Tropical deforestation: current trends and potential sustainable policies

On the basis of the most recent data concerning the extent of tropical deforestation and its implications for the terrestrial carbon budget, the paper describes the main drivers of deforestation and forest degradation in tropical regions. Although several studies indicate that it has no direct relationship with deforestation in the current situation (in particular as regards sugar cane cultivation in Brazil), production of biofuels (biodiesel, ethanol) through cultivation of energy crops, may represent a serious concern in the coming years, due to projected increases in the demand of biodiesel and ethanol. In order to limit the environmental and social impacts of such productions, both legal restrictions and market instruments have been used: certification systems are expected to play a major role in the future, in connection with sustainability criteria. Finally, current efforts under the UNFCCC to reach a global agreement on reducing emissions from deforestation and forest degradation may represent an important contribution to efforts already in place, provided that policy tools take into account the diverse national circumstances faced by forest-rich developing countries seeking to reduce their emissions

Domenico Gaudioso, Alessandra Magrini

Trends in forest land and carbon sink

Deforestation, consisting in the conversion of tropical forest to agricultural land, continues at the global level, despite signs of decreasing in several countries. A quantitative assessment of deforestation levels and trends is hindered by the differences in national approaches to forest monitoring: countries use differing frequencies, classification systems and assessment methods, which makes it difficult to obtain consistent data at the global level. These uncertainties were already discussed by the authors in a report published in 1992, which focused on the assessment of deforestation rates in Brazil (Magrini and Gaudioso, 1992). According to FAO's Global Forest Resources Assessment 2010 (FRA 2010), around 13 million hectares of forest were converted to other uses or lost through natural causes each year in the last decade, compared

Domenico Gaudioso
ISPRA, Dipartimento Stato dell'Ambiente e Metrologia Ambientale, Servizio Monitoraggio e Prevenzione degli Impatti sull'Atmosfera, Rome, Italy

Alessandra Magrini
Universidade Federal do Rio de Janeiro, Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia, Programa de Planejamento Energético, Rio de Janeiro, Brazil

TABLE 1 Annual change in the area of tropical forsts by region, 1990-2000
Source: FRA 2010 (FAO 2010)

Region/subregion	1990–2000		2000–2010	
	1000 ha/yr	%	1000 ha/yr	%
Eastern and Southern Africa	-1 841	-0.62	-1 839	-0.66
Western and Central Africa	-1 637	-0.46	-1 535	-0.46
South and Southeast Asia	-2 428	-0.77	-677	-0.23
South America	-4 213	-0.45	-3 997	-0.45

with 16 million hectares per year in the 1990s (FAO, 2010); annual deforested areas by region are shown in Table 1. It is worth noting that FAO's 2010 estimate for the 1990s is significantly higher, but more accurate, than FAO's 2005 estimate, equal to 13 million hectares per year.

Estimates for the net exchange of carbon between terrestrial ecosystems and the atmosphere are even more differentiated, depending on the approach used: inverse calculations, compilation of national forest inventories, top-down calculations based on land-use change data. A recent study, which makes use of recent forest inventory data and long-term field observations coupled to statistical or process models, quantifies emissions due to tropical deforestation in 3.0 PgC yr^{-1} in 1990-1999 and 2.9 PgC yr^{-1} in 2000-2007. In particular, the sink reduction in tropical forests in the period 2000 - 2007 was caused by deforestation reducing intact forest area (8%), and a severe Amazon drought in 2005 which appeared strong enough to affect the tropics-wide decadal C sink estimate (15%).

Tropical deforestation emissions are partially offset by tropical forest regrowth, which amounted to 1.6 PgC yr^{-1} in 1990-1999 and 1.7 PgC yr^{-1} in 2000-2007. In addition to that, tropical intact forests remove carbon from the atmosphere, representing a carbon sink, the magnitude of which was estimated on the order of 1.3 PgC yr^{-1} in 1990-1999 and 1.0 PgC yr^{-1} in 2000-2007, as shown in Table 2 (Pan *et al.*, 2011).

Table 2 shows that, when both removals from intact forests and from forest regrowth are combined, the tropical sinks sum to 2.9 ± 0.6 and 2.7 ± 0.7 PgC yr^{-1} over the two periods, respectively (Table 2), and on average account for about 70% of the gross C sink in the world forests (~4.0 PgC yr^{-1}). However, given that gross emissions from tropical deforestation are almost of the same order, tropical forests are nearly carbon neutral.

TABLE 2 Carbon budget in tropical forests
Source: Pan et alt., 2011

Global forests:	1990-1999	2000-2007
Tropical *gross* deforestation	3.0±0.5	2.9±0.5
Tropical forest regrowth	1.6±0.5	1.7±0.5
Tropical land use change	1.5±0.7	1.1±0.7
Tropical intact forests	1.3±0.4	1.0±0.5
Tropical *net* forest emissions	0.1±0.8	0.2±0.8

Without implementation of effective policies and measures to slow deforestation, clearing of tropical forests will likely release an additional 87 to 130 GtC by 2100, corresponding to the carbon release of more than a decade of global fossil fuel combustion at current rates. On the contrary, reducing deforestation rates 50% by 2050 and then maintaining them at this level until 2100 would avoid the direct release of up to 50 GtC this century (equivalent to nearly 6 years of recent annual fossil fuel emissions, and up to 12% of the total reductions that must be achieved from all sources through 2100 to be consistent with stabilizing atmospheric concentrations of CO_2 at 450 ppm. Emissions reductions from reduced deforestation may be among the least expensive mitigation options available at the global scale (although this should not lead to lower reduction commitments for other GHG emitting sectors). The IPCC estimates that reductions equal to or greater than the scale suggested here could be achieved at ≤U.S.$20 per ton CO_2 (IPCC, 2007).

Drivers of deforestation and forest degradation

Global demand for agricultural products such as food, feed and fuel is now a major driver of cropland and pasture expansion across the developing world. However, the environmental consequences of this expansion are significantly influenced by the conversion pathways: new agricultural land can in fact replace forests, degraded forests or grassland. As a whole, between 1980 and 2000 more than 55% of new agricultural land came at the expense of intact forests, and

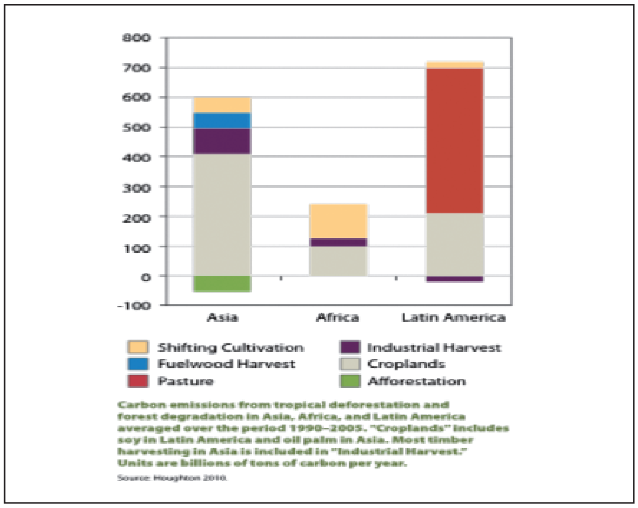

FIGURE 1 Sources of Carbon Emissions from Deforestation and Degradation in Tropical Regions
Source: Houghton, 2010

another 28% came from disturbed forests, according to a recent global survey which used the library of classified Landsat scenes originally processed by the FAO as part of the Forest Resources Assessment (Gibbs *et al.*, 2009).

However, as tropical forests are not all the same, so the drivers of tropical deforestation vary a great deal between continents (see, for instance, the assessment of sources of carbon emissions in Fig. 1): cattle and soy are important only in Latin America, while palm oil plantations are found almost exclusively in Indonesia and Malaysia. The timber industry has a particularly important role in deforestation in southeast Asia, where logging is often followed by conversion to plantations to produce palm oil or pulpwood (UCS, 2011).Soybean production is heavily concentrated in three countries: the United States, Brazil, and Argentina. Expansion of large-scale commercial soy production into the Amazon in the 1990s was an important cause of deforestation, and Brazil became the largest soybean exporter in the world. However, pressure from civil society led to an industry moratorium on buying soybeans from deforested areas beginning in 2006, and recent data indicates that soy's role as an agent of deforestation has greatly diminished; although attributing this recent reduction in deforestation in part to the soy moratorium is still premature, nevertheless the initiative has certainly exerted an inhibitory effect on the soybean frontier expansion in the Amazon biome (Rudorff *et al.*, 2011).

Pasture expansion to produce beef cattle is the main agent of deforestation in Brazil, occupying more than three-quarters of the deforested area. Beef production in the Amazon tends to be extensive, with low levels of meat production per unit area. As with soy, civil society pressure in Brazil has led to a moratorium since 2009 on buying beef from ranches that have cleared forests to create pasture. Pasture expansion remains an important driver of deforestation in Colombia and other Latin American countries, although over much smaller areas than in Brazil. Cattle breeding is not an important cause of deforestation in Africa or Asia (UCS, 2011).

Expansion of sugarcane cultivation in Brazil takes place, according to recent surveys, through conversion of pasture land (71%) or land previously hosting soy (19%) corn (5%) or orange (5%) crops (MAPA and CONAB, 2008). In the traditional Brazilian agricultural practices, sugar cane does not have a role as a pioneer crop in agricultural frontier areas; a direct relationship between the expansion of sugar cane and deforestation should therefore be excluded, and sugarcane is likely to expand in previously cleared area (Cardoso Silva, 2010).

The palm oil industry is heavily concentrated in two tropical forest countries, Indonesia and Malaysia, and has been expanding rapidly in recent years. Emissions from deforestation caused by palm oil plantations are particularly important as concerns their impact on global warming, as considerable plantation expansion take place in peat swamps with very large amounts of carbon in the soil. The palm industry is dominated by large integrated companies, that are also involved in timber cutting and establishing tree plantations for pulpwood production, so southeast Asian deforestation depends on complex interactions between logging and palm and pulp plantations.

Sp

Though only a small part of global timber production and trade, logging in tropical forests can be an important cause of forest degradation. In southeast Asia, where many more tree species are commercially valuable, it leads to deforestation as well. In Latin America and Africa most clearing is for land, not timber, but logging is often the first step to complete the deforestation of an area. Plantations of native species can supply large amounts of wood to take some of the pressure off of natural forests, but only if established in already cleared areas.

Firewood collection has often been blamed for deforestation, but although the volume of wood involved is large, most of it comes from already dead trees and branches, from non-forest areas, or from small trees and shrubs in the understory. Thus it is generally not causing deforestation or even significant degradation. Moreover, firewood use is expected to diminish in the tropics in coming decades, and has already dropped considerably in Latin America (UCS, 2011). On the contrary, charcoal use is expected to increase considerably over the next 20 years, particularly in Africa, to supply nearby cities; charcoal production can be a locally important driver of degradation and eventual deforestation. In Brazil there is a great deal of concern over charcoal produced for the pig iron and cement industries. Brazil is the largest consumer of industrial charcoal in the world: much of this comes from native forests, but the amount supplied by eucalyptus plantations is increasing to meet these demands: charcoal from native forests has increased from 16.9 million m^3 in 1980 (86%) to 18.8 million m^3 in 2005 (49.6%), while coal originating from planted forests has increased from 2.8 million m^3 in 1980 (14.1%) to 19.2 million m^3 in 2005 (50.4%) (Oliveira *et al.*, 2007). As in other regions, charcoal use is expected to increase in the future.

Small-scale farming has become less important to deforestation in recent decades, as rural populations have leveled off or declined and large businesses producing commodities for urban and export markets have expanded into tropical forest regions, in particular in the Amazon and southeast Asia; Africa is an exception to this generalization (Rudel *et al.*, 2009).

Impacts of biofuels production on deforestation

Globally, there is a large interest, in expanding the energy use of biomass, with a view to mitigating climate change while enhancing energy security, and in particular in finding renewable fuels to substitute for petroleum-based fuels. Biofuels such as biodiesel and ethanol are being promoted in several industrialised and developing countries through targets for substituting biofuels for diesel and gasoline, with proportions ranging from 5% to 20%, to be met at various times within the period 2010-2030 whereas in specific cases, such as Brazil, replacement with ethanol can reach 100% in "flex-fuel" cars.

Increasing biofuel production requires crop expansion. On the basis of current projections of the demand for transportation fuels, the amount of land required to meet 10% of the projected biodiesel demand for 2030 – i.e., 179 Mt - has been estimated to be 173 Mha for jatropha, 48 Mha for palm oil and 361 Mha for soybean; similarly, the land required to meet the ethanol demand – i.e., 289 Mt - has been estimated to be 147 Mha for maize, 70 Mha for sugarcane and 116 Mha for sweet sorghum (Ravindranath, 2009). This corresponds to an increase in the extent of agricultural land (arable land + permanent crops) ranging from 3,2% to 23,8% for biodiesel, and from 4,6% to 9,7% for ethanol, at the global level.

However, actual carbon savings offered from biofuels depend on how they are produced. Crop expansion leads to direct and, in many instances, indirect land-use change (LUC), depending whether additional cropland is made available through the conversion of native ecosystems such as peat lands, forests and grasslands or, alternatively, by diverting land currently cropped for non-energy production.

Recent studies by Fargione *et al*. (2008) and Gibbs *et al*. (2008) show that land-use conversion from native land-uses to biofuel crops would lead consistently to significant GHG emissions and a negative carbon balance, or carbon-debt, for decades to centuries. Only in a limited number of cases (conversion of Brazilian Cerrado to sugarcane ethanol or soybean biodiesel, conversion of Indonesian or Malaysian grasslands to sugarcane or oil palm), the time required to offset the carbon-debt is of the order of some decades.

If biofuels are to help mitigate global climate change, they need to be produced with little reduction of organic carbon stocks in the soils and vegetation of natural and managed ecosystems. Degraded and abandoned agricultural lands could be used to grow native perennials for biofuel production, which could spare the destruction of native ecosystems and reduce GHG emissions.

In addition to the impact on GHG emissions, cultivation of food-based biofuel crops could have adverse impacts on food security, biodiversity and water. Second-generation biofuels, produced through the conversion of lignocellulosic feedstocks, use less or no water for irrigation, will not compete with food if grown on abandoned or marginal cropland and may maintain or increase biodiversity if grown in ways that are compatible with wildlife (FAO, 2008). However, these technologies have yet to become commercially viable.

Sustainability criteria and sustainable policies

As part of policies aimed at promoting the energy use of biomass, many industrialized countries, some countries where energy crops are cultivated and, more recently, some international organizations are envisaging and implementing public and private environmental management policies (legal restrictions and market instruments, respectively) aimed at limiting the environmental and social impacts of such productions. In particular, Brazil, the first country to launch a large-scale program – PROALCOOL – for the substitution of biofuels for petroleum derivatives (1975) and the dissemination of flex-fuel vehicles in 2003, introduced in 2009 a land-use regulation - Zoneamento Agroecológico da Cana-de-Açucar (ZAE), which bans the production of bioethanol in the territories of the Amazon, the Pantanal and the Upper Paraguay Basin (Daemon, 2010). Brazil had already introduced in 2006 a moratorium on soy expansion in the Amazon, whereas in 2009 a moratorium was established on buying beef from ranches that had cleared forests to create pasture. In 2011, Indonesia has introduced a moratorium on new forestry, agricultural and mining business permits on natural primary forest and peat land over the next two years.

Zoning approaches are an essential tool for protecting land with high biodiversity value; however, they have serious limitations, consisting not only in the difficulty of enforcing the protection regime, but especially in the lack of protection for the remaining territory. In the specific case of sugarcane cultivation in Brazil, the Zoneamento Agroecológico da Cana-de-Açucar (ZAE) does not provide any protection for the Cerrado ecoregion, which would not be affected, as well as the possible production of sugar cane, but also by the displacement of traditional activities (cereal cultivation, livestock breeding) that currently take place in the areas affected by a more rigorous system of protection (Daemon, 2010).

To address these limitations, initially at the national level but increasingly at the international level, in relation to the growing trade of biofuels, different subjects have developed sustainability criteria, which generally focus on greenhouse gas emissions, biodiversity, agricultural practices and social impacts. At the international level, the most influential criteria have been those proposed by the Government of the Netherlands, adopted by the Cramer Commission in 2006 (Cramer, 2008), by the Roundtable on Sustainable Development (RSB, 2008) and by the Bonsucro / Better Sugarcane Initiative (BSI), a global non-profit initiative (Bonsucro, 2011).

Certification is a tool compatible with market approaches, and its ability to ensure sustainable production systems is recognized in other areas of agribusiness (as shown by the experience of the FSC, Forest Stewardship Council). Its effectiveness depends on several factors related to its practical implementation, and in particular by:

1. the identification of the subject responsible for the monitoring of production systems and the preparation of statements;
2. the definition of criteria and indicators that are appropriate to the reality of each country;
3. the costs of the certification scheme, compared to production costs.

The experience with traditional certification systems shows that they have the ability to reduce emissions of greenhouse gases from production processes (if only by stimulating improvements in the efficiency of the conversion process), while they are not effective in protecting biodiversity, ensuring net GHG emission benefits (taking into account the entire life cycle) and avoiding adverse impacts on the availability and the quality of water resources (Searchinger, 2009). The most effective environmental management model should therefore comprise a land-use regulation, a certification scheme and appropriate policy incentives.

A similar approach has been used by the European Union in the definition of sustainability criteria that must be met by biofuels so that they can help achieve the targets set under Directive 2009/28/EC for the promotion of renewable energy sources. In fact, these criteria include a minimum GHG emissions reduction target from the fuel production cycle (35% initially, rising to 50% from 1 January 2017 and 60% from 1 January 2018), together with a series of production bans for protected areas, primary forests and areas with high biodiversity or carbon stock. The directive provides for the economic operators to demonstrate that the criteria have been met, and also provides that the Commission may enter into agreements with third countries allowing for the recognition of certification schemes. As for solid biomass or biogas, for which no provisions are included in the directive, the European Commission recommends that where Member States impose sustainability criteria, they should be in almost all respects the same as the ones imposed by the Renewables Directive for bioliquids.

Possible impact of a successful REDD+ policy process

Despite the huge emission reduction potential, forest clearing is not addressed by the flexible mechanisms introduced in the first commitment period (2008-2012) of the Kyoto Protocol. Article 3.4 of the Protocol only considers afforestation and reforestation activities, although the impact of these activities on annual emissions and removals from Land-Use, Land-Use Change and Forestry is very low, as shown in Fig. 2. This the reason why current negotiations aimed at reaching a global agreement for the period after 2008-2012 focus on Reducing Emissions from Deforestation and Forest Degradation (REDD).

Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. "REDD+" goes beyond de-

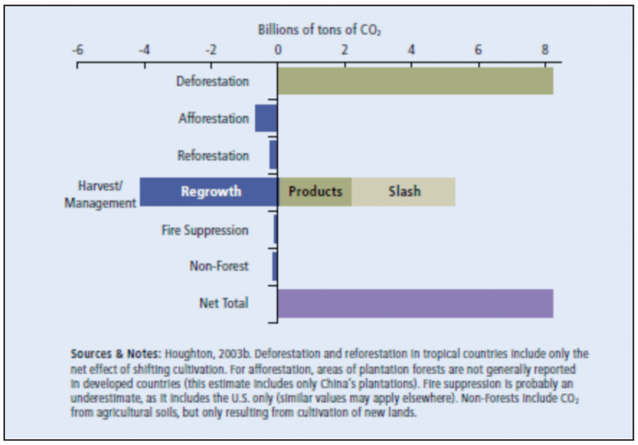

FIGURE 2 Annual emissions and removals from LULUCF activities, global estimates for the 1990s
Source: Baumert et al., 2005

forestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

Different policy approaches are needed to address the diverse national circumstances faced by forest-rich developing countries seeking to reduce their emissions. In some countries, it may be possible, at relatively low cost, to reduce emissions from deforestation and forest degradation that provide little or no benefit to local and regional economies, for example reducing accidental fire and eliminating forest clearing on lands inappropriate for agriculture. Other measures are unlikely to be implemented at large scales without financial incentives, that may be possible only within the framework of comprehensive environmental service payments, such as through carbon-market financing. In forests slated for timber production, for example, moderate carbon prices could support widespread adoption of sustainable forestry practices that directly reduce both emissions and the vulnerability of logged forests to further emissions from fire and drought exacerbated by global warming. On forested lands threatened by agricultural expansion, financing could provide significant incentives for forest retention and enable, for example, more effective implementation of land-use regulations on private property and protected area networks (Gullison *et al.*, 2007).

Key requirements for effective carbon-market approaches to reduce tropical deforestation include strengthened technical and institutional capacity in many developing countries, agreement on a robust system for measuring and monitoring emissions reductions, and commitments to deeper reductions by industrialized countries to create demand for REDD+ carbon credits and to ensure that these reductions are not simply traded off against less emission reductions from fossil fuels.

Whether a successful REDD+ policy process will make an important contribution to global efforts to stop deforestation and forest degradation depends on how it will be negotiated and actually implemented. Current negotiations mainly refer to technical issues, such as the establishment of baselines and the definition of reliable MRV (monitoring, reporting and verification) procedures, but also reflect the uncertainty about the general architecture of the mechanism.

The central question is to create a multilevel scheme (national and international) of payments for the environmental services offered by forests. At the international level, buyers of services will make payments (driven by mandatory markets or voluntary compliance) for service providers (government or sub-national entities in developing countries) for an environmental service (REDD+), or by measures to provide this service (for example, land reform, law enforcement). Nationally, buyers of services (government or other intermediaries) will pay service providers (sub-national governments or local landowners) to reduce emissions or to take other measures to reduce emissions (e.g., reduced impact logging) (de Oliveira Faria, 2010). One advantage of a national approach is that these broad policies can be implemented and credited to the extent that result in emission reductions; on the other hand, a sub-national approach would favor the involvement of the private sector in developing countries with serious institutional and technical deficiencies at national level (Rubio Alvarado and Wertz-Kanounnikoff, 2008).

In the background, two opposing options compete: on one side the creation of a publicly financed international fund that supports public policies; and on the other side the development of a market-based mechanism responsible for organizing the distribution of tradable carbon credits on international carbon markets (Pirard 2008). The final architecture of the system will depend on the balance of negotiations between North and South and by an evaluation of the effectiveness of two types of approaches. There are, of course, more general uncertainties related to the current economic crisis in the industrialized countries and the push for growth by developing countries, which could even jeopardize the outcome of the negotiations.

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