## Annex 7.f Emissions from the land-use change and forestry sector

This annex provides some background on what causes emissions from land-use change, the main sources of emissions from this sector today, historical and projected business-as-usual trends, drivers behind emissions growth, and prospects for emission cuts.

Land-use change accounted for 18% of global greenhouse gas emissions in 2000, making it the second largest source of emissions, after the power sector. These emissions arise from a change in the management of land by humans, such as conversion of forests to pasture land. The following sections will explain the role of the land, that is plants and soils, in the natural carbon cycle, and how changes in the use of land by humans, can lead to such substantial emissions of carbon dioxide.

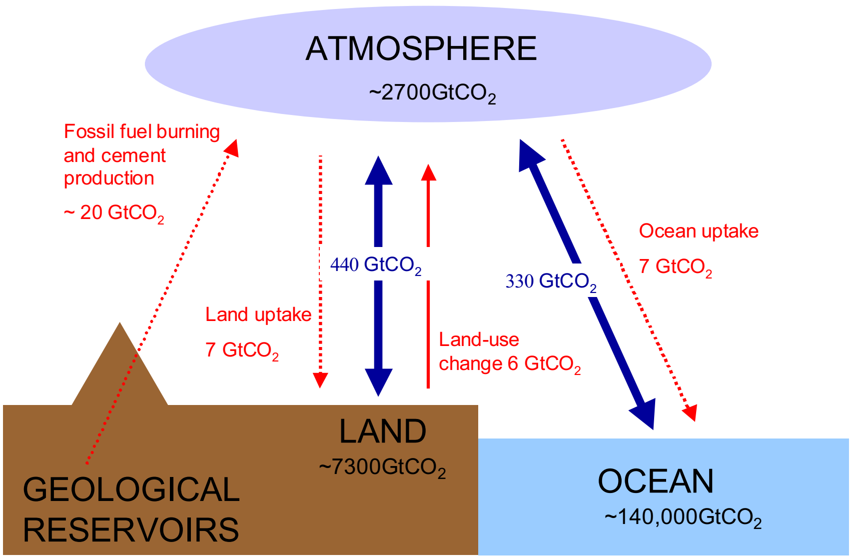
### Natural carbon cycle

Carbon (and in its oxidised form, carbon dioxide) is cycled continuously through the Earth's natural systems. Figure 1 is a schematic diagram of the principle flows (see IPCC 2001 for more details). The components of this cycle of relevance here are those relating to the land, predominantly plants and soils. The main natural flows are:

- Carbon *released* (emitted) to the atmosphere by respiration (the biosphere 'breathing' - taking in oxygen and releasing carbon dioxide) and the decay of organic matter;
- Carbon *sequestered* (absorbed) by plants as they grow, through photosynthesis, creating a natural store or stock of carbon in their tissues. Some of this is transferred to the soil through the roots and as leaves and other litter fall.

As shown in Figure 1, these natural flows total around 440 $GtCO_2$/yr between the land and the atmosphere and are approximately in balance. A stock equivalent to just over 7,300 $GtCO_2$ is currently stored in plants and soils, more carbon than contained in all remaining oil stocks, and more than double the amount currently in the atmosphere. If these stocks were perturbed, there is potential for sizeable emissions.

**Figure 1[1]: IPCC estimates of main natural flows of carbon (blue) and human perturbation (red) for the 1980s (in $GtCO_2$/yr).** Net emissions from land-use change are shown as a solid red arrow. Estimates of stocks of carbon are given for the atmosphere, land and ocean. Half of all human-induced emissions (from land-use change, burning fossil fuels and cement production) are taken up by the land and ocean; half remain in the atmosphere, adding to its stock of carbon. The increased uptake by the land and ocean is shown below; this is a natural response to the rising concentration of carbon dioxide in the atmosphere.




[1] Source: Adapted from IPCC (2001), Figure 3.1

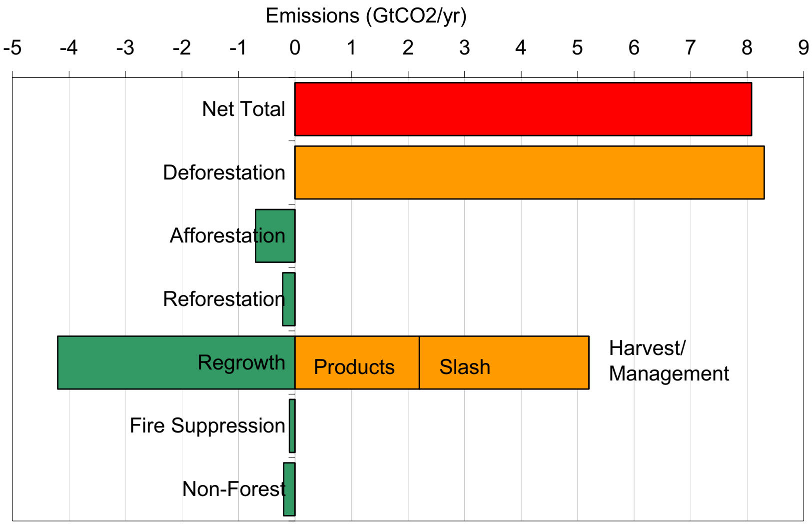
**Sources of (man made) land-use change emissions now**

Man-made land-use changes alter the *local* balance between $CO_2$ emissions released into the atmosphere and absorbed by the ecosystem, leading to an accumulation or loss of carbon from the land stock. Measuring these flows accurately is very difficult[2], but estimates by Houghton (2003) suggest that in 2000, human changes to land led to a loss (release) of around 8 $GtCO_2$. This is clearly a small fraction (less than 2%) of the total flow to the atmosphere from land but can have a significant impact on the climate.

Figure 2 shows that deforestation is the single largest source of land-use change emissions, responsible for over 8 $GtCO_2$/yr in 2000. Deforestation leads to emissions through the following processes:

- The carbon stored within the trees or vegetation is released into the atmosphere as carbon dioxide, either directly if vegetation is burnt (i.e. slash and burn[3]) or more slowly as the unburned organic matter decays. Between 1850 and 1990, live vegetation is estimated to have seen a net loss of 400 $GtCO_2$ (almost 20% of the total stored in vegetation in 1850)[4]. Around 20% of this remains stored in forest products (for example, wood) and slash, but 80% was released into the atmosphere.
- The removal of vegetation and subsequent change in land-use also disturbs the soil, causing it to release some of its stored carbon into the atmosphere[5]. Between 1850 and 1990, there was a net release of around 130 $GtCO_2$ from soils.

**Figure 2[6] Sources of emissions from global land use change in 2000**




[2] All estimates show that emissions from land-use are significant, but the scale of emissions varies between studies. The WRI estimates (using Houghton and Hackler 2002) here lie in the mid- to upper- range of estimates given by the Third Assessment Report of the IPCC. For a fuller discussion of the range of estimates and uncertainties in measurement, see Houghton (2003).

[3] Note that emissions from the combustion of wood and other biomass products are not typically included in land-use change estimates, as these are instead captured by the end-use sector (e.g. heat generation, buildings or industry).

[4] Houghton (2005)

[5] Deforestation can lead to up to a 40% loss of soil carbon depending on the new use of land. Conversion to crops, pastures and grasslands leads to the largest removal of carbon. Palm et al. (2005)

[6] Source: Reproduced from Baumert et al (2005), original data from Houghton (2003). Deforestation and reforestation in tropical countries includes only the net effect of shifting cultivation. For afforestation, areas of plantation forests are not generally reported in developed countries (this estimate includes only China's plantations). Fire suppression is probably an underestimate, as it includes the US only (similar values may apply elsewhere). Non-forests include $CO_2$ sequestered through woody encroachment onto agricultural soils and emissions from soils (only that resulting from cultivation of new lands and not carbon accumulation that may have resulted from recent agricultural practices).

Deforestation also reduces the uptake of carbon dioxide by vegetation, hence leaving more carbon dioxide to accumulate in the atmosphere. However, this effect is typically much smaller than the immediate release of stored carbon, particularly for the case of the removal of older vegetation, which absorb little carbon.

Planting new trees and other vegetation can enhance carbon uptake and thus, increase the amount of carbon stored in land. In 2000, the planting of new forests (afforestation) and re-establishing old forest areas (reforestation) is estimated to have led to an uptake of around 1 $GtCO_2$ (Figure 2). These can be thought of as 'negative' emissions as they offset emissions from other activities. It should be noted that, in terms of emissions, the planting of one tree does not immediately offset the removal of another tree. Trees absorb carbon dioxide very slowly – it could take a century or more for a growing tree to recover all the carbon dioxide that is rapidly released when another tree is cut down.  This means that a policy to reduce deforestation would be more productive, in terms of emissions saved, than afforestation and reforestation.

Other contributions to emissions in the land-use sector include forest management and harvest, which contributed net emissions of over 1 $GtCO_2$ and smaller contributions from fire suppression measures and non-forest activities. These smaller contributions may be underestimated because, due to data scarcity, they include only specific regions or types of land-use change. For example, they exclude some $CO_2$ emissions from agricultural soils.

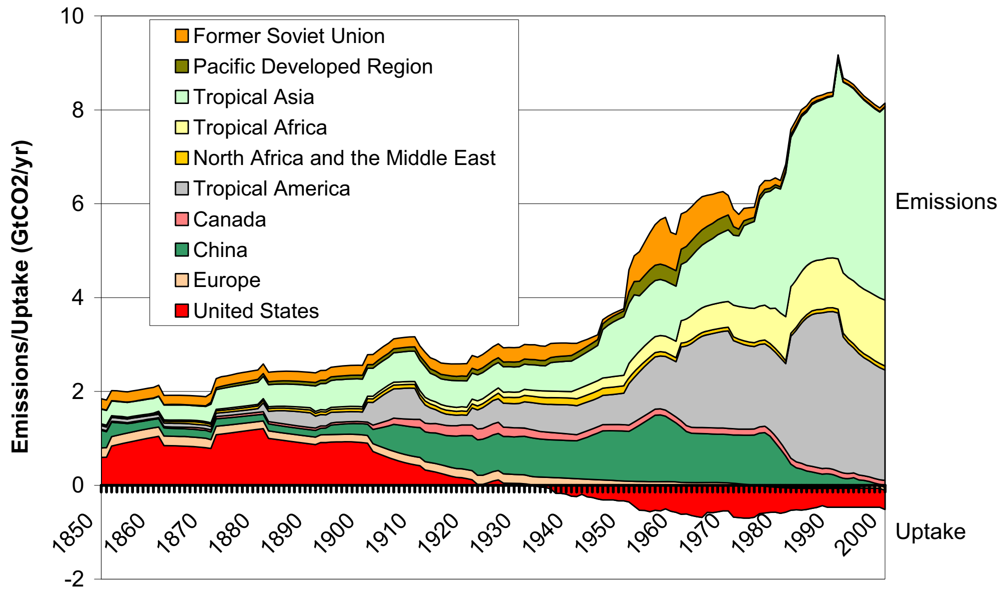
**Historical emission trends**

Emissions from land-use change are different to other sectors in that the majority of emissions originate from tropical (developing) countries. In 2000, 55% of emissions came from tropical Asia, 30% from tropical America and 20% from tropical Africa[7]. Conversely, United States, Europe and China were each net absorbers in 2000 due to their afforestation and reforestation programmes. However, this absorption was not large enough to negate the large emissions from deforestation in the tropics.

Figure 3 shows a regional breakdown of the net emissions and uptake due to land-use changes between 1850 and 2000. Up until the early 20$^{th}$ century, emissions came predominantly from developed regions. Since then, there has been an explosion in emissions from developing regions. This reflects the fact that land-use change is closely tied to development. As regions develop they tend to clear forestland for expanding agricultural production and habitation. Between 1950 and 2000, emissions from land-use changes more than doubled due strong growth in emissions from tropical regions. Tropical deforestation has a particularly strong effect on emissions because trees in tropical forests typically hold, on average, about 50% more carbon per hectare than trees outside the tropics[8]. Since about 1995 total annual emissions appear to have stabilised at around 7 - 8 $GtCO_2$/yr.

[7] Carbon Dioxide Information Analysis Centre (CDIAC) using Houghton and Hackler (2002).
[8] Houghton (2005)

**Figure 3**[9] **Uptake and emissions from land-use changes between 1850 and 2000.** The negative emissions (uptake) post-1940 are largely due to increasing forest area in the US (0.4Gt$CO_2$/yr in 2000) and Europe (0.07Gt$CO_2$/yr in 2000). The peak in 1990 linked to forest fires in Indonesia.




## Drivers for emissions

As suggested above, the primary driver for land-use changes is the conversion of land from forest to agriculture. What drives the demand for additional agricultural land varies globally. In Africa, it is primarily small-scale subsistence farming. In South America, it is large-scale farming enterprises, producing beef and Soya for export markets. In South Asia, the driver is somewhere between the two, with oil palm, coffee and timber the main products. At a global level demand for agriculture is driven by population and income (see Annex 7.g). At a more local level, agricultural prices (and subsidies), infrastructure, access to markets, and land tenure can drive conversion to agriculture.

Demand for forest products is also a driver of land-use change emissions. Loggers tend to remove the oldest and most valuable trees, releasing their stored carbon, as well as some of that from neighbouring trees damaged in the process. If logging is conducted sustainably, for example, limited to single valuable trees, then forest regrowth can offset emissions over time. For these reasons, logging itself need not be a major driver of deforestation. Also, if the timber is used in long-lived wooden products it actually conserves carbon during the product lifetime. Significant emissions are generated where logging is conducted at an unsustainable rate, for example in regions of South East Asia, where intensive logging is fuelled by the strong demand for timber from fast growing regional economies. The wider impact of logging is that building access roads, to bring in equipment and take out logs, makes forests more vulnerable forest clearing for settlement and agricultural production. New logging roads open up formally closed regions and allow access to markets for agricultural products.

[9] Source: Carbon Dioxide Information Analysis Centre (CDIAC) using Houghton and Hackler (2002)

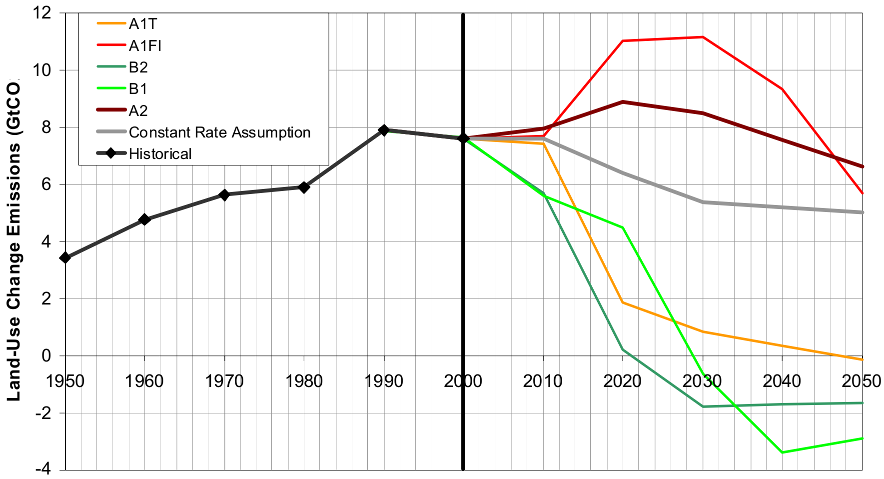
**Business-as-usual emission projections**

Like all emissions projections, future emissions from land-use changes are uncertain. However, it is clear that at the current rate of deforestation, most of the top ten deforesting nations would completely clear their forests before 2100. The one exception is Brazil, which due to its vast forest area (540mha[10]) could continue at its current rate of deforestation for over 200 years. If all of Brazil's remaining forests were removed it could lead to emission of over 300 $GtCO_2$. Figure 4 shows six different emissions projections, five of which are IPCC illustrative emissions scenarios.

The IPCC projections cover a wide range of future socioeconomic scenarios, giving divergent projections for future land-use change emissions. In each scenario, deforestation emissions are driven by factors including: population growth, depletion of forest and the demand for agricultural commodities. Those worlds with more focus on environmental sustainability (B1 and B2) have the lowest emissions. Beyond 2020-2030, these socioeconomic scenarios actually have negative emissions due to afforestation and reforestation programmes.

The final scenario shown in Figure 4 is from Houghton (2005). In this scenario, the national emissions are assumed to continue at the historical rate (the rate of deforestation averaged over the past two decades). The only factor that is assumed to effect emissions is the depletion of forest. Houghton makes the arbitrary assumption that countries will halt deforestation when only 15% of their 2000 forest area remains. Due to its simplicity and transparency, this is the scenario used as 'business as usual' in the Review. Under this scenario, emissions are projected to remain at around 7.5 $GtCO_2$/yr until 2012, reducing to 5 $GtCO_2$/yr by 2050 and 2 $GtCO_2$/yr by 2100[11].

**Figure 4[12] $CO_2$ emissions from land-use changes between 1950 and 2000 against projections of future emissions**




**Prospects for emissions savings**

Current estimates suggest that the land-use sector offers significant potential for future emissions savings. Chapter 9 (Section 9.4) of the Review suggests a total economic abatement potential of at least 5.5 $GtCO_2$ in 2050. If this could be achieved, net emissions

[10] FAO 2001
[11] Houghton 2005, based the FAO 2001
[12] Source: Historical emissions from the Carbon Dioxide Information Analysis Centre (CDIAC) using Houghton and Hackler (2002), projections from Houghton (2005) and IPCC (2000). Note that the IPCC SRES projections have been scaled to give consistency with historical estimates.

from the sector would be around –0.5 $GtCO_2$ (assuming a business as usual emissions based on Houghton 2005). This includes savings from avoided deforestation, afforestation, reforestation and land management practices (such as agro-forestry measures, as discussed in Chapter 25, Box 25.4). This may be an underestimate as it only includes savings from a limited number of countries and types of abatement (more details in Chapter 9). Most of this saving comes from avoided deforestation, which could be achieved at a cost equivalent to under \$5/$tCO_2$, or possibly as little as \$1/$tCO_2$.

In the past, clearing forests for agriculture and habitation has been a standard component of development. However, it does not need to be in the future. Chapter 25 of the Review discusses how deforestation could be avoided by supporting the development process, through for example, poverty reduction and establishing property rights, and implementing sustainable forestry and agricultural techniques.

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