

THE RAINFOREST FOUNDATION
SECURING LANDS, SUSTAINING LIVES

CLOUDS ON THE HORIZON:

The Congo Basin's Forests and Climate Change

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EXECUTIVE SUMMARY

- Forests have an important influence on the world's climate processes – both through their role in the cycling of greenhouse gases and through the exchange of water and energy with the atmosphere.

- Tropical forests are particularly important as a carbon store, because of their high biomass, containing on average 50% more carbon than temperate forests. The Congo Basin's forests are estimated to contain between 25-30 billion tonnes of carbon in their vegetation – this is equivalent to about 4 years of current global anthropogenic emissions of CO_2. Over half of this carbon is stored within the forests of the Democratic Republic of Congo.

- Conversion of tropical forests can result in nearly all the above ground carbon being released to the atmosphere, while forest degradation may result in 25-50% of stored carbon being released to the atmosphere. Selective logging prevails as the main 'forest management' strategy in Central Africa, and for this reason, forest degradation may be a more important source of carbon emissions than deforestation – one estimate suggests that forest degradation accounts for nearly double the emissions resulting from deforestation within the region.

- Emissions from land-use change in the tropics could be as high as 2.5 billion tonnes of carbon per year. A frequently cited figure is that this is equivalent to about one fifth of total global emissions, although the variation in estimates means that this could in fact be anywhere between one tenth and one third of the total. Land-use change in the Congo Basin is estimated to account for emissions of between 20 and 440 million tonnes of carbon per year – equivalent to 90% of all anthropogenic emissions from the region. Although this represents a relatively small proportion of the total emissions from tropical land-use change worldwide, its contribution is likely to increase if the wrong policy options are pursued.

- In the case of the Democratic Republic of Congo, if the entire area of 60 million hectares which has been suggested as being 'production forest' were actually opened up to new industrial logging activities, it would potentially release an additional 3 to 6 Gt of carbon into the atmosphere. A further similar amount could be released if these logged forests are eventually completely cleared – the usual pattern following forest degradation and fragmentation.

- The Congo Basin's forests also play a crucial role in climate processes through the exchange of water and energy with the atmosphere. There is strong evidence to show that deforestation affects local climate, causing a decline in rainfall and increase in temperatures. The region's forests are also a major driving force of large-scale atmospheric circulations, and so land-use changes within the Congo Basin influence both regional and global weather patterns. Thus, deforestation within Central Africa could result in large-scale climate effects, changing temperatures, the distribution of rainfall and climate variability in distant parts of the world.

- Such evidence raises the stakes in terms of the need to protect the forests of the Congo Basin. The use of carbon financing has great potential as a means to fund such efforts, although the development of an effective and equitable system will require further investigation and negotiations. Any such mechanisms depend on the establishment of good forest governance and the resolution of land tenure and resource rights, and so these issues must be the priority in the immediate-term.

INTRODUCTION

Until recently, much of the debate and concern surrounding the loss of tropical forests has focused on the loss of biodiversity, and to a lesser extent, the loss of resources on which forest-based peoples depend. More recently, the potential impacts on climate and weather have been highlighted, in part reflecting growing evidence of the onset of the effects of global warming. These discussions have mainly been concerned with the role of forests as sinks and sources of carbon. However, this is not the whole picture. Forests also influence climate through their physical characteristics, influencing the transfer of water and energy to the atmosphere.

This report presents current evidence for the role of tropical forests, and in particular, those of the Congo Basin, in local, regional and global climate processes. Firstly, data on their significance as both a sink and source of greenhouse gases is presented. This is followed by a review of research into the role of this region's forests in weather patterns through their influence on atmospheric circulations. Finally, the significance of these findings for forest policy within the region and internationally is considered, focusing in particular on recent proposals to develop mechanisms to promote forest conservation within the international climate regime.

FORESTS & GREENHOUSE GASES

In the tropics, depletion of forest resources and land-cover change have been the primary source of carbon emissions. These phenomena are estimated to be releasing about 1.6 (0.8-2.4) Gt C/yr.[1], most of which is attributable to deforestation and degradation. By comparison, fossil fuel emissions are about four times this level, at 6.3 Gt C/yr. (Chomitz, 2006). These figures not only highlight the crucial role of forests in the carbon cycle, but also the shortcomings in our understanding of it, apparent from the wide range of possible values for emissions from land-use change.

BACKGROUND

Forests play an important role in the cycling of greenhouse gases, acting as both a sink and source of these gases. In discussions of global warming, most discussion is focussed on the role of carbon dioxide (CO^2), and indeed this is the most important of the greenhouse gases, having contributed some 58% of the greenhouse effect up to 2000 (Houghton, 2005a). However, there are in fact a number of greenhouse gases, and forests play a role in the cycling of a number of these. The most important after CO^2 are methane (CH^4) and nitrous oxide (N^2O), which contributed 21% and 6% of the greenhouse effect respectively until 2000 (Houghton, 2005a).[2] However, most assessments of the role of forests on climate change only consider CO2 emissions, and in fact, there are no reliable global estimates of emissions of either CH^4 or N^2O from land-use change (Baumert et al., 2005). Since there is little information available on the importance of other greenhouse gases, this report will only focus on the carbon cycle. However, it should be noted that emissions of these other gases are significant, one estimate suggesting that they could add up to 15% to the impact of forests on climate change (Fearnside & Laurance, 2004).

Forests influence the carbon cycle through their ability to store carbon and exchange it with the atmosphere. Plants absorb CO^2

[1] 1 Gt = 1 billion tonnes / 1 x 109 tonnes
[2] The Kyoto Protocol is concerned with 6 greenhouse gases: Carbon dioxide (CO2), Methane (CH4), Nitrous oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6)

through photosynthesis, and some is released through respiration or the decomposition of dead vegetation, while the remainder is stored in biomass, necromass and the soil (Locatelli & Karsenty, 2004). Therefore, forests act as a reservoir (storing carbon), a sink (absorbing carbon) and also as a source of carbon.

Calculating the carbon stored in forests and also the flux of carbon between the forests and atmosphere is extremely challenging. This is because of the lack of data on: the biomass values of forests, and thus the amount of carbon stored in forests; the extent and quality of the world's forests; and rates of deforestation and forest degradation (Achard et al., 2004; Palm et al., 2005; Zhang & Justice, 2001). Consequently, there remains considerable uncertainty among researchers as to the magnitude of these emissions.

Some figures have been placed on the level of uncertainty over the figures, illustrating the difficulties of budgeting within the carbon system. Houghton (2005b) suggested that there is 50% uncertainty in biomass values for the tropics, and that this translates into an uncertainty level of 80% for carbon flux estimates. Baumert et al. (2005) also highlighted the uncertainties of estimates of carbon emissions, suggesting that at the national level, the degree of uncertainty could be as high as 150%. Indeed, according to the IPCC's (Intergovernmental Panel on Climate Change) estimates, there is a gap in the global carbon budget, with a missing carbon sink of between 2-4 Gt C/yr. (Achard et al., 2004). While there is debate over this figure, this does illustrate our limited understanding of the land-atmosphere flux and the global carbon cycle.

FORESTS AS A RESERVOIR OF CARBON

Tropical forests are important reservoirs of carbon. Of the total carbon pool found in the terrestrial biosphere (which is an estimated 2480 Gt), about 17% is contained in tropical forests - 45% (212Gt) of which is found in vegetation and 11% (221Gt) in soils (Locatelli & Karsenty, 2004).

The importance of tropical forests as a carbon store lies in their high biomass. Dense lowland forests contain significantly higher biomass, and thus, carbon than other types of vegetation and even other types of forests – for example, they are estimated to contain 50% more carbon per unit area than temperate and boreal forests, and as much as 20-50 times more carbon than cleared lands (Houghton, 2005a).

The highest estimate for the biomass density of tropical rainforests is 500 t/ha. (cited in Gaston et al., 1998), although more typical values are between 100-400 t. The biomass of Central African forests is estimated to range between 200-344 t/ha. by Gaston et al. (1998) and between 125-281 t/ha. by FAO (1993). Brown & Gaston (1996) gave an average figure for the above-ground biomass in tropical African closed forests of 209 t/ha., while a figure of 250 t/ha. for the biomass (above and below-ground) of tropical forests was reported by Watson et al. (2000, citing Dixon et al., 1994)[3].

Translating these figures into the amount of carbon stored in forests depends on the estimates used for forest area as well as assumptions made about the distribution of different forest types. As the figures above illustrate, the biomass of forests varies considerably and its distribution within the tropics is particularly poorly known making it difficult to extrapolate over large areas and to produce average densities (Houghton, 2005a; 2005b; Locatelli & Karsenty, 2004). Estimates of the extent of forest are also uncertain. Many authors have used FAO's estimates for forest area, although these are known to be highly unreliable (Hoare, 2005), and the IPCC has noted that deforestation rates for the tropics could be in error by as much as 50% (cited in Achard et al., 2002).

[3] By comparison, this latter figure was 150 t/ha. for temperate forests, while average values for the above-ground biomass of temperate and boreal forests were reported to range from 20-140 t/ha. These figures do not include below-ground carbon, which is considerable for boreal forests.

Reflecting this uncertainty in the data, there is a wide range in estimates for the size of the carbon pool within tropical forests. However, the available figures do give some indication of the significance of tropical forests and of those of Central Africa in particular.

For Central Africa[4], the above-ground carbon stock of forests was estimated to be 28.92 Gt in 1980 and 24.79 Gt in 1990 (+/- 25% for both figures) (Justice et al., 2001; Zhang & Justice, 2001). Gaston et al. (1998) estimated the above and below-ground carbon stock for Central Africa's forests in 1980 to be 30.7Gt, calculating that this represented over 70% of the total terrestrial carbon pool of Africa. Most recently, FAO (2006) estimated that the forests of central Africa contained 29.5 Gt of above-ground carbon and 39.2 Gt of carbon in total (including both above and below ground carbon, dead-wood and litter)[5].

Within Central Africa, the Democratic Republic of Congo (DRC) contains by far the greatest biomass because of the country's extensive forest resources. Gaston et al. (1998) estimated the carbon pool of DRC to be 16.9 Gt in 1980, equivalent to 55% of the regional total, or one third of the total carbon pool of tropical Africa. Zhang & Justice (2001) produced a similar figure, estimating that DRC accounted for 59% of the total for Central Africa in 1980, while FAO's figure was slightly higher, at 63% (FAO, 2006).

To put these figures in some perspective, the carbon stored in Central Africa's forests is equivalent to about 4 years of total global emissions of CO^2 based on current estimates. This brings us to the issue of carbon flux, and the role of forests as a source of carbon.

FORESTS & CARBON FLUX

Globally, the biosphere is currently a sink of carbon. Of the 7-8 Gt of carbon emitted each year from anthropogenic sources, about one third is taken up by forests (Locatelli & Karsenty, 2004). However, in the tropics, due to the high rates of deforestation and degradation, forests are a net source of carbon. Indeed, if current trends continue, it is estimated that these land-cover changes will contribute about 50% as much carbon as has been emitted from fossil fuel combustion since the start of the industrial revolution (Houghton, 2005a).

However, as mentioned above, there remains considerable uncertainty about the flux of carbon between the biosphere and atmosphere because of shortcomings in the basic data: namely biomass values, forest area and rates of deforestation and degradation.

It is not only the rates of deforestation, but also its distribution that is poorly understood in many regions. The types of forests that are being cleared will affect the levels of carbon emissions. For example, deforestation tends to occur primarily in forests of lower density. Indeed, in the 1990s in Amazonia, more than half the forest clearing was of forests of lower biomass (Achard et al., 2004). Furthermore, the rate of change between different types of vegetation or land-use is difficult to determine. For example, land-use change is often characterised by relatively small changes, for example, through the fragmentation of forests, although this may eventually result in complete conversion to agricultural land (Houghton & Hackler, 2006).

The level of forest degradation is an issue of much debate. For example, estimates of forest area based on satellite imagery often underestimate forest degradation, because small-scale clearings, such as those resulting from selective logging, are not detected (Achard et al., 2004). In Central Africa, forest degradation is highly significant, because of the prevalence of selective logging here – it has been estimated that 30% of the region's forests have already been selectively logged (Laporte et al., 2004).

[4] Defined by these authors as the 6 countries of the Congo Basin: Cameroon, Central African Republic, Congo-Brazzaville, Democratic Republic of Congo, Equatorial Guinea, Gabon.

Uncertainty over estimates also reflects the difficulties of modelling an evolving and responsive system. For example, in estimating carbon fluxes, there is a need to track the carbon beyond the initial deforestation, accounting for the use of the wood products extracted and the subsequent changes in vegetation – for example, whether it is converted to agriculture or reforested. There is also uncertainty as to how forests will respond to climate change as a result of the greenhouse effect – for example, this could result in forest deterioration if there is a decline in rainfall, so releasing additional carbon, or an increase in temperatures could stimulate photosynthesis and forest productivity, enhancing the role of forests as a carbon sink (Cramer et al., 2004; Locatelli & Karsenty, 2004). However, more complex models are constantly being developed to allow for different outcomes and feedback phenomena.

CHANGES IN BIOMASS

The amount of carbon that is released as a result of deforestation will depend on the rate at which this occurs, and also on the subsequent land-use. For example, if deforested land is reforested, then a significant proportion of the carbon initially released could be reabsorbed. However, if the land is converted to pasture or permanent agriculture, the net loss of carbon will be greater. In Sub-Saharan Africa it was estimated that during the 1990s only 16% of the change in forest area was accounted for by conversion to permanent agriculture, while the remaining area was converted to long and short-term fallows as well as being subject to forest degradation and fragmentation, for example, as a result of logging, grazing and fuel-wood harvesting (Houghton & Hackler, 2006).

One factor influencing the rate of land-use change is the intensity of logging activities, for example, whether there is clear-felling or selective logging. As mentioned above, selective logging prevails in Central Africa, and for this reason, forest degradation is thought by some researchers to be a more important source of carbon emissions than deforestation for this region. For example, Gaston et al. (1998) estimates that degradation and deforestation accounted for 63% and 37% of emissions respectively from Central Africa in the 1980s (see table 1).

Some studies have been undertaken in Congo-Brazzaville to assess the amount of carbon emitted as a result of selective logging, these calculating that 9-10 t C are released per hectare (Brown et al., 2005; Parveen et al., 2005). This is relatively low, given that the dense forests of the region typically contain over 250 t C / ha., but it needs to be borne in mind when modelling future scenarios that selective logging is often the first stage in a process of forest degradation and deforestation. In addition, there is evidence from research in Amazonia that forest fragmentation can in itself have a dramatic impact on biomass levels, because of the ecological changes that are brought about in the forest, in particular, with an increase in tree mortality. Laurence et al. (1997) found that, as a conservative estimate, 36% of the biomass was lost within 100m of forest edges.

As highlighted above, forest fragmentation is an important phenomenon in Central Africa, and could become even more widespread, depending on the policy options that are pursued in the near future, especially in DRC. In addition to the area of forest already being selectively logged, the network of logging roads is becoming ever more extensive. Satellite imagery from 1999-2001 showed that just one third of the region's forests were low access (that is those forest areas of at least 100,000 hectares and at least 2 km from public roads), and of this area, nearly 60% was within 10km of a logging road (Minnemeyer, 2002).

The carbon flux resulting from deforestation

[5] Although comparison of these estimates would suggest that there has been an increase in the size of the carbon pool in Central Africa over the last two decades, this does not represent reality since the region has experienced extensive forest degradation and deforestation. Rather, this represents the uncertainty of these estimates, as noted earlier, based as they are on very different estimates of forest biomass and forest area.

TABLE 1: Estimated decline in the above-ground carbon pool in Central Africa in the 1980s (million tonnes/decade). (Source: Gaston et al., 1998.)

COUNTRY	TOTAL REDUCTION IN C POOL	DEFORESTATION	DEGRADATION
CAR	348	80 (23%)	268 (77%)
Congo-B	320	14 (4%)	306 (96%)
Cameroon	416	123 (30%)	294 (70%)
DRC	2501	827 (33%)	1674 (67%)
Eq. Guinea	45	11 (24%)	34 (76%)
Gabon	803	606 (76%)	196 (24%)
TOTAL	4433	1661 (37%)	2772 (63%)

TABLE 2: Carbon lost by conversion of tropical forest to various land-uses. (Source: Houghton, 2005a)

LAND USE	CARBON LOST TO THE ATMOSPHERE AS % OF INITIAL CARBON STOCKS	
	VEGETATION	SOIL
Cultivated land	90-100	25
Pasture	90-100	12
Degraded cropland pasture	60-90	12-25
Shifting cultivation	60	10
Degraded forests	25-50	<10
Logging	10-50	<10
Plantations	30-50	<10

will depend on the subsequent vegetation, and some estimates have been made of the carbon lost as a result of conversion of tropical forest to other land-uses. Houghton (2005a) estimated the percentage of carbon stocks lost from tropical forests, from both soils and vegetation (table 2).

Palm et al. (2005), from research undertaken in Cameroon, sought to take into account the change in carbon levels over time, calculating the above-ground carbon storage of different land-use systems during a full agricultural rotation. On this basis, the loss of carbon resulting from conversion of logged over forest was estimated (see table 3) (Palm et al., 2005).

These data highlight the significant loss of carbon that can result from the conversion of forests to other land-uses, with 90-100% being lost from above-ground carbon for certain agricultural systems. Also apparent is that some land-use systems have a less drastic effect – including long rotation shifting cultivation and agroforestry systems.

TABLE 3: Above-ground time-average carbon storage of land-use systems in Cameroon. (Source: Palm et al., 2005)

LAND-USE	CARBON STORAGE (T C/HA.)	CARBON LOST ON CONVERSION FROM LOGGED FOREST TO ALTERNATIVE LAND-USE (T C/HA.)
Logged forest	228	-
Shifting cultivation (long fallow)	77	151
Jungle cacao (permanent)	89	139
Jungle cacao (rotational)	61	167
Oil palm	36	192
Crop-bush fallow	38	190
Crop-Chromalaena fallow	6	222

CARBON-FLUX ESTIMATES

Although there are wide variations in the estimates, it is apparent that deforestation and degradation is a significant source of carbon emissions. Indeed, land-use changes are the largest source of emissions in developing countries, accounting for about one third of their total emissions.

A widely quoted figure is that about one fifth of global anthropogenic CO^2 emissions, estimated at 7-8 Gt C / yr., come from tropical deforestation (Chomitz, 2006; Stern, 2006). These figures are based on IPCC's estimate of CO2 emissions for the 1990s, put at 1.6Gt C (+/- 0.8). However, if the full range of possible values is considered, these emissions could account for as little as one tenth or as much as one third of all anthropogenic emissions (Baumert et al., 2005; Fearnside & Laurance, 2004).

The reported values for emissions from land-use change in the tropics largely fall within those given by the IPCC, ranging from 0.5 to 2.5Gt C / yr. in the 1990s (Achard et al., 2004; DeFries et al., 2002; Fearnside & Laurance, 2004; Palm et al., 2005). For tropical Africa, the range of estimates for the 1990's is 0.12 to 0.42 Gt/yr. (UNFCCC, 2006a). Some of these estimates are shown in table 4 below.

An important factor accounting for the wide-divergence in these estimates was the figures used for forest area. For example, both Achard et al. (2004) and Defries et al. (2002) assumed a much lower rate of deforestation than the other three studies listed, based on their assessment of satellite data. Both these studies are also considered to have underestimated the level of forest degradation (UNFCCC, 2006a). Fearnside & Laurance (2004) suggest that Achard et al. (2004) may in fact have underestimated carbon emissions from forests by a factor of two, certainly for the Amazon and possibly in other tropical regions. They question these figures partly on the basis of the estimates used for forest degradation and biomass and their assumptions regarding forest re-growth.

Estimates for Sub-Saharan Africa also show a wide range in values. Achard et al. (2004) gave a figure of 0.157 Gt C / yr. for emissions from this region, while Brown et al. (1989, cited in Houghton & Hackler, 2006) gave a very high estimate of 0.47 Gt C / yr. The estimate of Houghton & Hackler (2006) is in between

TABLE 4: Estimates of carbon loss from African tropical forests to the atmosphere attributed to deforestation. (Gt C / yr) (Source: UNFCC, 2006a)

	Fearnside (2000)	Malhi & Grace (2000)	Houghton (2003b)	DeFries et al. (2002)	Achard et al. (2004)
Period	1981-1990	1980-1995	1990s	1990s	1990s
Africa	0.42	0.36	0.35	0.12	0.157
Total of regional estimates for the African, Asian and American tropics	2	2.4	2.2	0.91	0.98

these two, at 0.29 Gt, but they also state that the margin of error for this figure is +/-70%.

For Central Africa, estimates for emissions from land-use change are only available for the 1980s, and these range from 0.02 - 0.44 Gt / yr. (BSP, 1992; Gaston et al., 1998; Zhang & Justice, 2001). The highest figure, of 0.44 Gt is from the calculations of Gaston et al. (1998; & see table 1 above). These figures represent about 90% of all anthropogenic carbon emissions from within Central Africa (i.e. considering fossil fuel combustion and other sources) and 20% of the total emissions from tropical Africa (BSP, 1992).

All these studies show that DRC is by far the most significant source of carbon emissions from land-use change – a consequence of the vast areas of dense forest to be found within this country. Thus, Gaston et al. (1998) calculated that DRC accounted for 56% of the total for Central Africa (0.25 Gt), while Zhang & Justice (2001) estimated this to be 47% (0.2 Gt).

IN SUMMARY

Regardless of the uncertainties in the data, it is undoubted that continued deforestation will play a large role in the build-up of greenhouse gases in the atmosphere (Cramer et al., 2004). If current trends continue, tropical deforestation will contribute 3 billion tonnes of carbon each year (Chomitz, 2006), with emissions from deforestation from throughout the world expected to total 40 billion tonnes of carbon between 2008-2012. This alone will raise atmospheric CO2 levels by about 2 ppm – greater than the cumulative total of aviation emissions since the invention of aeroplanes (Stern, 2006).

Until recently, the Congo Basin forests have contributed a relatively small amount to the total emissions from land-use change, accounting for about 4% of all such emissions from the tropics in the 1980s. However, this figure is likely to grow if the wrong policy options are pursued in the coming months and years.

FORESTS & WEATHER SYSTEMS

The role of forests in influencing local climate is well documented. Studies from many parts of the world show that forests affect cloud formation, rainfall and temperature. In recent years, the evidence has been growing that forests also have an impact on global climate processes, and that tropical forests in particular play a crucial role. Studies of the hydrological cycle, energy budget and atmospheric circulation indicate that tropical deforestation could have large-scale climatic effects (Shem & Dickinson, 2006).

Much of this evidence comes from research in Amazonia, where the majority of work in this field has been undertaken. In contrast, there remains a lack of understanding of the climate of Central Africa, reflecting both the absence of long-term data and the limited research facilities for this region (Todd & Washington, 2004). This gap is beginning to be filled, and the existing research indicates that the forests of Central Africa play an important role not only in the local climate, but also that of Africa and other parts of the world.

HOW FORESTS AFFECT CLIMATE

Forests influence weather systems through the exchange of water and heat with the atmosphere. Forests tend to absorb solar energy (i.e. they have a low albedo or reflectivity). They also have a high leaf area index, and due to both these features, the rate of evapotranspiration is very high, comparable to the evaporation rate from the oceans. In addition, the surface of forests is aerodynamically rough, increasing air turbulence. In contrast, deforested areas tend to have a higher albedo, reflecting more solar energy. They also have lower surface roughness and leaf area index, and the moisture storage capacity of the ground is less (Mahé et al., 2005; Maynard & Royer, 2004). Consequently, changes in land-cover alter the cycling of energy and moisture within the atmosphere, affecting local air temperatures, humidity, as well as atmospheric circulation patterns.

The role of forests on climate have been studied using several approaches, including global climate modelling, regional climate modelling, theoretical approaches and also field observations and historical records (Berbet & Costa, 2003). Much of the research is based on modelling, and it should be noted that, because of the limitations of technology and computer power, relatively simple scenarios have had to be used, particularly in earlier studies (Nasi, 2005). For example, many models assume complete deforestation, whereas in reality, the process of deforestation may be a gradual one, forests undergoing gradual degradation and fragmentation and often being replaced by mosaics of vegetation. Furthermore, sea-surface temperatures (SST) and the effect of the El Niño-Southern Oscillation (ENSO) are often not included, both of which have a major impact on global and African climates (Hulme et al., 2001). However, even these relatively simple models are important in giving an indication of the processes at work and possible outcomes of land-use change. Furthermore, the models are becoming more sophisticated, for example, taking into consideration the evolution of vegetation types, and allowing for incorporation of various feedbacks between global warming and vegetation.

THE EVIDENCE

There is a large body of evidence to indicate that deforestation has a significant impact on local rainfall and temperature. In Amazonia, where much of this work has been undertaken, modelling experiments indicate that deforestation would result in an increase in local surface air temperatures, with figures of up to 5°c being suggested if there was complete deforestation (Dickinson & Henderson-Sellers, 1998, cited in Snyder et al., 2004b). Most research suggests that there would be a reduction in local evapotranspiration and rainfall (Costa & Foley, 2000; Mahé et al., 2005; Voldoire & Royer, 2004), although some studies indicate that if there is only small-scale or sporadic deforestation, then local rainfall could be increased (Berbet & Costa, 2003; Snyder et al., 2004b).

A number of studies have modelled the impact of complete deforestation in tropical Africa, and these all predict that this would result in a decline in rainfall and increase in surface temperatures within the affected region (Avissar & Werth, 2005; Maynard & Royer, 2004). Semazzi & Song (2001) suggest that during the dry season, when the effect would be severest, rainfall could decline by up to 3mm per day. Snyder et al. (2004b) reported similar findings, calculating that seasonal rainfall would decline by up to 3.2 mm per day, equivalent to a reduction of 47%.

Models of the impact of deforestation within Central Africa also suggest that there would be a decline in local rainfall (Shem & Dickinson, 2006). Baidya Roy et al. (2005) modelled the effects of complete deforestation in Gabon and Congo-Brazzaville, suggesting that this would result in a substantial reduction in rainfall during the wet season, of over 10% in some regions. Furthermore, they concluded that extensive logging could result in a shift in vegetation distribution because of the resulting decline in rainfall.

Changes in rainfall may be due to the impact of deforestation on mesoscale circulations within the atmosphere, as these strongly influence the transport of heat and moisture, and thus, cloud formation. Evidence for this has been found from observations of cloud patterns over deforested areas (Baidya Roy & Avissar, 2002; Chagnon et al., 2004; Lawton et al., 2001). Forest fragmentation may also influence rainfall patterns, because of its impact on convective flows and the hydrological cycle (Marland et al., 2003). In fact, edge effects may exacerbate changes in hydrology, for example, with drying of the soil. Therefore, fragmentation can have a greater impact than would perhaps be assumed from considering only the area of deforestation. For example, research in Amazonia found that a decline in forest cover of 17% had had a significant impact on regional rainfall regimes (Baidya Roy & Walsh, 2005).

In Central Africa it is thought that deforestation would have a particularly strong effect on local rainfall. This is because a large part of the rainfall in this region comes from the recycling of moisture by the forest, whereas in other monsoon regions most rainfall comes from water vapour accumulated from the oceans (Cadet & Nnoli, 1987; Monteny, 1987). One report estimates that as much as 75-95% of rainfall is recycled within the Congo Basin, while in Amazonia, this figure was put at 50% (Job, 1994, citing Brinkman, 1983). In particular, Cadet & Nnoli (1987) suggest that a significant source of rainfall in Central Africa is evapotranspiration of moisture in the coastal areas of the Gulf of Guinea.

The same is thought to be true in West Africa. Here, one estimate suggests that the tropical rainforests of the southern Ivory Coast inject water into the atmosphere equivalent to 55-75% of the annual precipitation in the region (Brou Yao, 1997 cited in Mahé et al., 2005). Indeed, deforestation in West Africa is thought to have been a major factor accounting for the decline in rainfall in the region in the last few decades, because of its impact on the monsoon circulation, as considered further below (Zheng & Eltahir, 1998).

REGIONAL AND GLOBAL EFFECTS

There is growing evidence that deforestation in tropical areas impacts on weather systems both regionally and globally. The tropics are thought to have a major influence on global weather systems because of their important role in the exchange of water and energy

[6] Teleconnections are linkages between changes in atmospheric circulation occurring in widely separated parts of the globe.
[7] The Hadley circulation dominates the tropical atmosphere, and is intimately related to the trade winds, tropical rainbelts, subtropical deserts and the jet streams. Within this circulation air rises near the equator, flows towards the pole some 10-15 km above the earth's suface, (cont. next page)

with the atmosphere and on atmospheric circulation patterns. Therefore, the impact of deforestation in this region is thought to be especially strong.

There remains considerable uncertainty as to the scale of such impacts. However, if the worst case scenarios prove true, then land-cover change in tropical regions could have devastating consequences for water resources, agriculture and other activities in various parts of the world (Avissar & Werth, 2005: 144-5).

Tropical land-use change is thought to affect the global climate through teleconnections[6]. This influence may be especially strong for tropical forests because the tropical forest regions are where the major deep convection systems are located (Shem & Dickinson, 2006; Todd & Washington, 2004). Through these systems, large amounts of moisture are transferred into the atmosphere from the transpiration and evaporation of water from the forest canopy and soil. This moisture is transported to higher levels in the atmosphere, and is redistributed to other tropical regions as well as to regions outside the tropics through the Hadley and Walker circulations[7] and forcing of the Rossby wave[8].

The Congo Basin is the third largest region of deep convection. As such, it is not only responsible for the majority of rainfall in tropical Africa (Mahé et al., 2005), but is also a major driving force of large-scale atmospheric circulation (Chase et al., 2000; Snyder et al., 2004a). Therefore, deforestation in this region could disturb global circulation patterns through changing the distribution and intensity of the convection system (Feddema et al., 2005; Marland et al., 2003; Maynard & Royer, 2004; Pielke et al., 2002; Snyder et al., 2004a).

A further reason why changes in land-cover in the tropics could have a significant impact on the climate is that horizontal temperature gradients are weak in this zone. This means that the atmosphere is sensitive to any changes in the distribution and intensity of heat sources and sinks. Therefore, any changes of surface condition in the tropics (such as those resulting from deforestation) will have a strong influence on vertical advection, with repercussions on circulation systems such as those of Hadley and Walker (Mahé et al., 2005).

Circulation of the monsoons could also be affected, since these are partly driven by the contrast between the land and oceans. Dense forests have high heat flows, because of their low albedo and high surface humidity. Deforestation lessens the contrast between the land and oceans, and so could disrupt the monsoons (Mahé et al., 2005; Zheng & Eltahir, 1998).

As a result of these processes, it has been hypothesised that continued deforestation in Central Africa could significantly affect the regional moisture balance, leading to irreversible regional climatic changes and also affecting global rainfall patterns. For example, research has indicated that Central Africa is a major source of moisture for West Africa (Cadet & Nnoli. 1987), with one study estimating that 17% of the latter region's rainfall comes from evapotranspiration in Central Africa (Gong & Eltahir, 1996).

Modelling of the changes induced by tropical deforestation either within Central Africa or the tropics as a whole gives some indication of the possible impact on the global climate, although there is some variation in the researchers' findings. Chase et al. (2000) investigated the possible role that existing vegetation change has played on the climate, by comparing model scenarios of current observed vegetation, with that of a simulated 'natural' land cover. Their findings suggest that deforestation in the tropics has increased temperatures globally and in many higher latitude regions, in particular over North America, southern Asia and central Europe, changes that could be

(from previous page) before descending in the subtropics, and flowing back towards the equator (the trade winds) near the surface. The Walker circulation lies over the Pacific Ocean - air rises over the Western Pacific and descends over the Eastern Pacific. It is an important element of the El Nino Southern Oscillation (ENSO).

[8] Rossby waves are large-scale motions in the atmosphere.

explained by the impact of land-cover change on large-scale atmospheric circulations. Based on models of future tropical deforestation, Avissar & Werth (2005) found that this would significantly reduce rainfall throughout the equatorial region. Voldoire & Royer (2004) predict that complete tropical deforestation would result in a decline in global rainfall. In addition, while there would be little effect on the mean global temperature, their research suggests that there would be an increase in the day-to-day variability with more extreme minimum and maximum temperatures. They also found that there would be greater variability between years, with extreme conditions becoming more frequent. Such changes in the variability of the climate could be more significant than changes in mean climate, since they would have a greater impact on agriculture and ecologically, while an increased occurrence of extreme weather could have potentially devastating consequences for people. For example, the daily maximum and minimum temperature are an important determinant of species distribution and the viability of different agricultural systems (Voldoire & Royer, 2004).

Semazzi & Song (2001) used a model based on the total clearing of African tropical rainforests, and predicted a decline in rainfall over Eastern and Western Africa, but an increase in other regions, including over southern DRC and southern Africa. They also estimated that there would be an increase in surface temperature of up to 2.5° C and of ground temperature of 5° C in deforested areas. In another such study, Avissar & Werth (2005) predicted that although deforestation in Central Africa would not affect the total amount of global rainfall, its distribution would be affected. Thus, they estimated that there could be reductions in rainfall of 5-15% in north America, and up to 25% over Ukraine and Russia, while there would be increases of up to 30% in the Arabian Peninsula and East Africa.

RELATIVE IMPORTANCE OF GREENHOUSE GAS EFFECTS AND LAND-USE CHANGE

Palaeoclimatic evidence and modelling of the climate both indicate that land-cover has a major role in climate. However, there remains uncertainty as to its relative importance compared with the impact of increases in the concentration of atmospheric greenhouse gases. Recent studies do suggest that at a global scale the latter may be more important than land cover change (Mahé et al., 2005). However, that is not to say that the impact of deforestation can be ignored, since its impact at the local and regional level may be significant, and it is changes at this scale that are of most concern to people, for example, through its impact on agriculture.

Additional modelling is needed at this scale to predict likely scenarios. For example, it has been suggested that in Africa, the effects of deforestation and global warming could be counteractive in relation to their effect on rainfall. Thus, deforestation is likely to reduce rainfall while global warming is predicted to increase this. However, these two factors are both likely to enhance temperatures, and so the effect of each will be exacerbated (Maynard & Royer, 2004). These researchers conclude that more detailed modelling is required to determine the interaction of these phenomena and thus, the direction and magnitude of any such changes.

FORESTS AND CLIMATE CHANGE POLICY

The research presented in this report demonstrates that the forests of the Congo Basin play a crucial role in maintaining the local, regional and global climate. This is because of their role in the carbon cycle – the region's forests are a sink of an estimated 24-39 Gt of carbon, and current deforestation rates are estimated to be releasing 0.02-0.44 Gt of carbon per annum. Furthermore, they are an important driver of atmospheric circulations, the exchange of energy and water between the forests and atmosphere influencing regional and global weather systems.

The potentially grave consequences of climate change raise the stakes in terms of forest conservation. The question now is what policy measures could be used to reduce deforestation and thus limit the impact of land-use change on the global climate. In recent years, this has been addressed within the context of the international climate regime, where the potential of using carbon financing mechanisms as an incentive to reduce deforestation is being discussed. It has been proposed that such an approach would not only provide substantial sources of funds for forest conservation but could also provide a relatively cheap means of reducing greenhouse gas emissions.

CURRENT POLICY SITUATION

The most direct means of reducing carbon emissions from the Congo Basin's forests would be through reform of the regulatory framework – in all countries of the region, current policies strongly favour industrial forest exploitation. In the case of DRC, up to 60 million hectares of forest could be opened up to mostly new industrial logging activities[9], potentially releasing an additional 3 to 6 Gt C into the atmosphere over the period in which the forest was logged[10]. A further similar amount could be released if these logged forests are eventually completely cleared – the usual pattern following forest degradation and fragmentation.

Clearly, any developments which increase the area under industrial logging are likely to run counter to global efforts to prevent climate change. However, the political reality in countries such as DRC is that expectations of increased wealth from forest exploitation have already been raised – and so there will be pressure for these short-term financial gains to be realised. Therefore, the question arises of what other policy and financial mechanisms would be needed to accompany any restrictions on industrial forest exploitation.

Under the current climate change regime, there is no incentive for developing countries to reduce their own emissions from deforestation (or any other source), since under the Kyoto Protocol no national baselines have been set for these countries. Furthermore, the mechanisms by which developed countries can support measures to reduce or avoid emissions in the forestry sector of developing countries are extremely limited.

Within the Kyoto Protocol, Annex 1 (developed) countries can obtain carbon credits by investing in energy and forestry projects. This can be done through the Joint Implementation (JI) mechanism for projects within Annex 1 countries, these including reforestation and afforestation projects and also forest management. Alternatively, under the Clean Development Mechanism (CDM), Annex 1 countries can support projects in non-Annex 1 (developing) countries. However, under this latter mechanism forestry projects are limited to reforestation or afforestation initiatives while forestry management and conservation projects are excluded (Locatelli & Karsenty, 2004).

Proposals to include forestry management and conservation within the next commitment

[9] See, for example, World Bank (2002) Democratic Republic of Congo, Mission de Suivi Sectoriel. 17-27 April 2002.
[10] Based on a loss of 25-50% of carbon (due to forest degradation - see table 2), and a conservative estimate of the average biomass density of 200 t C / ha. x 60 million hectares.

period are currently being discussed within the framework of the United Nations' Framework Convention on Climate Change (UNFCCC)[11]. Such an approach would not only make the scheme more equitable for developing countries (since forestry management projects would then also be allowable here), but could potentially provide them with a significant means of funding sustainable forest management. It would also remove the perverse incentive for deforestation which currently exists – in theory at least – as with no incentive for forest conservation, landowners could decide to clear a forest in order to obtain funding for reforestation (Niesten et al., 2002; Peskett et al., 2006b). A final benefit is that it would bring developing countries into the international climate change mitigation efforts – important not only because they are a significant source of emissions, but also politically, as nations seek an equitable means of progressing on this issue beyond the current Kyoto Protocol commitments (Peskett et al., 2006b; Skutsch et al., 2006).

ACCOUNTING FOR FORESTS AND CARBON

Thanks to the Kyoto Protocol and European Emissions Trading Scheme (ETS) there exists a market in carbon, and so it has a monetary value. Consequently, a price can be put on the costs of deforestation, or conversely, the benefits of forest conservation.

For example, a recent valuation of CO^2 within the EU was US$ 20 per ton (over US$ 70 per t C)[12]. If 1 hectare of tropical forest contains the equivalent of 500 t CO^2, (or 136 t C) this gives it a value of US$ 10,000 (Chomitz, 2006). Alternatively, if prices were as high as US$ 35-50, as was assumed in the Stern report (2006), then the value would be US$17,500-25,000 per hectare. In contrast, forests are often cleared for agricultural land which may only be worth a few hundred dollars per hectare and perhaps generating up to US$ 1000 from one-off timber sales. Based on the profitability of the particular land-use system that replaces a forest, the opportunity costs of forest conservation can be calculated. One estimate placed this at between US$ 3-11 / t C (Chomitz, 2006), while a study of 8 tropical countries produced slightly higher estimates, of US$ 7 – 37 / t C, with an average value of US$ 13 (Grieg-Gran, 2006)[13].

These figures would suggest that paying countries to prevent deforestation would provide a relatively cheap means of mitigating climate change. On the basis of his estimates, Chomitz (2006) calculated that relatively modest carbon prices, of perhaps US$ 5-10 could deter forest conversion of 1-2 million km2 of forest by 2050, so preventing the release of 8-15 Gt C, while a price of US$ 100 would promote the conservation of 5 million km2 of forest, equivalent to 47 Gt C. (As a comparison, the average price of carbon under the CDM was about US$ 25 per tonne in 2005 (Grief-Gran, 2006).) At the same time, such a system could generate significant amounts of money for developing countries. For example, one estimate suggests that such initiatives could be worth between US$ 179 million and US$ 1.278 billion to DRC (Mongabay, 2006)[14].

OPTIONS FOR CARBON FINANCING MECHANISMS

There exist numerous proposals for establishing a mechanism to reduce carbon emissions from forestry, with a range of methodological and technical differences. These entail the payment of incentives for 'avoided deforestation' – an approach that has been termed 'compensated reduction' (Moutinho & Schwartzman, 2005; Santilli et al., 2005; Skutsch et al., 2006; Streck & Scholz, 2006).

In essence, compensated reduction would involve a country making a commitment to targets to reduce their greenhouse gas emissions from deforestation below a national baseline, this based on their historic emissions

[11] For example, see details of a recent workshop at: http://unfccc.int/methods_and_science/lulucf/items/3745.php
[12] 1 g C = 3.664 g CO^2
[13] The 8 countries were: Cameroon, DRC, Ghana, Brazil, Bolivia, Indonesia, Malaysia, Papua New Guinea.

from deforestation. Any reduction below this level would enable emissions reductions credits to be issued, which could be traded within international carbon markets. Payments would be made at the end of the commitment period, or if the targets were not met, a mandatory cap on emissions would be imposed in a subsequent commitment period (Peskett et al., 2006a).

Recent discussions on this issue were reinvigorated by a proposal for such a scheme presented to the UNFCCC by Papua New Guinea and Costa Rica (on behalf of a group of developing countries termed the 'Coalition for Rainforest Nations') (UNFCCC, 2005). This, and other proposals, are now being considered by the Convention's Subsidiary Body for Scientific and Technological Advice (SBSTA).

OTHER FINANCIAL MECHANISMS

Linking forest conservation with the international climate regime, and more specifically, with the carbon trading system, has the benefit that there is the potential to tap into large amounts of finance. However, the disadvantage is that it is dependent on international negotiations, which typically are incredibly slow and usually result in political compromise rather than the most practical or effective solutions. Indeed, the earliest such a mechanism could now be established within the Kyoto Protocol would be for the next commitment period of 2013-2017.

Even if such a regime is established, experience with the CDM raises doubts as to the impact it would actually have. To date, very few projects have been established under this latter mechanism in developing countries, particularly within Africa, in part because of the high transaction costs involved (Desanker, 2005; Jindal, 2006; Peskett et al., 2006a).

An alternative approach would be to establish a system outside of the Kyoto Protocol, countries agreeing to voluntary targets for reducing their emissions. Activities to achieve these goals could be financed through an international fund, established for this purpose, or alternatively, from contributions made on a bilateral or perhaps multilateral basis – through grants, loans, etc. (Lanchberry, 2006; Morgan et al., 2005). For example, Brazil has suggested that such a fund could be paid for with voluntary contributions from developed countries (Stern, 2006), an approach that has received support from the Congo Basin countries (UNFCCC, 2006c). Alternatively, an independent market for carbon credits could be established (but not ones that could be traded within the Kyoto system), or a system of 'forest' or 'biodiversity' credits could be devised – for example, based on the area of forest protected. Such a market could be paid for by the private sector, for example, companies wishing to invest in forestry projects linked to corporate social responsibility or other goals (Stern, 2006).

Indeed, there is a rapidly expanding voluntary market, which includes schemes initiated by institutions to deal with their own emissions as well as those of companies who sell carbon offsets as a service to other companies or individuals (Peskett et al., 2006a). This has already proved to be a significant source of financing for conservation initiatives, and could either be an alternative to a Kyoto based scheme, particularly for the short-term while international negotiations are ongoing, or it could operate in parallel.

The disadvantage of this is that there is less money available than if the global market for carbon credits is tapped into. In addition, there is a higher risk of leakage if a project-based approach is taken, as has developed within the voluntary market – i.e. that deforestation or unsustainable forest practices will simply be shifted from a project site to another area. However, this can be minimised if the projects are placed within the framework of a national strategy. Indeed, regardless of where funding comes from, effective national systems are

[14] This estimate was based on a carbon price of US$ 20. The calculation was made simply from FAO's estimates of annual carbon emissions from deforestation during 2000-2005 – the rate of deforestation was estimated at 320,000 ha./yr., releasing an estimated 45-64 million tons of carbon. Therefore, the total values represent the amount that could be 'earned' if all current carbon emissions from deforestation were to be stopped – an unrealistic scenario.

needed in order to translate international incentives for reduced deforestation into incentives for forest owners, and also for countries to monitor their forests and carbon emissions.

Some countries have already begun to implement national strategies, and Costa Rica is at the forefront of such efforts. Here, a national system for certified tradable offsets has been established, which includes forest conservation projects. The first offset was issued in 1997 to a consortium of the Norwegian government and private companies, representing a credit for 200,000 t of carbon offset, for a reforestation and forest conservation project (Forest Trends, n.d.; Rosenbaum, 2004).

In many countries there are an increasing number of project-based efforts. For example, in Bolivia a national park was established in 2000 through a partnership between the national government, conservation organisations and US energy companies. This is aimed at protecting 1.5 million acres of forest, which it is expected will reduce carbon emissions by 17.8 million tonnes over a period of 30 years (Winrock International, 2002). Similar initiatives have also been established in Brazil and Belize[15].

Projects such as this can be funded through grants, loans or debt for nature swaps. There are various other means by which governments can support conservation of their own forests, including tax concessions, incentive payments and subsidies (UNFCCC, 2006b). Financial incentives for sustainable forest management have been established in a number of countries. For example, in Costa Rica, tax concessions are provided for landowners who implement forest conservation – a policy aimed at promoting the full-range of environmental services provided by forests, and not just that of a carbon sink (Rosenbaum, 2004).

Initiatives such as these provide valuable experience as to how best to reduce deforestation, and means by which such efforts could be scaled up or replicated in more countries. Therefore, while discussions are ongoing within the UNFCCC, options to support forest conservation and sustainable management should continue to be explored.

THE CHALLENGES

These various options present both scientific and policy challenges if they are to be effective, feasible and equitable. These include methodological issues such as determining baselines and defining deforestation; and practical questions such as how to prevent leakage, either between projects or countries (i.e. the shifting of deforestation from a target project or country to another region) and how to ensure the permanence of forest conservation. If a system for compensated reduction is established, there are also questions such as how to compensate countries that already have low deforestation rates, and how to ensure that any carbon credits for avoided deforestation do not remove the incentive for taking action in other areas (e.g. reducing emissions from industrial sources).

There also remains the fundamental problem of how to reduce deforestation, which is the result of a complex of social, economic and political factors. Such efforts would have to address a variety of issues, including logging, agricultural expansion, infrastructure development, land tenure and other factors (Peskett et al., 2006b). As is noted above, in most countries of the region, industrial exploitation is a central element of forest policy, and indeed can play an important role in political patronage and corruption. Therefore, there are serious doubts as to whether the long-term substitution of these timber 'rents' with carbon financing would be sufficient to discourage logging activities. Any such mechanism would have to be very

[15] http://www.nature.org/initiatives/climatechange/work/art4253.html

carefully targeted, to ensure that the right decision-makers were reached.

This relates to the question of how any funding mechanism should be established – should international funds be paid to a national government or to individual projects or landowners, and what activities should be supported? If a project-based approach is taken, funders would perhaps be able to chose the types of project they support, and it could help to ensure that the funds are not diverted to other areas. However, the disadvantage of this is that there is a higher risk of leakage, since it does not facilitate a whole landscape or national approach being taken, and would not necessarily support the establishment of a national forestry strategy (Chomitz, 2006; Peskett et al., 2006b).

Many of these issues are discussed in detail in the literature, and so will not be considered here (Chomitz, 2006; Lanchberry, 2006; Moutinho & Schwartzman, 2005; Peskett et al., 2006b; Santilli et al., 2005; Skutsch et al., 2006; Streck & Scholz, 2006). Rather, discussion will be limited to those issues of particular concern in the context of the Congo Basin and of relevance to efforts to maintain the region’s forests and their wider environmental and social values.

One fundamental issue is that the implementation of an effective, workable mechanism depends on being able to measure and monitor changes in forest area, and thus, to evaluate carbon emissions. Lack of data and understanding of these issues is a global problem, as has been highlighted in this report. However, the situation is particularly severe in the Congo Basin, where there are limited resources and capabilities for the necessary research and monitoring activities (Defries et al., 2005; Washington et al., 2004; 2006).

Therefore, significant investment is needed to build capacity. The proposed systems for carbon finance would result in payments for credits being paid at a later date – i.e. after there has been a reduction in deforestation. Therefore, raising the initial funding required is problematic and could present a financial barrier for many of these countries. This could be raised from financial institutions (such as the World Bank) or private sector finance could be sought, and these are valid options for the immediate term. Alternatively, a solution for the longer term could be to establish a mechanism by which developed countries could fund the required capacity-building programmes, claiming a percentage of the resulting emissions (thus, along similar lines to the current CDM) (Chomitz, 2006; Santilli et al., 2005; Skutsch et al., 2006).

The lack of data on land-use change and carbon flux is exacerbated by the fact that there remain no internationally accepted criteria or methodologies for assessing forest area and biomass, and thus, of carbon flux (Skutsch et al., 2006). One particular issue of concern is that many existing estimates of deforestation have taken insufficient account of forest degradation – this accounting for a significant proportion of the land-use change taking place within the Congo Basin, and consequently, representing an important source of carbon emissions in the region. One proposal for a system of carbon credits has been developed in which degradation is also accounted for. Achard et al. (2005) suggest that carbon credits could be calculated through monitoring not only the change from intact forest to non-forest (i.e. deforestation), but also that from intact to non-intact forest (i.e. degradation), as well as from non-intact forest to non-forest (deforestation). Non-intact forest is defined as forest which shows signs of human intervention, and under the proposed scheme would be assumed to contain 50% of the amount of carbon of the equivalent intact forest. While such an approach does present considerable practical problems – forest degradation being difficult to assess – it would enable more realistic calculations of carbon emissions.

In addition, a more nuanced approach to the role of forests on climate is also needed. To date, most of the discussions on an international climate change regime have focused purely on the role of greenhouse gases, with little attention being given to the impact of land-cover change. For example, the Kyoto Protocol is only concerned with limiting greenhouse gas emissions and not with other anthropogenic effects on climate change. The research findings highlighted above demonstrate that a more holistic approach is needed, in which both the flux of CO^2 and changes in albedo and energy flow are incorporated. This would clearly be much more complex if a system for carbon credits were to be established that was fully exchangeable with those from fossil fuels, requiring an evaluation of the relative contribution of albedo, evapo-transpiration and surface roughness in relation to carbon emissions.

The feasibility of such an approach is uncertain, particularly given that some of these factors may operate synergistically while others may be counteractive. However, it would perhaps be possible within a system that was outside of the Kyoto protocol, for example, under a scheme for biodiversity or forest conservation credits. This needs further exploration, since focusing purely on carbon flux could result in land management decisions that do not in fact produce the intended climatic results (Marland et al., 2003; Pielke et al., 2002).

As well as greater consideration of the role of land-use effects, climate research also needs to focus more on local effects and on climate variability, rather than on global averages, which are cited in many studies. Thus, more data is needed on the way in which climate change could manifest itself at the local level, on seasonal and inter-annual time-scales, and also how climate variability would be affected (for example, changes in daily temperature ranges). It is such information that is of most significance for agriculture and non-timber forest products (for example, influencing fruiting patterns and species distribution). Furthermore, this shift in approach could also help prioritise climate research in Africa, which has been neglected here, perhaps in part because of the seeming distance between much climate research and immediate development priorities (Washington et al., 2006).

In addition to these methodological issues, there are a number of more general concerns related to equity, both between the various stakeholders in the forestry sector within a particular country (indigenous and rural peoples, timber and other forest-based industries, et al.), and also between developing and developed countries.

One issue is that in discussions of carbon financing, most attention is given to forest protection rather than looking more broadly at sustainable forest management. This is reflected in the use of terminology – for example, the term 'avoided deforestation' is widely used but this tends to imply strict conservation measures. Consequently, Peskett et al. (2006b) have suggested that the term 'reduced deforestation' is more appropriate. Whatever the terminology, the aim of such measures is to reduce carbon emissions, something that could be achieved not only through forest protection but also through facilitating traditional forest management systems – where these are found to be sustainable (Skutsch et al., 2006). In fact, there is evidence that recognition of traditional land rights promotes forest conservation – research in Brazil found that many indigenous reserves have prevented deforestation, even when they are located in frontier areas of agricultural expansion (Nepstad et al., 2006).

Forest-dependent peoples are at risk of losing out under such mechanisms. For example, logging companies could end up being paid incentives not to log, while local people, who may have been using the forest sustainably, would receive nothing. Therefore, mechanisms need to be explored by which forest-dependent communities could be compensated for sustainable forest use, while also discouraging unsustainable practices (Skutsch et al., 2006).

With this in mind, caution is needed that governments do not adopt heavy policing policies of forest areas (as has been done in the past, either for timber production or conservation goals), and cut off the livelihood options of forest-dependent peoples (Peskett et al., 2006b). Indeed, there is a danger that any such scheme will result in primacy being given to the reduction of carbon emissions at the expense of all other forest values. In much of the Congo Basin, shifting cultivation has been practiced by Bantu farmers for several thousand years (Vansina, 1990). These agricultural systems have been broadly sustainable in ecological terms (Wilkie et al, 1998), and indeed, may have contributed to the present high forest structure (Willis et al, 2004). It would be ironic, if not environmentally and socially catastrophic, if such sustainable farming practices were to be proscribed on the basis that they result in carbon emissions.

A balanced approach is needed in which the full range of forest values is recognised, these including biodiversity and other environmental values, harvesting of forest products (both timber and non-timber), and the rights of forest-dependent peoples. To facilitate this, any system to mitigate the impact of deforestation on climate change must be part of a wider national forest strategy. This will enable the development of measures to reduce deforestation that are appropriate to the particular country, taking into account national priorities and circumstances.

CONCLUSIONS

There are huge challenges to the successful implementation of such mechanisms. Addressing these issues in Central Africa is particularly daunting, where there is widespread poor governance, conflict, and unclear land tenure (Jindal, 2006).

All the options for reducing deforestation as a climate change measure depend on the abilities of countries to control and manage their forest resources, and to monitor these resources and associated greenhouse gas emissions. The countries of the Congo Basin are a long way from being able to quantify and monitor their carbon resources or emissions. Furthermore, the challenges that they face in implementing measures to reduce deforestation are immense, due to the severe political and governance problems prevalent in the region. Pre-requisites for the sustainable management of forests – and thus, the reduction of deforestation – are the existence of strong and effective national policies and institutions. Therefore, any system for compensated reduction will entail significant institutional development and high transaction costs (Peskett et al., 2006b).

However, although the challenges are huge, the costs of taking no action are also potentially huge. There is growing acceptance of the need for drastic reductions in the emissions of greenhouse gases – for example, the Stern report (2006) states that a reduction of carbon emissions of at least 25% by 2050 is needed if the worst impacts of climate change are to be avoided. If this is to be achieved, it will require action on various fronts – including the reduction of emissions from tropical deforestation and forest degradation.

There remains uncertainty as to the costs of such mechanisms, and whether in fact payments for emissions would be sufficient to offset all the costs involved (Sedjo, 2006; Skutsch et al., 2006). Indeed, there has been a tendency to overstate the potential financial benefits from carbon financing (Obersteiner, 2006). For example, alternative methods for calculating opportunity costs suggest that these could be as high as US$ 100 t C, significantly higher than the estimates of US$ 3-37 cited earlier in this report (Stern, 2006). However, even with such values, carbon credits could still prevent deforestation on marginal lands and for unprofitable land-uses. It could also make sustainable forest management more profitable, helping to shift the balance away from practices based on the mining of forest resources.

However, there is an important proviso – any efforts to reduce deforestation can only be implemented if issues of land tenure and resource rights are first resolved. Without such a basis, either forest conservation will fail or it will result in increased conflict over resources and further disadvantage forest-dependent communities. Fair and equitable land-use planning is therefore key.

What is clear is that the Congo Basin forests have a crucial role in influencing the local, regional and global climate, and so they need to be maintained. It is also clear that additional support is needed to help the countries of the region do this – indeed, it is in all our interests that this is done.

RECOMMENDATIONS

POLICY

Options for establishing an international mechanism for avoided deforestation are continuing to be explored and discussed, and these efforts need to continue. Within these discussions, a number of issues require particular attention:

- Support is needed to develop national strategies and infrastructure for forests and climate. This will need to include institutions to: monitor deforestation and degradation; develop and implement policies for forest management that will mitigate carbon emissions and land-surface impacts.

- A more holistic view of the role of forests in climate change needs to be adopted, considering not only their role in the cycling of greenhouse gases, but also the importance of land-cover characteristics. Means by which the latter role could be accounted for within a carbon credit system should be explored.

- Activities related to forests and climate must be co-ordinated and balanced with other forest issues and priorities. Priority should be given to projects that would bring a variety of benefits, e.g. securing land-rights, biodiversity maintenance, provision of forest products, etc., rather than to those aimed purely at carbon storage.

- Means by which indigenous peoples could be incorporated in a system for avoided deforestation should be explored.

- Any projects and activities aimed at avoided deforestation must incorporate monitoring processes to assess their impact on forest-dependent communities and on the wider environment.

RESEARCH

The limited data in many areas has been widely reported, for example, the need for better assessments of biomass, forest area and rates and distribution of forest degradation and deforestation have all been highlighted. This is particularly true in Central Africa, where also understanding of, and data on, meteorological processes is limited. Therefore, there is a need for additional research facilities and activities within the region.

More specifically, the following issues need to be addressed:

- More attention in climate change predictions must be given to climate variability and to local effects, rather than the global average climate, in order to improve assessments of the ecological and agricultural impacts of climate change.

- Research is needed into traditional systems of forest management and agriculture that are carbon neutral, or minimise carbon loss to the atmosphere, as options for sustainable land-use.

- The role of forests in the cycling of greenhouse gases other than carbon dioxide should be investigated further.

- More detailed research into the interactions between global warming and the land-surface impacts of deforestation is needed.

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