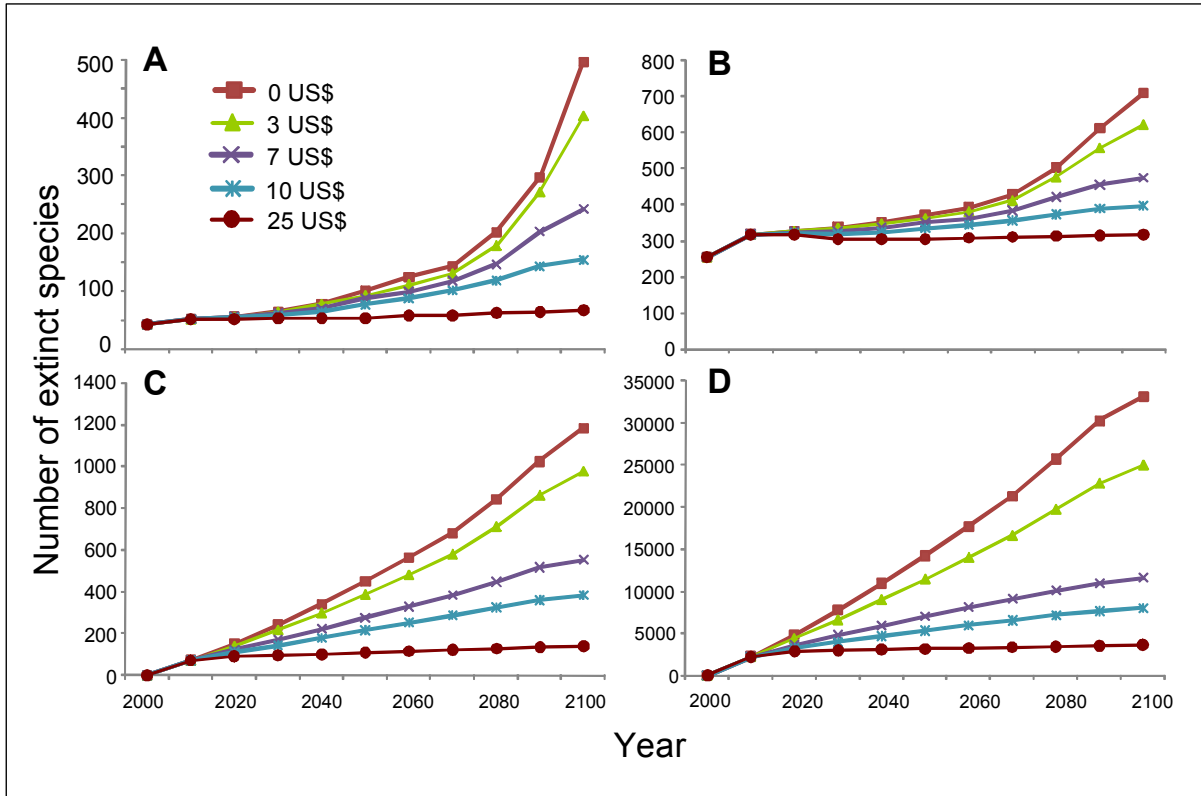
[Source: IIASA]

Biodiversity baseline

Baseline for biodiversity stems from the work of the United Nations Environmental Programme (UNEP) - World Conservation Monitoring Centre (WCMC) and is such that 10% of the land area of all types of ecosystems is protected through to 2030.

All currently applied modelling approaches project that a business-as-usual deforestation scenario would lead to very heavy losses in global species richness (Figure 6.7). Despite being conservative in several ways, the three methods based on individual species data all predict that by 2100, deforestation would commit between 452 and 1,186 mammal and amphibian species to extinction. This is four to ten times the total number of species (117) known to have become extinct globally amongst these taxa since 1500 (IUCN, 2008), confirming predictions of extinction rates over 1000 times above background levels for the 21st century (Pimm, et. al, 1995). The aggregated approach across biogeographic regions estimates that business-as-usual would result in the extinction of 20% of their endemic plants and vertebrates, or more than 33,000 species.

Figure 6.7 Variation in the number of predicted species extinctions, under each scenario of carbon price, over time



[Legend:

- Panels correspond to each of the methods used to predict extinctions from deforestation: binary (A), categorical (B) and continuous (C) models of species' extinction risk; and aggregated predictions across biogeographic regions (D).
- Carbon prices are in US\$/tonne CO₂.
- In A, B and C, species correspond to forest-dependent mammals and amphibians restricted to the study area; in D they correspond to plants and terrestrial vertebrates endemic to the 22 hotspots and four high-biodiversity wilderness areas analysed. In all cases, the values for 2000 and 2010 are the same across scenarios, because the land use model assumes that RED starts in 2012.]

[Source: IIASA]

Meat demand baseline

The meat and milk demand baseline comes from the population projections and from the per capita projections of calorie consumption from Alexandratos (2006).

Infrastructure development baseline

Infrastructure will be approximated by cost of transport according to the following methodology. Ad valorem freight rates ($f_{i,j,k}$) have been computed using Hummel's estimates⁵. They depend on the characteristics of the importing country (low income or

⁵ Hummels, D. (2001). Time as a trade barrier. Purdue University.

International trade occurs in physical space and moving goods requires time. This paper examines the importance of time as a trade barrier, estimates the magnitude of time costs and relates these to patterns of trade and the international organization of production. Estimates indicate that each additional day spent in transport reduces the probability that the US will source from that country by 1 – 1.5 %. Conditional on exporting country, estimates directly identify a willingness-to-pay for time savings using variation across exporters and commodities in the relative price / speed tradeoff for air and ocean shipping. Each day saved in shipping time is worth 0.8 % ad-valorem for manufactured goods. Relative declines over time in air shipping prices make time-savings less expensive, providing a compelling explanation for aggregate trade growth, compositional effects in trade growth, as well as growth in time-intensive forms of integration such as vertical specialization. Specifically, the advent of fast transport (air shipping and faster ocean vessels) is equivalent to reducing tariffs on manufactured goods from 32% to 9% between 1950-1998.

not), α_j is the coefficient associated with the dummy, the distance between the two partners ($DIST_{i,j}$), and the ratio weight over value of the good ($WGT_{i,j,k}/V_{i,j,k}$) to take into account the transportability of the good, where i is the exporting country, j is the importing country, k is the traded good.

$$\ln f_{i,j,k} = \alpha_j + \beta \ln DIST_{i,j} + \delta \ln \frac{WGT_{i,j,k}}{V_{i,j,k}} + \epsilon_{i,j,k}$$

The regressions from Hummels have been made from US, New Zealand, Argentina, Brazil, Chile, Paraguay, Uruguay for data availability reasons : customs officials from those countries collect data on import values and quantities but also for the freight and insurance charges for each entering shipment, and there are not so many countries which can provide this kind of data. Thus, they can directly estimate the technological relationship between ad-valorem freight rate (transportation expenditures / imports expenditures net of transportation charges) and distance.

In order to take into account the higher transportation costs in average in low income countries, we have applied the coefficients of Paraguay to lower income countries and United States coefficients were applied to compute freight costs for the other countries.

	α_j	β	δ
US	-4.62	0.246	0.267
Paraguay	-3.99		

Coefficients of Paraguay have been applied to other lower income countries, because it is a low populated, landlocked country - 2 handicaps shared by many other lower income countries and which can explain some higher transportation costs. Those lower income countries have been defined according to the World Bank classification and correspond to the 2 categories, 'Lower income countries' and 'Lower middle income economies' except China and India.

For the other countries, no distinction has been made between higher income and emerging countries. It appears more straightforward to apply different coefficients to the different categories since we will make some special simulations on transportation costs of emerging countries. However, for the scenario building we think of emerging countries such as the BRICs (Brazil, Russia, India and China) and alike countries, even if they face lower quality of infrastructure, their markets are so dynamic that total transportation costs at the end should not be so high. We believe the scenario is still consistent because they are currently investing to improve their infrastructures (over half of the world infrastructure investment is taking place in emerging economies) and it will probably decrease their transportation costs in the future.

Then, a weighted average of freight rate has been obtained for each region of the model. The equivalent freight cost per tone is the ad valorem freight rate multiplied by the

product world price according to the GLOBIOM commodity list.⁶ Resulting transportation costs differ for each pair of regions and for each product.

The calibration procedure leads to a consistent framework between bilateral trade flows, net trade, regional prices (P), tariffs and transportation costs (TC).

If the country i exports to the country j, then we observe for the product k:

$$P_{i,k} + \text{tariff}_{i,j,k} + \text{TC}_{i,j,k} = P_{j,k}$$

If the country i does not export to the country j, then we observe:

$$P_{i,k} + \text{tariff}_{i,j,k} + \text{TC}_{i,j,k} > P_{j,k}$$

Governance baseline

Governance and institutional change are crucial drivers for land use patterns. However, they are poorly understood and hardly measurable. There are very few reliable indicators available on global scale to measure “governance quality”. The modelling cluster, however, allows measuring, through model calibration, the ensemble of effects which can not be explained by the model variables and that lead to more or less deforestation. We call this ensemble of effects the ‘hurdle rate’, which is determined by an inverse modelling procedure: The hurdle rate is computed for each land use change – deforestation and afforestation – separately at the country level. Thus, a hurdle rate can be interpreted as a land use change inhibition factor due to, according to our interpretation, governance and institutional factors. For the baseline scenario the hurdle rate is assumed to be constant and thus no changes in land use change inhibition are triggered by changing governance quality or structures.

⁶ The GLOBIOM commodity list is still subject to change in order to increase the comprehensiveness. It is the aim to comprise 90% of world crop product prices under the list.

7 Annex B: GLOBIOM additional information

This extract is taken from the draft document “GLOBIOM: Global Biomass Optimization Model” by Petr Havlík^{a*}, Uwe A. Schneider^b, Erwin Schmid^c, Rastislav Skalský^d, Michael Obersteiner^a.

Variables

D	demand quantity [tonnes, m ³ , kcal]
W	irrigation water consumption [m ³]
Q	land use/cover change [ha]
A	land in different activities [ha]
B	livestock production [kcal]
P	processed quantity of primary input [tonnes, m ³]
T	inter-regionally traded quantity [tonnes, m ³ , kcal]
E	greenhouse gas emissions [tCO ₂ eq]
L	available land [ha]

Functions

φ^{demd}	demand function (constant elasticity function)
φ^{splw}	water supply function (constant elasticity function)
φ^{lucc}	land use/cover change cost function (linear function)
φ^{trad}	trade cost function (constant elasticity function)

Parameters

τ^{land}	land management cost except for water [\$ / ha]
τ^{live}	livestock production cost [\$ / kcal]
τ^{proc}	processing cost [\$ / unit (t or m ³) of primary input]
τ^{emit}	potential tax on greenhouse gas emissions [\$ / tCO ₂ eq]
d^{targ}	exogenously given target demand (e.g. biofuel targets) [EJ, m ³ , kcal,...]
α^{land}	crop and tree yields [tonnes / ha, or m ³ / ha]
α^{live}	livestock technical coefficients (1 for livestock calories, negative number for feed requirements [t/kcal])
α^{proc}	conversion coefficients (-1 for primary products, positive number for final products [e.g. GJ/m ³])
L^{init}	initial endowment of land of given land use / cover class [ha]
L^{suit}	total area of land suitable for particular land uses / covers [ha]

ω irrigation water requirements [m3/ha]

$\varepsilon^{land}, \varepsilon^{live}, \varepsilon^{proc}, \varepsilon^{lucc}$ emission coefficients [tCO2eq/unit of activity]

Indexes

r	economic region (27 aggregated regions and individual countries)
t	time period (10 years steps)
c	country (203)
o	altitude class (0 – 300, 300 – 600, 600 – 1100, 1100 – 2500, > 2500, in meter above sea level)
p	slope class (0 – 3, 3 – 6, 6 – 10, 10 – 15, 15 – 30, 30 – 50, > 50, in degree)
q	soil class (sandy, loamy, clay, stony, peat)
l	land cover/use type (cropland, grassland, managed forest, fast growing tree plantations, pristine forest, other natural vegetation)
s	species (37 crops, managed forests, fast growing tree plantations)
m	technologies: land use management (low input, high input, irrigated, subsistence, “current”), primary forest products transformation (sawnwood and woodpulp production), bioenergy conversion (first generation ethanol and biodiesel from sugar cane, corn, rapeseed and soybeans, energy production from forest biomass – fermentation, gasification, and CHP)
y	outputs (primary: 37 crops, sawlogs, pulplogs, other industrial logs, fuel wood, plantations biomass, processed products: forest products (sawnwood and woodpulp), first generation biofuels (ethanol and biodiesel), second generation biofuels (ethanol and methanol), other bioenergy (power, heat and gas)
e	greenhouse gas accounts: CO2 from land use change, CH4 from enteric fermentation, rice production, and manure management, and N2O from synthetic fertilizers and from manure management

I. Objective function

$$\begin{aligned}
 \text{Max } WELF_t = & \sum_{r,y} [\int \varphi_{r,t,y}^{demd} (D_{r,t,y}) d(\cdot)] - \sum_r [\int \varphi_{r,t}^{splw} (W_{r,t}) d(\cdot)] \\
 & - \sum_{r,l,\tilde{l}} \left[\int \varphi_{r,l,\tilde{l},t}^{lucc} \left(\sum_{c,o,p,q} Q_{r,t,c,o,p,q,l,\tilde{l}} \right) d(\cdot) \right] \\
 & - \sum_{r,c,o,p,q,l,s,m} (\tau_{c,o,p,q,l,s,m}^{land} \cdot A_{r,t,c,o,p,q,l,s,m}) \\
 & - \sum_r (\tau_r^{live} \cdot B_{r,t}) - \sum_{r,m} (\tau_{r,m}^{proc} \cdot P_{r,t,m}) \\
 & - \sum_{r,\tilde{r},y} [\int \varphi_{r,\tilde{r},t,y}^{trad} (T_{r,\tilde{r},t,y}) d(\cdot)] \\
 & - \sum_{r,e} (\tau_{t,e}^{emit} \cdot E_{r,t,e})
 \end{aligned}
 \tag{1}$$

Exogenous demand constraints

$$D_{r,t,y} \geq d_{r,t,y}^{targ} \quad (2)$$

II. Product balance

$$D_{r,t,y} \leq \sum_{c,o,p,q,l,s,m} (\alpha_{t,c,o,p,q,l,s,m,y}^{land} \cdot A_{r,t,c,o,p,q,l,s,m}) + \alpha_{r,t,y}^{live} \cdot B_{r,t} + \sum_m (\alpha_{r,m,y}^{proc} \cdot P_{r,t,m}) + \sum_{\tilde{r}} T_{\tilde{r},r,t,y} - \sum_{\tilde{r}} T_{r,\tilde{r},t,y} \quad (3)$$

III. Land use balance

$$\sum_{s,m} A_{r,t,c,o,p,q,l,s,m} \leq L_{r,t,c,o,p,q,l} \quad (4)$$

$$L_{r,t,c,o,p,q,l} \leq L_{r,t,c,o,p,q,l}^{init} + \sum_{\tilde{l}} Q_{r,t,c,o,p,q,\tilde{l},l} - \sum_{\tilde{l}} Q_{r,t,c,o,p,q,l,\tilde{l}} \quad (5)$$

$$Q_{r,t,c,o,p,q,l,\tilde{l}} \leq L_{r,t,c,o,p,q,l,\tilde{l}}^{suit} \quad (6)$$

recursivity equations (calculated only once the model has been solved for a given period)

$$L_{r,t,c,o,p,q,l}^{init} = L_{r,t-1,c,o,p,q,l} + \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,\tilde{l},l} - \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,l,\tilde{l}} \quad (7)$$

$$L_{r,t,c,o,p,q,l,\tilde{l}}^{suit} = L_{r,t-1,c,o,p,q,l,\tilde{l}}^{suit} + \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,\tilde{l},l} - \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,l,\tilde{l}} \quad (8)$$

IV. Irrigation water balance

$$\sum_{c,o,p,q,l,s,m} (\varphi_{c,l,s,m} \cdot A_{r,t,c,o,p,q,l,s,m}) \leq W_{r,t} \quad (9)$$

V. GHG emissions account

$$E_{r,t,e} = \sum_{c,o,p,q,l,s,m} (\epsilon_{c,o,p,q,l,s,m,e}^{land} \cdot A_{r,t,c,o,p,q,l,s,m}) + \epsilon_{r,e,t}^{live} \cdot B_{r,t} + \sum_m (\epsilon_{r,m,e}^{proc} \cdot P_{r,t,m}) + \sum_{c,o,p,q,l,\tilde{l}} (\epsilon_{c,o,p,q,l,\tilde{l},e}^{lucc} \cdot Q_{r,t,c,o,p,q,l,\tilde{l}}) \quad (10)$$

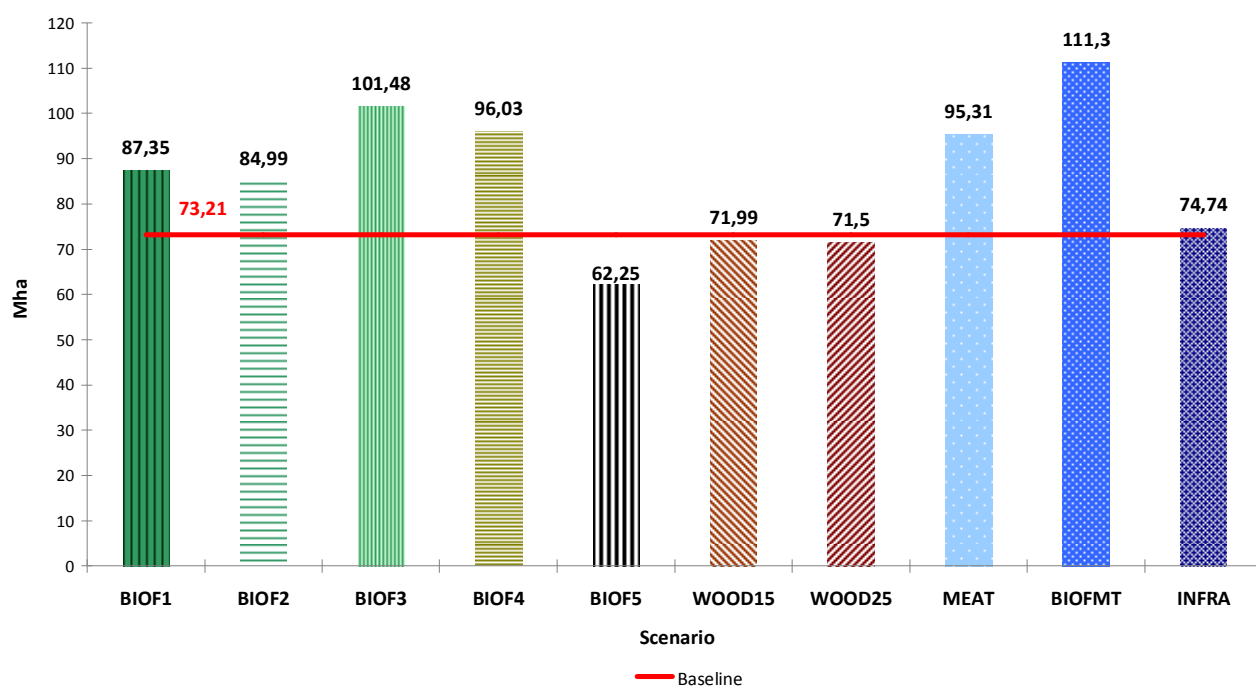
8 Annex C: Modelling Results

8.1 Alternative analyses under different baselines

8.1.1 Worst case for deforestation

The following tables and figures depict the scenario results under the worst case of the range of possible baselines.

Figure 8.1 No co-products – Global deforested area without REDD between 2020 and 2030 (Mha)



[Source: IIASA]

Table 8.1 No co-products – Deforested area without REDD between 2020 and 2030 in Mha per hotspot region

	<i>Baseline</i>	BIOF1	BIOF2	BIOF3	BIOF4	BIOF5	WOOD 15	WOOD 25	MEAT	BIOFMT	INFRA
Sub-Saharan Africa	5,61	6,53	6,27	7,28	7,04	5,25	5,58	5,50	6,84	7,54	5,61
Pacific Asia	12,38	14,95	14,55	15,96	14,98	9,97	11,40	10,83	15,94	16,96	11,70
Latin America	55,28	65,87	64,16	78,25	74,02	47,07	55,01	55,17	72,53	86,80	57,43

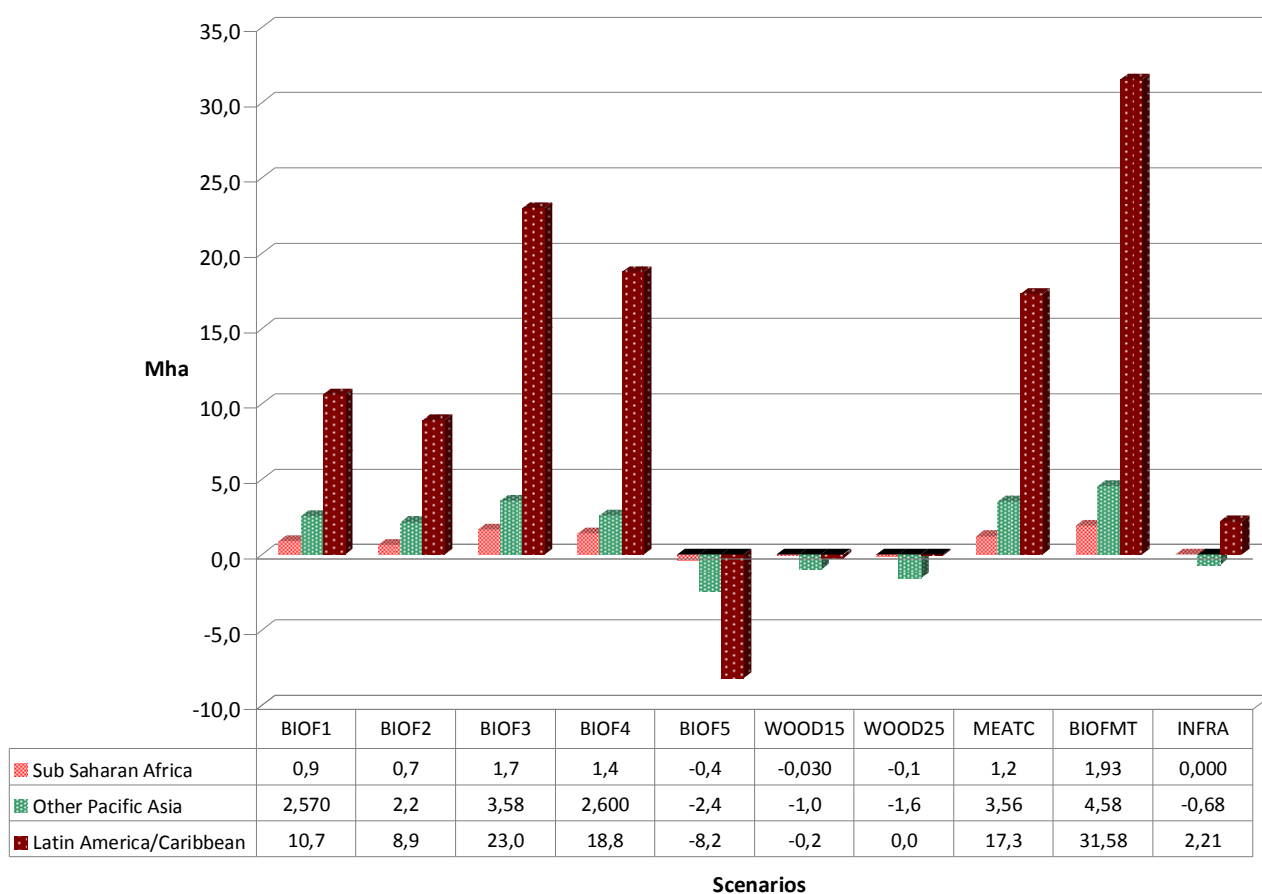
[Source: IIASA]

Table 8.2 No co-products – Percentile changes of deforested area without REDD between 2020 and 2030 against baseline

	Baseline	BIOF1	BIOF2	BIOF3	BIOF4	BIOF5	WOOD 15	WOOD 25	MEAT	BIOFMT	INFRA
Sub-Saharan Africa	0%	+16%	+12%	+30%	+25%	-6%	-1%	-2%	+34%	+34%	+/-0%
Pacific Asia	0%	+21%	+18%	+29%	+21%	-19%	-8%	-13%	+29%	+37%	-5%
Latin America	0%	+19%	+16%	+42%	+34%	-15%	+/-0%	+/-0%	+31%	+57%	+4%

[Source: IIASA]

Figure 8.2 No co-products – Impacts of policy shock scenarios on deforested area without REDD between 2020 and 2030 (Mha) compared to baseline



[Source: IIASA]

Table 8.3 No co-products – Indexed sequence of scenario policy shock rankings amongst selected regions

	Worst case 10th	9th	8th	7th	6th	5th	4th	3rd	2nd	Best case 1st
Sub-Saharan Africa	BIOFMT	BIOF3	BIOF4	MEAT	BIOF1	BIOF2	INFRA	WOOD15	WOOD25	BIOF5
Pacific Asia	BIOFMT	BIOF3	MEAT	BIOF4	BIOF1	BIOF2	INFRA	WOOD15	WOOD25	BIOF5
Latin America	BIOFMT	BIOF3	BIOF4	MEAT	BIOF1	BIOF2	INFRA	WOOD25	WOOD15	BIOF5

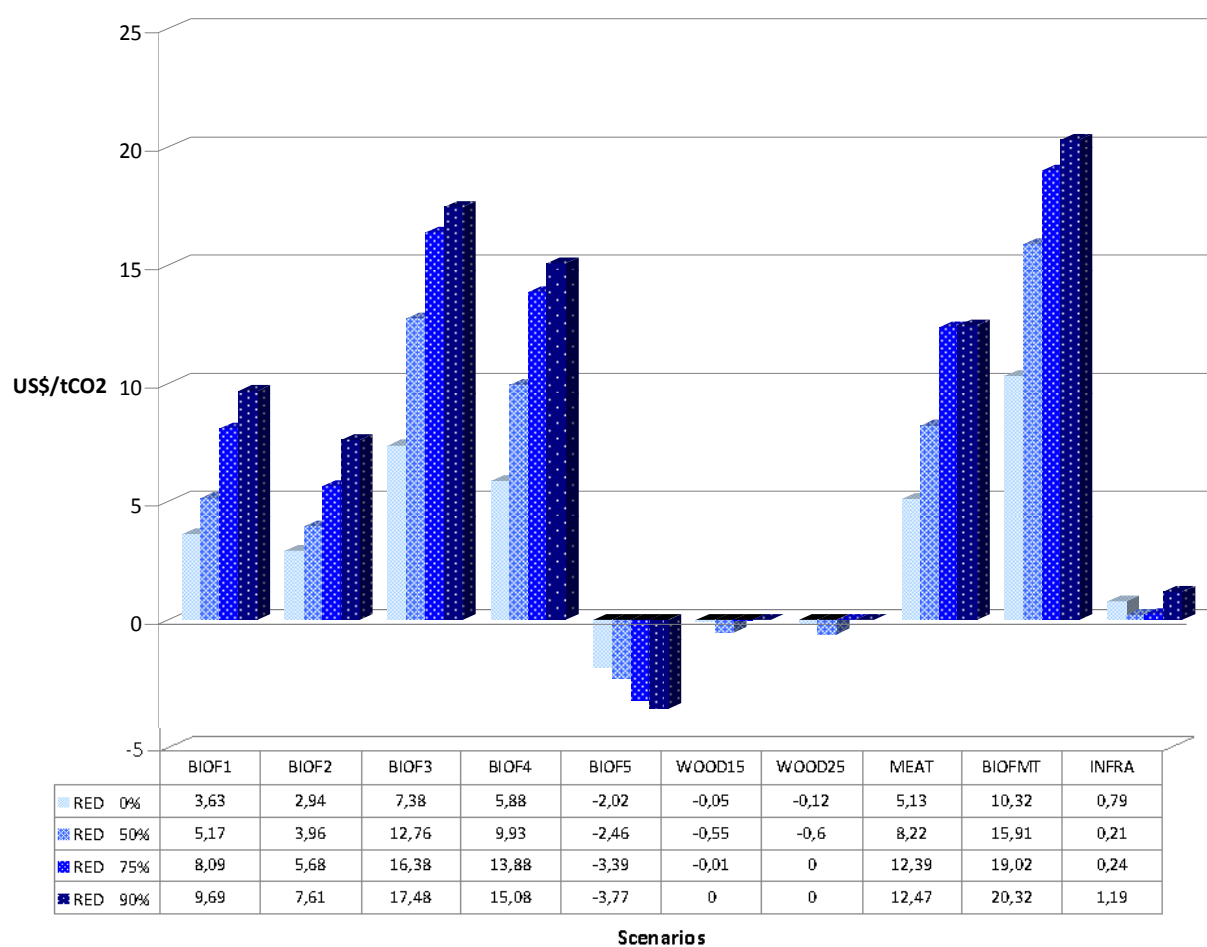
[Source: IIASA]

Table 8.4 No co-products – Marginal costs of RED under different policy shock scenarios in US\$/tCo2

	<i>Baseline</i>	BIOF1	BIOF2	BIOF3	BIOF4	BIOF5	WOOD15	WOOD25	MEAT	BIOFMT	INFRA
RED 0%	2,77	6,4	5,71	10,15	8,65	0,75	2,72	2,65	7,9	13,09	3,56
RED 50%	11,75	16,92	15,71	24,51	21,68	9,29	11,2	11,15	19,97	27,66	11,96
RED 75%	18,21	26,3	23,89	34,59	32,09	14,82	18,2	18,21	30,6	37,23	18,45
RED 90%	24,74	34,43	32,35	42,22	39,82	20,97	24,74	24,74	37,21	45,06	25,93

[Source: IIASA]

Figure 8.3 No co-products – Marginal costs of RED under different policy shock scenarios compared to baseline

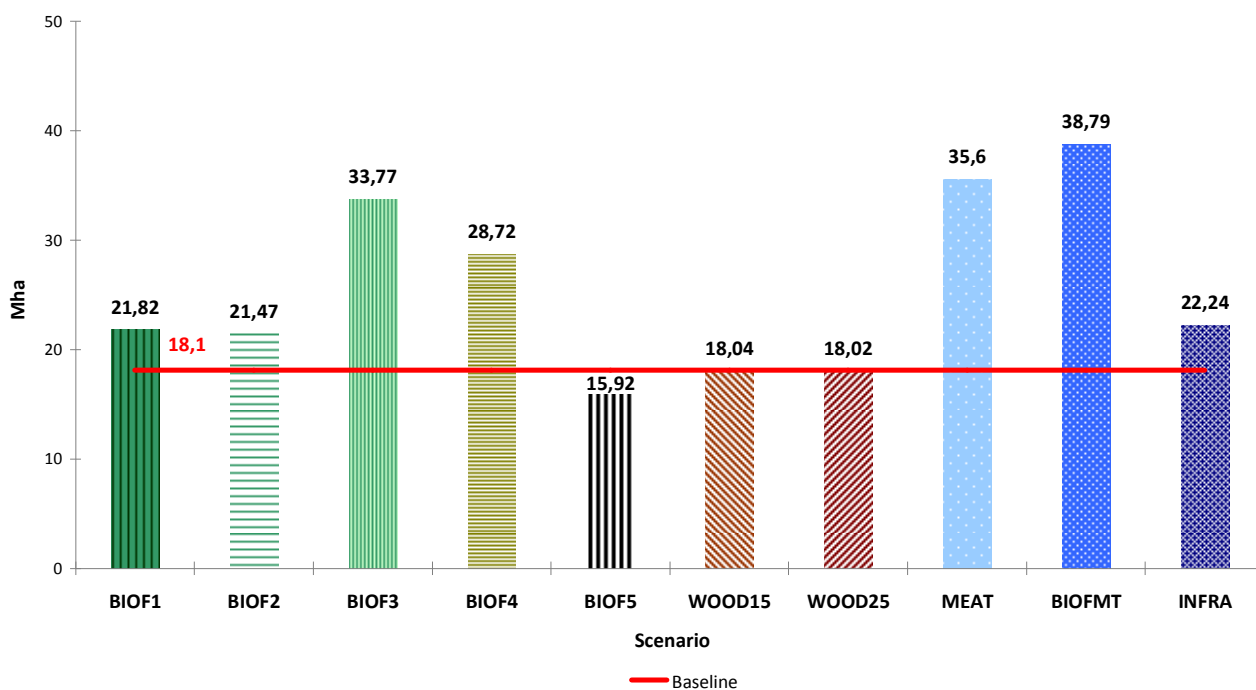


[Source: IIASA]

8.1.2 Best case for deforestation

The following tables and figures depict the best case range limit of the possible baseline scenarios.

Figure 8.4 Yield increase – Global deforested area without REDD between 2020 and 2030 (Mha)



[Source: IIASA]

Table 8.5 Yield increase – Deforested area without REDD between 2020 and 2030 in Mha for three hotspot regions

	Baseline	BIOF1	BIOF2	BIOF3	BIOF4	BIOF5	WOOD 15	WOOD 25	MEAT	BIOFMT	INFRA
Sub-Saharan Africa	3,61	3,94	3,91	4,17	4,21	3,27	3,58	3,58	4,18	4,61	3,35
Pacific Asia	4,95	5,95	5,95	7,33	6,94	4,30	4,95	4,95	8,92	9,91	4,56
Latin America	9,53	11,93	11,61	22,26	17,57	8,35	9,50	9,48	22,50	24,27	14,33

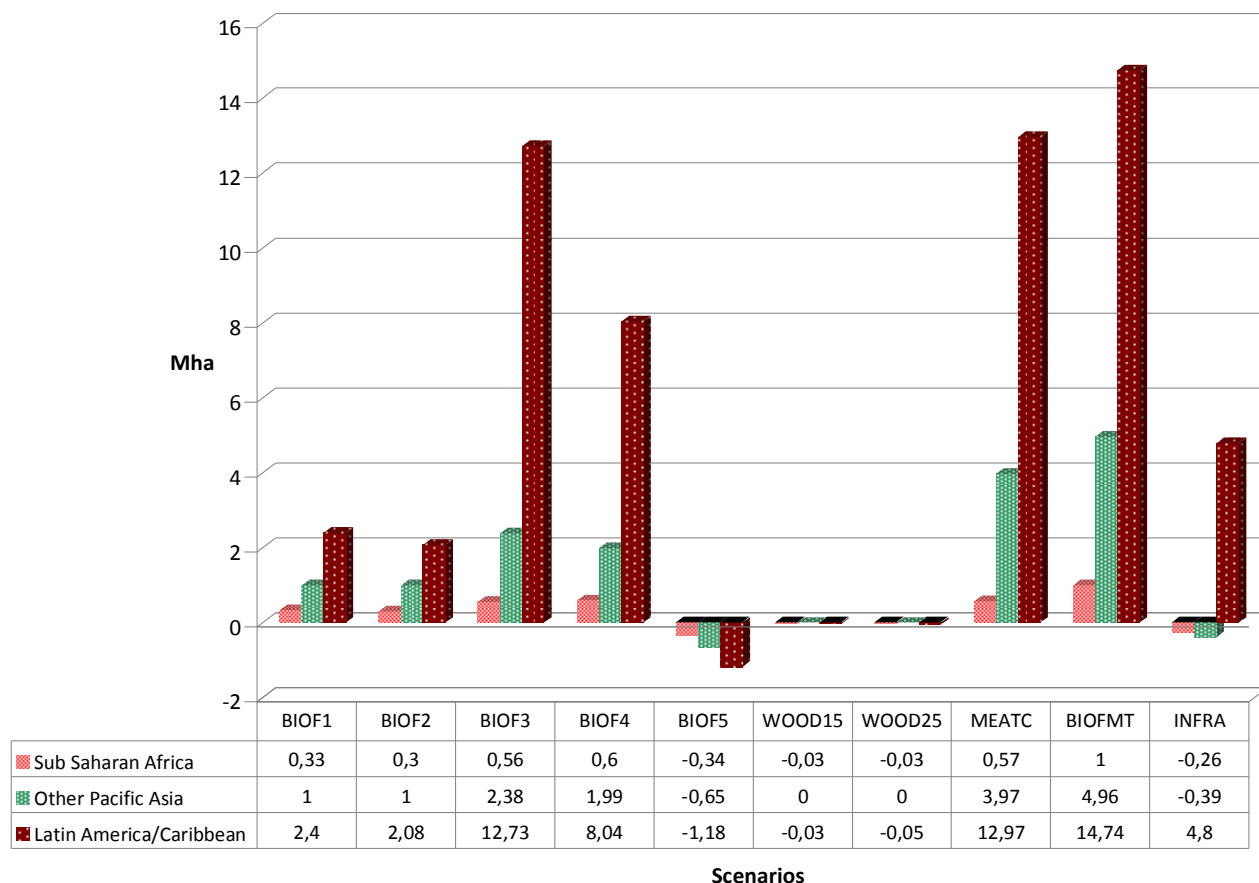
[Source: IIASA]

Table 8.6 Yield increase – Percentile changes of deforested area without REDD between 2020 and 2030 against baseline

	Baseline	BIOF1	BIOF2	BIOF3	BIOF4	BIOF5	WOOD 15	WOOD 25	MEAT	BIOFMT	INFRA
Sub-Saharan Africa	0%	+9%	+8%	+16%	+17%	-9%	-1%	-1%	+28%	+28%	-7%
Pacific Asia	0%	+20%	+20%	+48%	+40%	-13%	+/-0%	+/-0%	+80%	+100%	-8%
Latin America	0%	+25%	+22%	+134%	+84%	-12%	+/-0%	-1%	+136%	+155%	+50%

[Source: IIASA]

Figure 8.5 Yield increase – Impact of policy shock scenarios on deforested area without REDD between 2020 and 2030 (Mha) compared to baseline



[Source: IIASA]

Table 8.7 Yield increase – Indexed sequence of scenario policy shock rankings amongst selected regions

	Worst case 10th	9th	8th	7th	6th	5th	4th	3rd	2nd	Best case 1st
Sub-Saharan Africa	BIOFMT	BIOF4	MEAT	BIOF3	BIOF1	BIOF2	WOOD15	WOOD25	INFRA	BIOF5
Pacific Asia	BIOFMT	MEAT	BIOF3	BIOF4	BIOF1	BIOF2	WOOD15	WOOD25	INFRA	BIOF5
Latin America	BIOFMT	MEAT	BIOF3	BIOF4	INFRA	BIOF1	BIOF2	WOOD15	WOOD25	BIOF5

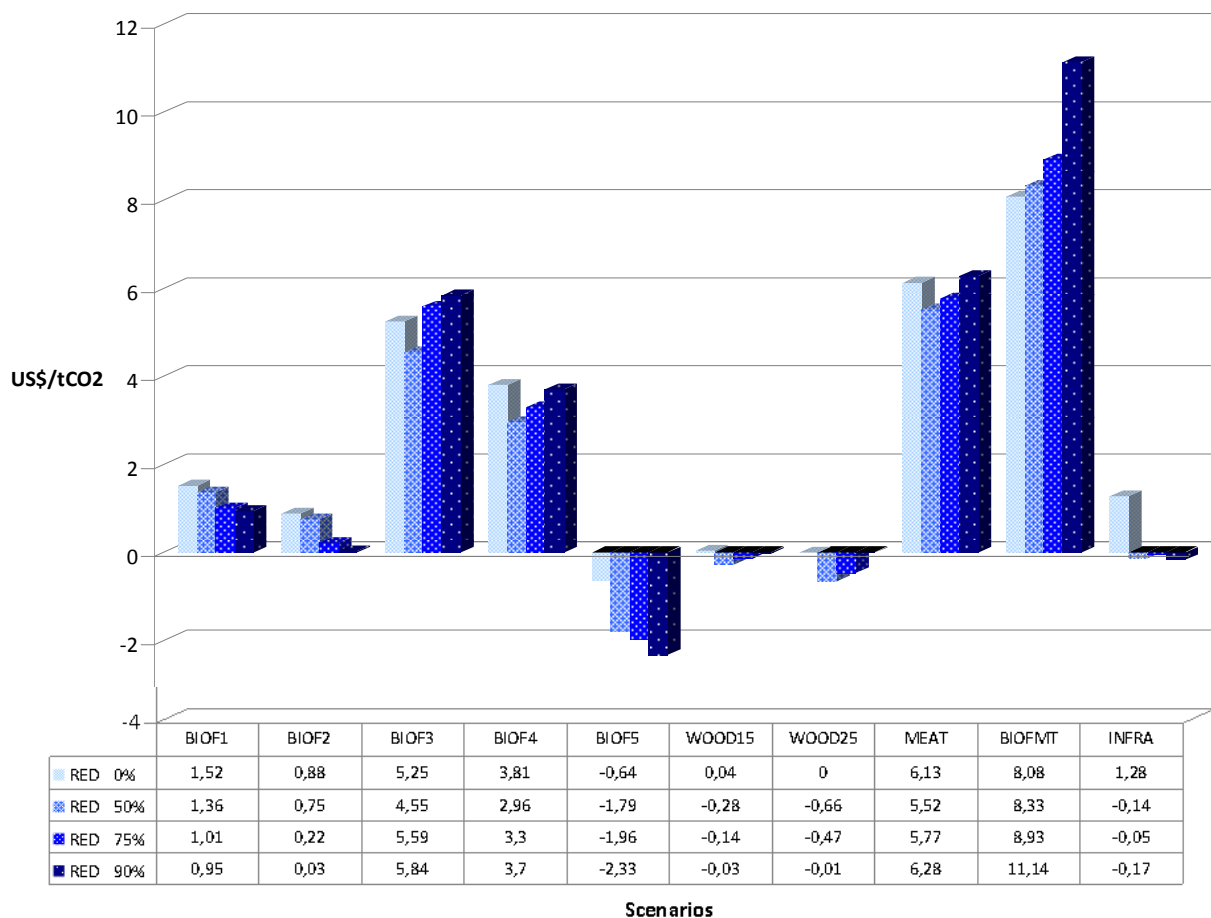
[Source: IIASA]

Table 8.8 Yield increase – Marginal costs of RED under different policy shock scenarios in US\$/tCo2

	Baseline	BIOF1	BIOF2	BIOF3	BIOF4	BIOF5	WOOD15	WOOD25	MEAT	BIOFMT	INFRA
RED 0%	0,92	2,44	1,8	6,17	4,73	0,28	0,96	0,92	7,05	9	2,2
RED 50%	6,43	7,79	7,18	10,98	9,39	4,64	6,15	5,77	11,95	14,76	6,29
RED 75%	9,76	10,77	9,98	15,35	13,06	7,8	9,62	9,29	15,53	18,69	9,71
RED 90%	11,84	12,79	11,87	17,68	15,54	9,51	11,81	11,83	18,12	22,98	11,67

[Source: IIASA]

Figure 8.6 Yield increase – Marginal costs of RED under different policy shock scenarios compared to baseline



[Source: IIASA]

8.2 Additional information for biodiversity protection scenario

8.2.1 Classification of current and future protection status

To assess potential impacts on deforestation and marginal costs of avoided deforestation, baseline protection levels are juxtaposed to those in 2030 under the policy shock of 20% additional biodiversity protection.

Current protection status

The geographic location and classifications of currently protected areas are based on the World Database on Protected Areas (UNEP-WCMC, 2009). The current classification of protected areas was then reclassified according to protection statuses: high-very high protection and middle-low protection status. The International Union for Conservation of Nature (IUCN) classes Ia, Ib, II, IV and international and national government managed protected areas (e.g. World Heritage Convention, United Nations Educational Scientific and Cultural Organisation programme on Man and the Biosphere Reserve, Ramsar Convention area, wildlife reserves) are grouped into the category of high-very high protection status. Whereas the IUCN classes III, V, VI and all other categories (e.g. forest park, wildlife management area) are classified into middle-low protection status category.

The classification used in this study is based on management objectives for conserving biodiversity provided by IUCN (1994) and the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (2003). Their guidelines are compared in the table below.

Table 8.9 Comparison of MCPFE and IUCN classes (MCPFE, 2003)

MCPFE Classes		EEA*	IUCN**
1. Main Management Objective 'Biodiversity'	1.1 'No Active Intervention'	A	I
	1.2 'Minimum Intervention'	A	II
	1.3 'Conservation through Active Management'	A	IV
2. Main Management Objective 'Protection of Landscapes and Specific Natural Elements'		B	III, V, VI
3. Main Management Objective 'Protective Functions'		(B)	n.a.

* References as identified in the Standard Data Form of the Natura 2000 and Emerald networks and used in the same way in the framework of the Common Database on Designated Areas (CDDA), managed by the EEA on behalf of two other organizations (Council of Europe and UNEP-WCMC). The groups (A, B or C) are related to designation types and not to individual sites.

** Indicative reference:

- The equivalence of IUCN Categories may vary according to the specific management objective (of the forested part) of each individual protected area. A technical consultation process with IUCN and its World Commission on Protected Areas (WCPA) is underway to ensure full comparability between the MCPFE and IUCN systems.
- IUCN Categories III, V and VI have biodiversity conservation as their primary management objective. However, they fit more easily under MCPFE Class 2 than 1.
- The area of forest and other wooded land assigned to the classes 1 and 2 should not be summed up with the data collected under class 3 to avoid double counting.

Projected protection status: baseline

The projected protection area has originally been created for global biomass assessment by the Dutch Planbureau voor de Leefomgeving (PBL) (Lysen et. al, 2008). In their database there are two reference years of protected area projections (2030 and 2050), which are based on the Sustainability First Scenario designed by Lera Miles (WCMC). The WCMC Sustainability First Scenario assumes an expansion of the terrestrial network of protection areas to 10% of all biomes. In addition, all areas where single-site endemic species occur become protected by 2025. By 2050 the terrestrial network area under protection for all biomes is assumed to expand to 20%. The new sites allocations assume different degrees of protection: as 30% full and successful protection, 65% under sustainable use regulations, and 5% under failed protection.

The projected protection area is classified by the protection status (simplified from IUCN classes) in the data set:

1. Fully protected, no use is allowed;
2. Protected, but sustainable use of area is allowed; and
3. Protection failed, these areas in practice are not protected at all (not considered).

Failure indicates that there is no barrier to land use change in this protected area. In the Sustainability First scenario, the new protected areas are first allocated to priority areas for biodiversity to attain at least 10% of each biome/region combination. Additional areas are then allocated to cover single-site endemic species that have not captured, based upon the Alliance for Zero Extinction (AZE) point dataset. These additional areas are circles of equivalent size to that specified in the AZE dataset, thus giving an artificial appearance to the scenario data. The coverage of some biomes is therefore expanded to greater than 20% by 2025 within these two scenarios.

For this study, the 2050 protected area projection by PBL is assumed as the status of 2030 under the Sustainability First Scenario. In order to maintain consistency across the current and projected biodiversity scenarios, the variation of the future protection statuses shown above has been considered as one category, i.e. future protection area, rather than distinguishing between the types of future protection.

8.3 Congo Basin case study on governance development

Governance as well as other policy factors and corresponding institutional change are crucial drivers for land use patterns. Currently these patterns are, however, poorly understood and hardly measurable. The Congo Basin lends itself as a suitable case study area as governance levels are currently rather low compared to other parts of the world and thus there is room for projecting considerable improvements in governance in the future.

To assess the impact of changing governance, the improved governance scenario (governance development takes place and policy factors improve over time) is compared to the baseline under constant governance (no governance development over the next decades).

Within each set of scenarios, two baseline deforestation scenarios were assessed– these are based on two different reference datasets and one has a higher innate deforestation rate than the other:

- BAU 1 Scenario (A) is based on a data set, which was reported by countries to The Global Forests Resource Assessment (FRA) from FAO (FAO, 2001). According to FRA, it can be estimated that in tropical countries approximately 0.60% of forests were converted per year between 1990 and 2000 and 0.63% between 2000 and 2005. BAU 1 Scenario (A) assumes that forests in tropical regions (between 23.4 N and 23.6 S) are deforested at a rate of approximately 1 % annually. The G4M model is calibrated with the countries' net forest area change based on average FAO-FRA 2000-2005 figures. Then the model is forced to follow a deforestation rate of about 1 %/year (compared to 2000) for all tropical forests. In the model decisions on deforestation and deforestation rate in a grid cell with higher resolution (approximately 15 x 15 km at the equator) are made by taking into consideration a comparison of forestry and agriculture net present values, population and gross domestic product in the cell.
- The deforestation rate of BAU2 Scenario (B) is originated from a historical remote sensing data. This deforestation rate is slightly lower than BAU 1 Scenario (A) and the projected protection area is considered to preserve some forested area for biodiversity conservation. The deforestation rate of the current forest cover is spatially distributed in the G4M model.

In the scenario analysis -with and without changing governance-, the effects of incentive payments (Carbon price in USD/tC) on the deforestation rates were assessed. In total, 5

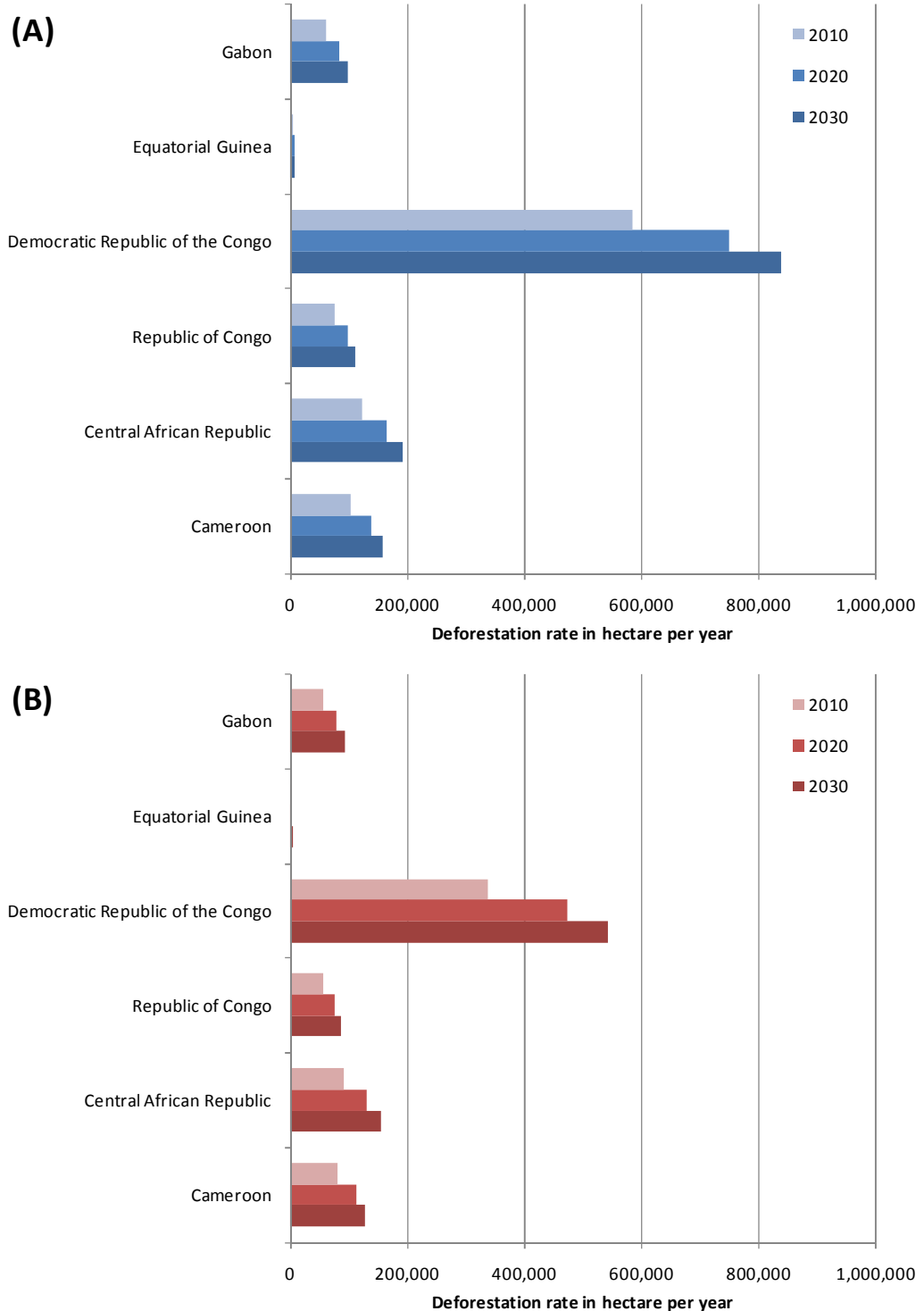
different prices were considered to evaluate the effects: 0 USD/tC (business-as-usual), 3 USD/tC, 10 USD/tC, and 25 USD/tC. The incentive payment is arranged every 5 years starting from 2013.

8.3.1 Deforestation rates under constant governance development

The modelling results for the constant governance scenario (constant hurdle rates) show deforestation levels without REDD and with REDD at 10\$/tC. Constant governance is defined as continued deforestation as to the latest FAO deforestation rates, while other drivers including governance are assumed constant.

Both BAU scenarios are calculated for 6 Congo Basin countries (Cameroon, Central African Republic, The Democratic Republic of the Congo, Equatorial Guinea, Gabon, and Republic of Congo) in 2010, 2020 and 2030. The comparison of deforestation rates between the two scenario variants for each country is highlighted in the figure below (business-as-usual with constant governance).

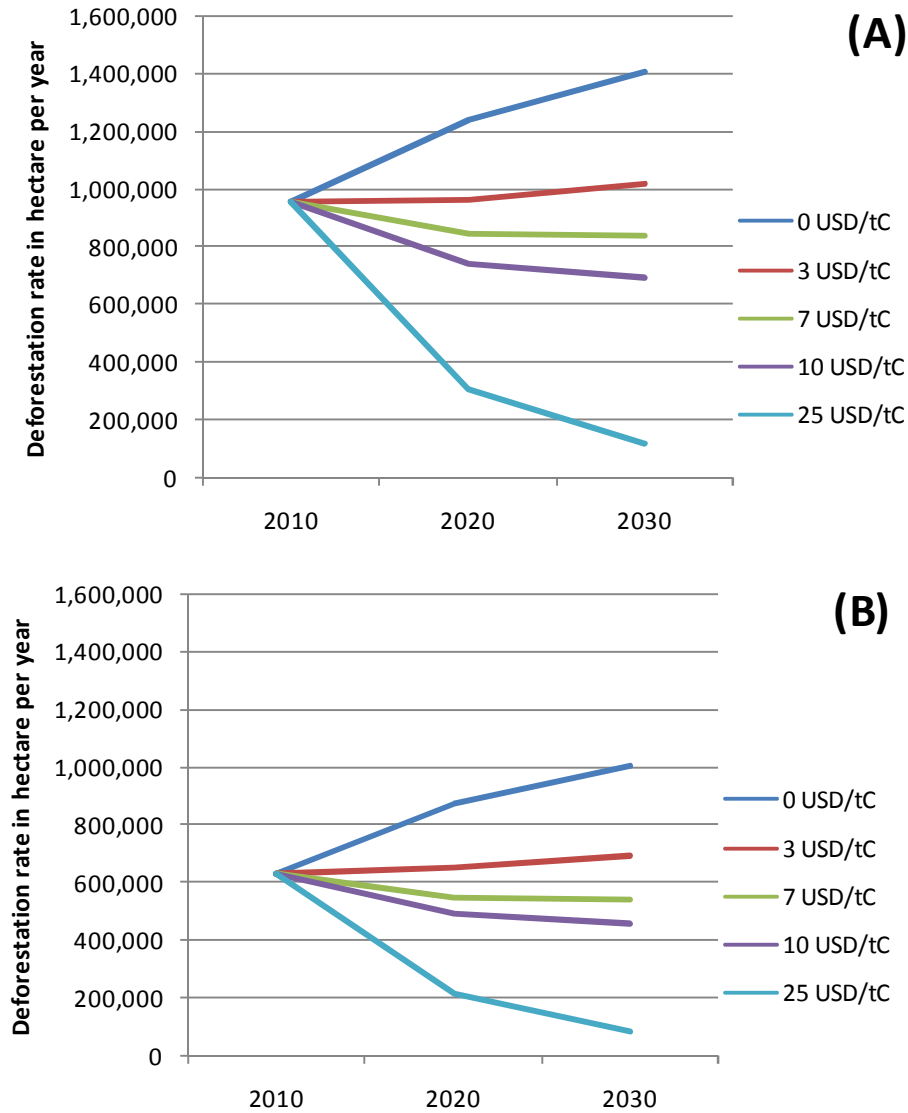
Figure 8.7 Estimated deforestation rates in the 6 Congo Basin countries for 2010, 2020 and 2030 for BAU 1 Scenario (A) and BAU 2 Scenario (B) without incentive payments (business as usual under constant governance)



[Source: IIASA]

The next figure shows the effects of incentive payment with different carbon prices (USD/tC) for the two BAU scenario variants under constant governance in the Congo Basin countries (total deforestation rate). The deforestation rate is decreasing by increasing incentive payment.

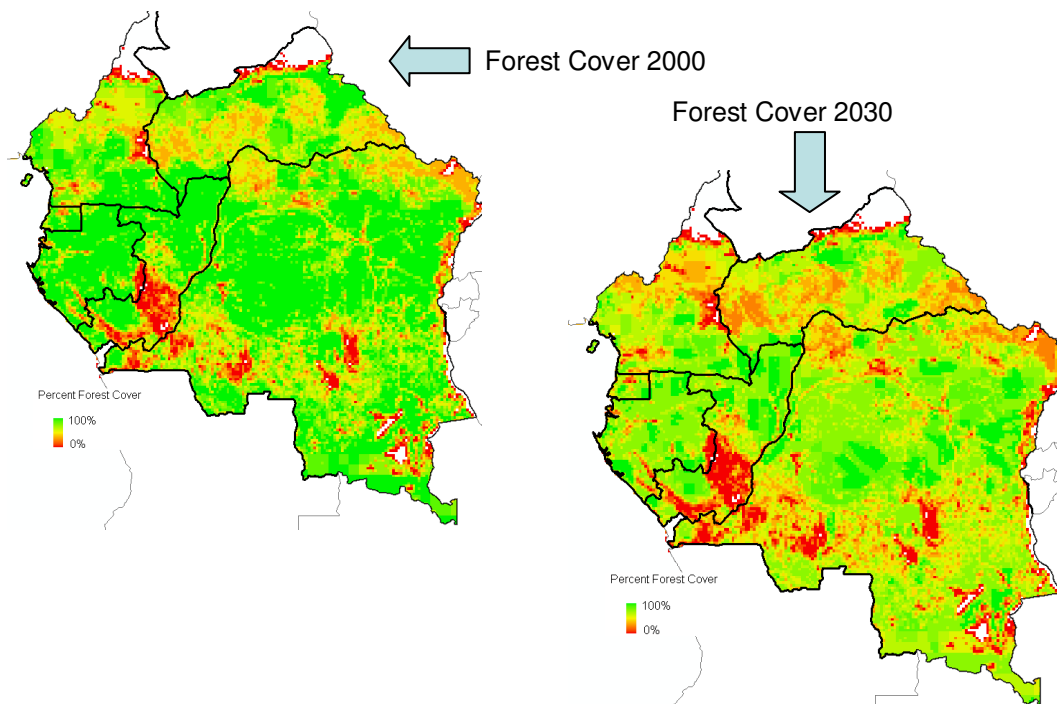
Figure 8.8 Effects of incentive payment (carbon price in USD/tC) on deforestation rates in the Congo basin (6 countries) in 2010, 2020 and 2030 under BAU 1 Scenario (A) and BAU 2 Scenario (B)



[Source: IIASA]

Having a closer look at what these overall figures mean in a geographic context, Figure 8.9 indicates that the BAU scenario without REDD shows significant deforestation particularly in the southern and central regions of the Republic of the Congo, the north western tip of Angola and the central regions of the Democratic Republic of the Congo. A further area with decreased forest cover by 2030 is the most northern reaches of the basin in the Central African Republic.

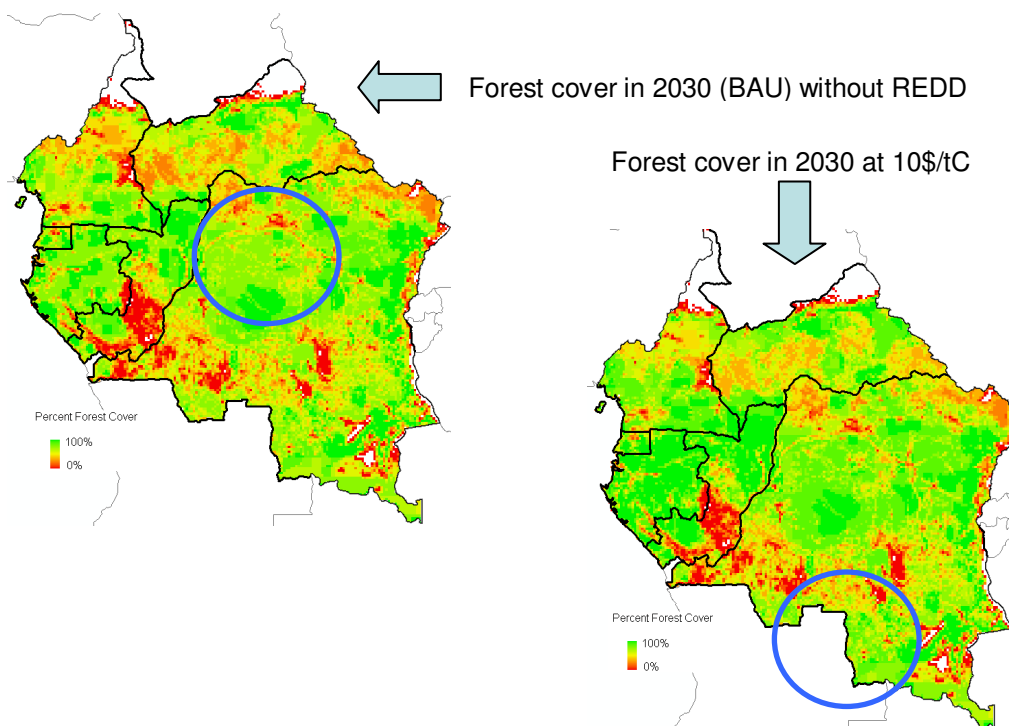
Figure 8.9 Congo Basin: change in forest cover 2000 versus 2030 according to FAO scenario (BAU)



[Source: IIASA]

When comparing this BAU scenario with the one including a REDD scheme at 10\$/tC at constant development of governance (Figure 8.10), only a small incremental improvement can be observed as to the percentage of forest cover remaining by 2030.

Figure 8.10 Congo Basin: difference in forest cover in 2030 according to FAO BAU scenario and REDD scenario (10 \$/tC)



[Note: Blue circles highlight apparent differences]

[Source: IIASA]

8.3.2 Deforestation rates under changing governance and other policy factors

The next step is to model changes in governance, i.e. improvements in institutional accountability and other policy factors and to assess their impact on deforestation rates. The governance scenarios are modelled by overlaying them on top of the two previous business-as-usual deforestation scenarios (BAU1 and BAU2). We considered the effects of governance by using hurdle rates over time, which represent net present values of forestry decreasing in time.

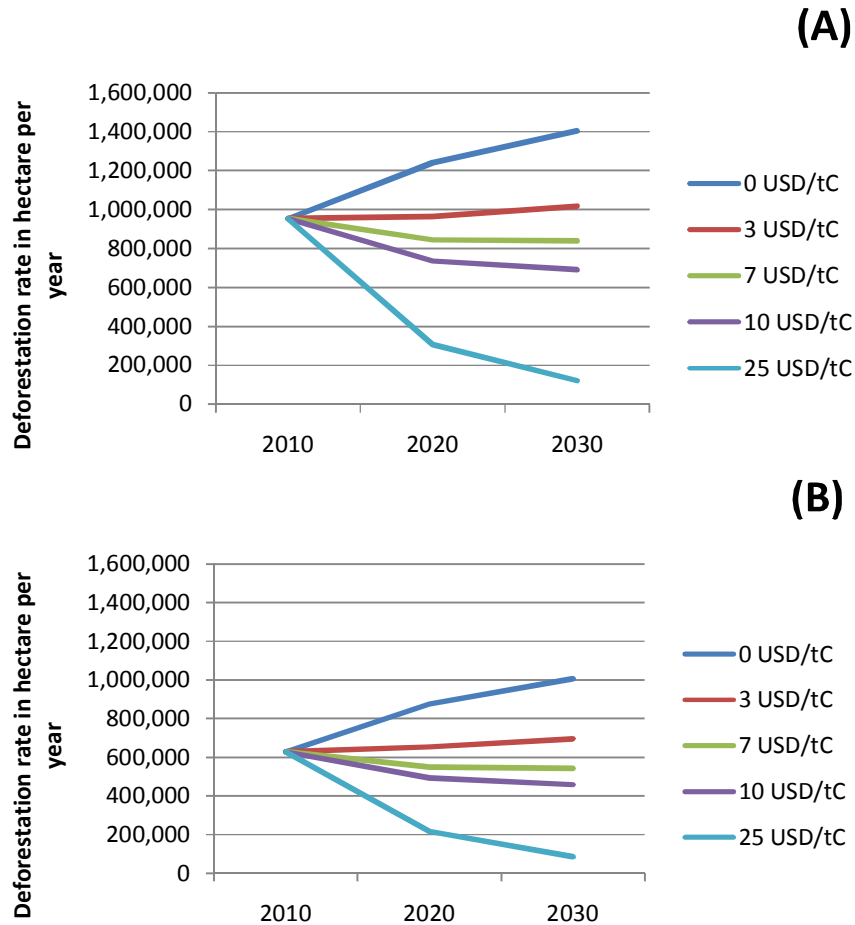
Table 8.10 Applied hurdle rates for the Congo Basin countries in 2010, 2020 and 2030

Hurdle rates	2010	2020	2030
Cameroon	100%	79.4%	82.6%
Central African Republic	100%	77.9%	81.0%
Congo	100%	78.4%	81.5%
Democratic Republic of the Congo	100%	78.3%	81.6%
Equatorial Guinea	100%	87.0%	90.4%
Gabon	100%	78.4%	81.8%

[Source: IIASA]

Figure 8.11 shows the effects of incentive payment under different carbon prices (USD/tC) on deforestation rates. This time it includes the effects of governances (hurdle rates). However, the difference between Figure 8.8 and Figure 8.11 is minimal because the model is forced heavily.

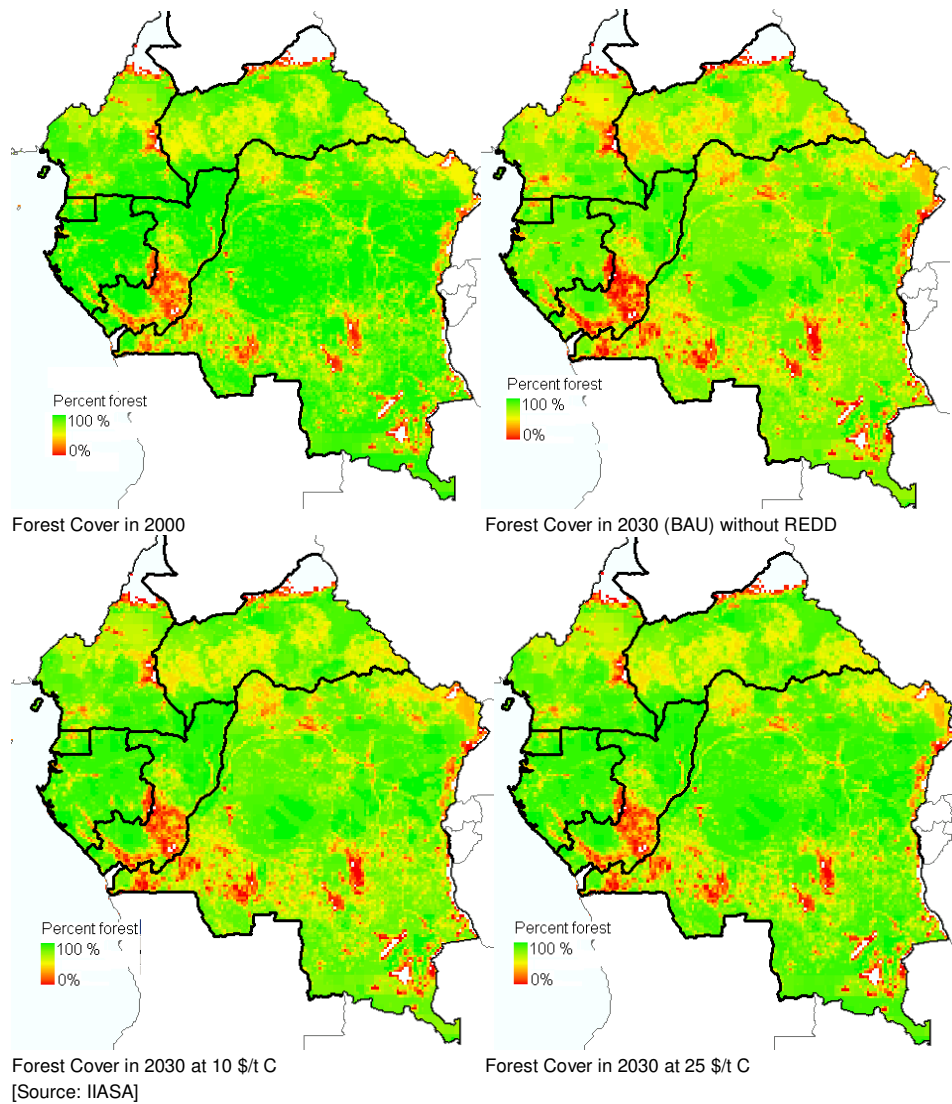
Figure 8.11 Effects of incentive payment (carbon price in USD/tC) on deforestation rate in the Congo Basin (6 countries) with governance development scenario in 2010, 2020 and 2030 of deforestation BAU 1 Scenario (A) and BAU 2 Scenario (B)



[Source: IIASA]

The following figure maps the predicted governance policy shock effects in a geographically explicit manner. As can be seen from this figure, a changing governance scenario including a REDD scheme can help prevent some deforestation by 2030.

Figure 8.12 Forest cover projections under different governance scenarios, 2000 and 2030



8.3.3 Comparing constant and changing governance scenarios

The following tables depict the above graphical results in precise numbers. When comparing the two constant governance BAU scenarios with those of changing governance, only little variation in terms of less deforested area under a variety of carbon prices is seen. Numbers that differ are marked in bold.

Table 8.11 Deforestation rates in hectares per year for various governance scenarios

Deforestation rate in hectare per year at different carbon prices in the 6 Congo basin countries					
Year \ US\$/tCO ₂	0 US\$/tCO ₂	3 US\$/tCO ₂	7 US\$/tCO ₂	10 US\$/tCO ₂	25 US\$/tCO ₂
BAU 1 Scenario (A) results under constant governance					
2010	953.839	953.839	953.839	953.839	953.839
2020	1.241.068	963.916	845.514	736.297	306.994
2030	1.404.202	1.017.381	839.609	691.218	121.182
BAU 1 Scenario (A) results under changing governance					
2010	953.839	953.839	953.839	953.839	953.839
2020	1.241.068	963.916	845.514	736.304	306.994
2030	1.404.202	1.017.381	839.609	691.218	121.192
BAU 2 Scenario (B) under constant governance					
2010	627.818	627.818	627.818	627.818	627.818
2020	875.672	653.583	550.304	491.673	215.043
2030	1.007.228	695.806	542.219	457.092	82.783
BAU 2 Scenario (B) under changing governance					
2010	627.818	627.818	627.818	627.818	627.818
2020	875.672	653.672	550.385	492.447	215.757
2030	1.007.228	696.036	542.608	458.575	84.498

[Source: IIASA]

The relatively minor impact of the governance shock scenario in the Congo Basin can be seen in this table. This relatively minor effect can be explained by the fact that already under the BAU 1 and 2 scenario variants (constant governance), deforestation rates based on FAO and remote sensing data are extremely high and improvements in governance do not make a major difference in terms of reducing deforestation. The little difference appears as a “model artefact” due to calibration of the model to follow a historical BAU path. The model is not informed by “true” driver information and can, thus, not react to changes in parameters that mimic governance. Therefore, a different governance assessment methodology will need to be developed to assess changes in governance. This would include detailed field studies on how to eliminate practices of illegal logging, their drivers and geography.

9 Annex D: Supporting information

This annex provides additional more detailed information for some aspects of the report, including bioenergy policies as an indirect driver as well as more detailed analysis of governance drivers in each region.

9.1 Supporting information on bioenergy policies as global indirect drivers

EU legislation

After the EU had introduced its first directive on the promotion of the use of biofuels in 2003 and therewith set specific targets for the use of biofuels, the European energy strategy, which was presented in January 2007, reaffirmed the aim for a share of 10 percent biofuels use in overall energy used for transportation by 2020. The Renewable energy directive, adopted in December 2008, sets a mandatory target of 10% renewable energy in transport. Biofuels are expected to provide most of this target. These directives state that biofuels ought to be subsidized and their use enforced through agricultural subsidies, total or partial de-taxation and legally binding biofuel obligations.

The revised Fuel Quality Directive includes a mandatory reduction of 6% of the lifecycle greenhouse gas emissions of fuels supplied to the EU. This includes greenhouse gas savings from biofuels. Both the Fuel Quality Directive and the Renewable Energy Directive include a set of sustainability criteria for biofuels, which include a ban on certain direct land use changes (forest, wetlands, undrained peatlands) and the direct land use change emissions are included in the lifecycle greenhouse gas calculation.

North American legislation

Similar to the trend in Europe are US policies in favor of biofuel generation through extensive corn cultivation and subsidization. Examples of policy initiatives to promote bioenergy include:

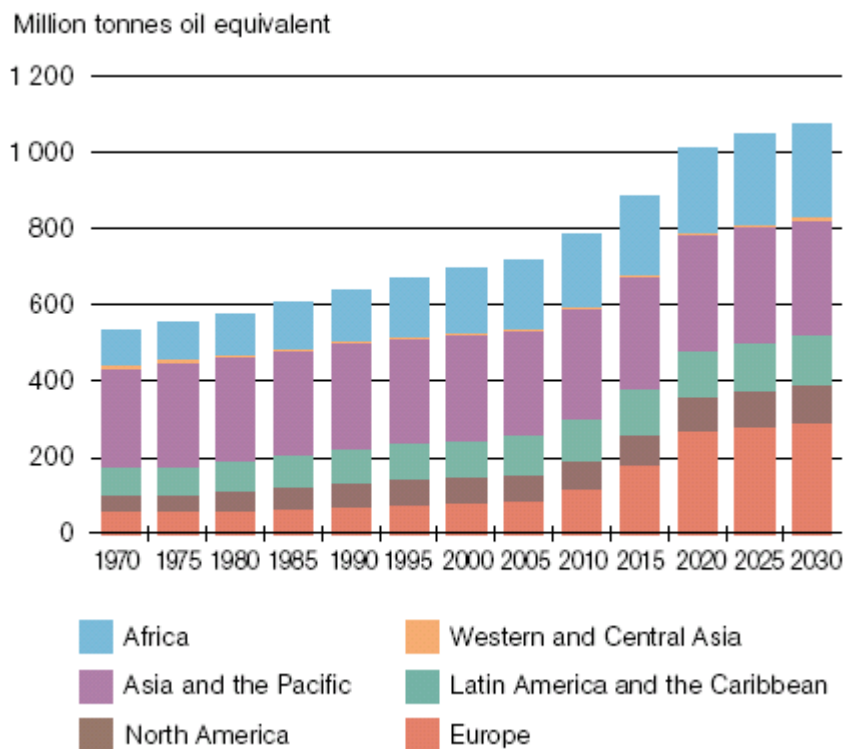
- US “Biofuels Initiative (2006)” aiming to make cellulosic ethanol cost competitive by 2012 and replacing 30% of current petrol consumption with biofuels by 2030.
- US “Energy Independence and Security Act (2007)” setting targets for biofuel use (including wood-derived biofuels) to 2022 and for a national fuel economy standard of 15km per litre by 2020.
- Canadian “Clean Air Agenda (2006)” setting federal emission targets, allocating resources for the ecoENERGY for Renewable Power programme and promoting blended transportation fuels.

- Canadian “Regulatory Framework for Air Emissions” using carbon credits to encourage renewable power production through cogeneration.
- The Mexican “Law for the Promotion and Development of Bioenergy (2008)” aiming to promote biomass energy without compromising food security.

Trends and projections for bioenergy production

Trends and projections for biomass energy production reveal an increase in global production from about 530 million tonnes oil equivalent (MTOE) in 1970 to about 720 MTOE in 2005 and likely reaching 1075 MTOE in 2030 (combination of data sources from FAO and International Energy Agency).

Figure 9.1 Global production of energy from biomass, 1970-2030



[Note: 1 tonne of oil equivalent is equal to approximately 4m³ of wood. Figures include the use of black liquor, agricultural residues and dung in addition to wood.]

[Source: FAO, 2009]

Table 9.1 Global bioenergy production trends and projections, as total amount and average annual change

Region	Amount (MTOE)					Average annual change (%)			
	Actual			Projected		Actual		Projected	
	1970	1990	2005	2020	2030	1970-1990	1990-2005	2005-2020	2020-2030
Africa	87	131	177	219	240	2.1	2.0	1.4	0.9
Latin America and the Caribbean	70	88	105	123	133	1.1	1.2	1.1	0.8
Pacific Asia	259	279	278	302	300	0.4	0.0	0.6	-0.1
Europe	60	70	89	272	291	0.7	1.6	7.7	0.7
North America	45	64	65	86	101	1.8	0.1	2.0	1.6
Western and Central Asia	11	7	6	8	10	-2.7	-1.0	2.4	1.9
World	532	638	719	1010	1075	0.9	0.8	2.3	0.6

[Note: MTOE = million tonnes of oil equivalent]

[Source: FAO, 2008]

Increased bioenergy production directly and indirectly impacts on forests: on the one hand, competing land uses may lead to deforestation for clearing land for bioenergy crop plantations; on the other hand, recent interpolation also suggests that wood used directly for bioenergy production increased from about 2 billion cubic metres in 1970 to 2.6 billion cubic metres in 2005 (FAO, 2009). Thinking further along these trajectories, up to 3.8 billion cubic metres of wood could be required by 2030, if relative shares of various bioenergy inputs remain stable. However, some of the future demand may be satisfied by biomass from agricultural residues and energy crops.

Historic increases in global biomass energy production up to 2005 occurred mainly in developing countries (with exception of Pacific Asia where biomass energy production declined due to switching to preferred types of energy as a result of increasing income), because wood is still used as a primary fuel source.

Future projections, on the other hand, predict a significant and rapid increase in the use of biomass for energy production in Europe and, to a lesser extent, North America as renewable energy policies and targets set for 2020 come into effect. Europe's per capita biomass energy use, for example, is projected to triple by 2020 as a consequence of the renewable energy targets. It should be stated, however, that some of this production will also come from agricultural residues and energy crops. Aiding to the strain that this significant increase in bioenergy production will likely put on the forests worldwide, future large-scale commercial production of cellulosic biofuels could increase the demand for wood even further and well beyond that shown in the projections above. Under such scenarios, low and middle-income forest-rich countries will experience continued forest decline primarily attributable to a combination of the expansion of agriculture (including the production of biofuels feedstock) and increased demand for wood as a direct source for bioenergy.

9.2 Detailed information on governance drivers per region

Changes in institutional and governance drivers

In order to provide a framework for assessing policy and governance change, a ‘light version’ of existing governance theories will be applied for drafting realistic scenarios. The assessment framework will thus be based on governance theory, i.e., be structured along the three dimensions of governance (multi-actor, multi-sector and multi-level, based on the United Nations Conference on Environment and Development (UNCED) Agenda 21, see e.g., Pierre 2000). It will use the widely applied Institutional Analysis and Development Framework (IAD) (Ostrom et al., 1994; Ostrom, 2005) as well as the “good governance” principles (Kauffman et al., 2005; Sudders and Nahem, 2004) as the basis for further structuring elements to capture main institutional⁷, economic⁸, and performance aspects of policy change options⁹.

The World Bank-supported research project publishes indicators for the level of governance in each country worldwide. These are available for 1996, 1998, 2000, and every year for 2002 and 2005 (Kaufmann et. al, 2008). The indicators express six dimensions of governance. In the report we will refer to these dimensions of governance when describing the drivers. The six indicators are (YSSP Report):

1. Voice and Accountability: indicates the level of participation of a country’s citizens in political decisions.
2. Political Stability: describes the stability of the existing government.
3. Government Effectiveness: represents the quality and reliability of government’s services and policies.
4. Regulatory Quality: measures the ability of the government to formulate and implement policies.
5. Rule of law: judges the effectiveness of society’s rules.
6. Control of Corruption: decides the degree of corruption to be controlled.

9.2.1 Africa

Voice and accountability: According to the World Bank’s Worldwide Governance Indicators from 1996 to 2007, many African countries score very poor as far as voice and accountability is concerned. The Democratic Republic of Congo, Zimbabwe and Sudan face an extremely poor worldwide ranking regarding this indicator (The World Bank, 2008).¹⁰ All three countries are ranked among the lowest decile (10%) of all countries in the world.

⁷ E.g.: governance structures, processes, scope, compliance mechanisms, non-compliance rules, policy and governance quality dimensions such as policy and institutional feasibility, policy coherence and compatibility with existing policies, actor inclusiveness.

⁸ E.g.: financing establishment, transaction costs, etc.

⁹ Critical elements for performance include e.g., Rewarding real reductions in emissions (additionality, leakage), Long term sustainable land management, Strengthening of institutions and support of legal framework, Recognition of existing commitments, Availability and mobilizing of resources, Acknowledgement of local circumstances, Simplicity, flexibility and practicability, Consistency with existing monitoring and accounting approaches, Linkage to national programmes, Promoting synergies, Encouragement of early action (possibility of early action).

¹⁰ The governance indicators presented in the Report “Governance Indicators 1996-2007” present aggregated views on the quality of governance provided by a large number of enterprise, citizen and expert survey respondents in industrial and developing countries. These data are gathered from a number of survey institutes, think tanks, non-governmental organizations, and international organizations.

Political stability: Africa has a history of civil wars with devastating consequences for society and natural resources. The bulk of the remaining rainforest in Central Africa is found in the Congo Basin, an area highly affected by internal displacement of people. Recently these forests have been increasingly threatened by large crowds of refugees fleeing rebel forces in the Democratic Republic of Congo and the movement of local militias. These large movements of people affect the forest resources in the area, which are used to provide energy to satisfy basic needs including cooking and lighting.

Regulatory quality: Once again, according to the World Bank's Worldwide Governance Indicators from 1996 to 2007, many African countries score very poor as far as government effectiveness and regulatory quality are concerned. Again the ranking reveals that the Democratic Republic of Congo, Zimbabwe and Ivory Coast face an extremely poor worldwide ranking regarding these indicators, ranking in the lowest decile (10%) of worldwide countries (The World Bank, 2008).

During the past two decades Africa has witnessed significant political changes, though these changes must be characterised as slow (African Development Bank, 2003). If government forestry agencies that have historically dominated the forestry policy scene fail to adapt to the changes, they risk losing their influence. "Adapting forestry institutions to rapid changes in the larger environment is a major challenge", says Jan Heino, Assistant Director-General of FAO's Forestry Department. "Of particular importance is the need to re-invent public sector forestry agencies that have been slow in adapting to changing customer needs" (FAO, 2009). This results in poor inter-sectoral linkages where high-priority sectors, such as agriculture, mining, industrial development and energy, effectively have a greater impact on forests than forest policy itself.

Land tenure arrangements are important indirect causes for deforestation and an example of a forest related regulation influencing the deforestation rate. Insecure ownership related to uncertainties of land tenure, which drives the shift from communal to private property, is a common pattern in Africa. (Geist and Lambin 2002)

Rule of law: The majority of African countries rank within the 25th and 50th percentile and a large number of countries rank within the lowest decile (10%). These countries are Nigeria, Angola, Sudan, the Democratic Republic of Congo, Zimbabwe and Ivory Coast (The World Bank, 2008).

Corruption: Countries such as Angola, Sudan, Ivory Coast, the Democratic Republic of Congo and Zimbabwe are rated very poorly on a worldwide scale and rank in the lowest decile.

9.2.2 Latin America and the Caribbean

Voice and Accountability: Another aspect, as far as governance of environmental and forest policies are concerned, is the lack of participation of social organizations, indigenous people, black people and peasant communities in policy design and implementation (Manta Nolasco, 2007). It is argued that the knowledge potential of

indigenous people related to forest land and environmental maintenance is not taken into account by not actively involving these communities in the policy making process (Manta Nolasco, 2007). Furthermore, the indigenous groups and organic cultural regimes do not cope with the goals the capitalist regimes (State, capital) strive to achieve (Manta Nolasco, 2007).

Non-recognition of local communities: It has surfaced that indigenous people and local communities are thought to have substantial knowledge as far as forest land and environmental maintenance is concerned. Nonetheless, the inclusion of local communities and indigenous groups in the policy making process remains weak. Grau and Aide state that in some cases, logging concessions have been granted without asking local and indigenous communities living in those areas first (Grau and Aide, 2008). In other cases, concessions had been titled to both, the local communities and the concessionaires which caused severe conflict and in the end increased deforestation (Grau and Aide, 2008). The study states that a stronger involvement of indigenous and other traditional communities could enhance that forests are managed in a more sustainable manner.

Political Stability: Latin America is often seen as relatively political stable. However, the World Bank's Worldwide Governance Indicators from 1996 to 2007 indicate a shift among Latin American countries. While the report rates Uruguay and Costa Rica amongst the 25% of countries worldwide with the highest degree of political stability, most Latin American countries, amongst them Brazil, Argentina and Mexico are rated not to belong to the 50% of worldwide countries with the highest rate of political stability (World Bank, 2008). The politically most unstable country in Latin America is rated to be Colombia, belonging to the 10% of most politically unstable countries in the world.

Regulatory Quality: Land policies and property rights: Tenure issues and policies play an important role in the manifold dynamics associated to deforestation in Latin America. At present, many Latin American governments do not have the capacity to fully enforce adequate agrarian reforms which distribute land equally and may also provide financial assistance to poor farmers (Jaramillo and Kelly, 1998).

In many Latin American countries, a lack of property rights exists in agricultural and forest areas and many regions experience inefficient agriculture and land use. According to economic theory, improving property security in established agricultural areas should increase productivity, labour use, and the efficiency of land market transactions (Jaramillo and Kelly, 1998). As this tenure security is missing - some policies even state that trees are a public resource standing on private lands, and therefore encourage forest exploitation - and governments have further not been able to enforce alternative property regimes for forested areas, the deforestation continues in order to raise agricultural production and establish new settlements.

Policies on economic growth: Surfaced above, several policies have been implemented in order to enhance economic growth rather than protect the environment and forests. Macroeconomic and sectoral policies have stimulated inefficient land uses and enhanced agricultural expansion in many Latin American countries (Azevedo-Ramos, 2008). Subsidies and tax reliefs for agricultural machinery and the construction of infrastructure

had the effect of stimulating forest industries and agriculture expansion (Jaramillo and Kelly, 1998).

Another aspect that is believed to enhance deforestation in Latin America is the foreign debts of many countries and the related structural adjustment policies by the International Monetary Fund and the World Bank. Gullison and Losos have found that external debts have contributed to economic stagnation and an increase in poverty in Latin America, this, among other factors, has caused the degradation of marginal lands (Gullison, R., and Losos, E., 1992). Furthermore, debt payments are likely to lead to governmental budget cutbacks in environmental spending.

Environmental policies: The lack of clear forest management policies for the conversion of forested areas provides a further incentive for deforestation. The already mentioned promotion of colonisation, infrastructural projects, energy, biofuel, timber and pulp production fall under such policies (Azevedo-Ramos, 2008 and Grau and Aide, 2008). The agricultural reform in the Brazilian Amazonian region has for example promoted the creation of additional settlements and therewith enhanced forest loss (Azevedo-Ramos, 2008). Furthermore, the industrial forces as far as industrial appropriation of public land is concerned remain powerful..

Rule of law: Weak and centralized regulatory systems: for the most part, Latin American governments do not have the means to enforce effective environmental policies due to poor governance, poor governmental supervision and endemic corruption (Jaramillo and Kelly, 1998). However, a study aiming to quantify the impacts of governance on deforestation states that enhanced regulatory quality, corruption control as well as voice and accountability could help against deforestation in Latin America (Umeya et al., 2008).

Corruption: Some Latin American countries are rated amongst the most active countries worldwide, as far as corruption control is concerned. According to the ranking, Chile belongs to the 10% of worldwide countries with the most effective control of corruption, followed by Uruguay in the 75-90th percentile. These rankings are interesting to note as the two mentioned countries experience comparably little deforestation. On the lower end of the ranking, on the other hand, are Nicaragua, Ecuador, Paraguay and Venezuela (The World Bank, 2008). All three countries rank within the lowest 10-25th percentile of worldwide countries and experience much higher deforestation rates.

9.2.3 Pacific Asia

Voice and Accountability: In Asia, especially countries like Vietnam, Laos, China, North Korea and Myanmar are rated on the very bottom of worldwide countries regarding the governance indicator of voice and accountability, ranking within the lowest decile of worldwide country comparison (The World Bank, 2008).

Political Stability: Asia is a relatively politically stable region. However, the Philippines, East Timor, Thailand, Papua New Guinea and Indonesia are rated among rather politically unstable countries, placed within the lowest 10-25th percentile.

Regulatory Quality: Formal policies on land and economic development form an important driver for deforestation in Pacific Asia. Examples of such land policies are land/agricultural colonisation (new settlers in forested areas) and land distribution (to marginalized people) policies in many Pacific Asian countries, but also issuing permits for logging area, plantations etc. On the other hand, in many Pacific Asian countries land and resource allocation policies concentrate land and resources under the domain of a few and block access and rights of indigenous and local people to land resources. This indirectly supports illegal logging and land squatting¹¹ and discourages sustainable forest management because indigenous and subsistence farmers / loggers have no secure tenure position. Economic development policies often include expansion of agricultural land and infrastructure extension. (Geist and Lambin, 2001)

Rule of law: In addition to the mal-functioning land and resource allocation policies, a lack of rights and extreme physical remoteness often lock forest populations into poverty. The causality between poverty and deforestation cannot be established as such; instead it is rather an interplay of various exacerbating factors, including the lack of other subsistence and income opportunities due to remoteness and the lack of rights (Chomitz, 2007).

Table 9.2 Case study: restoration of rights to indigenous communities in Asia

Of the estimated 210 million to 260 million indigenous people in Asia and the Pacific, about 60 million are forest-dependant. Many countries have policies and laws to remedy their marginalization (e.g. Australia, India, Malaysia, New Zealand, Papua New Guinea and the Philippines). For example, the Scheduled Tribes and other Traditional Forest Dwellers (Recognition of Forest Rights) Act enacted by India in 2006 recognize the rights of traditional forest-dwelling communities, including title over land that they have been cultivating (up to a maximum of 4 ha per family) and the right to collect and use non-wood forest products.

[Source: FAO (2009); Rights and Resources Initiative (2008)]

Corruption: Illegal activities and corruption remain major drivers of deforestation in Asia. In 31% of all case studies in Asia, deforestation is (partly) caused by corruption, mostly due to unsustainable timber logging (Geist and Lambin, 2001). In 1993, for example, a study showed that up to 40% of total Malaysian log exports to Japan were not declared.

¹¹ Land squatting is the illegal commandeering of land. Squatting on land at the edge of developments is more common in the developing world when land rights are poorly defined and people try to make their living based on subsistence agriculture.

Table 9.3 Case study: forest law enforcement and governance in Asia

In Asia, multilateral arrangements on forest law enforcement and governance (FLEG) target explicit improvements in reducing corruption and illegal activities in, and associated with, forests and forestry. The East Asian FLEG process emerged from a series of multistakeholder consultations in 2001. A ministerial FLEG meeting held in Bali, Indonesia, in 2001 affirmed commitments to eliminate illegal logging and associated illegal trade and corruption. It also developed a comprehensive list of actions – encompassing political, legislative, judicial, institutional and administrative actions as well as associated research, advocacy, information disclosure and sharing of knowledge and expertise – to be undertaken nationally and internationally. However, while the FLEG process has helped to draw attention to forest governance, it is difficult to ascertain its impact on the ground.

[Source: FAO, 2009]

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