**Supplementary Materials: supply of reduced deforestation and reforestation**

# Endogenous deforestation and reforestation emissions

We use deforestation and reforestation mitigation supply curves to make emissions reductions from tropical forests endogenous. Our modified version of the DICE model includes three abatement cost curves:

* Fossil fuel abatement as in the original version of DICE;
* Reduced tropical deforestation;
* Tropical reforestation;

All three are increasing functions in carbon price. The model looks for an optimal solution minimizing the discounted abatement cost over the period 2020-2100. The cost of reforestation and the cost of reducing deforestation are included in the cost of climate policy. Due to the low convexity of the MAC curves in Busch et al. (2019), plus our added assumption of no REDD+ supply beyond $100/ton, the total cost of avoided deforestation and reforestation is relatively high, such that the estimates we use for our analysis are on the conservative side of the REDD+ potential, compared to previous studies (e.g. Golub et al. 2017). Net emissions from tropical deforestation and reforestation over 2020-2050 are shown in Table 1 above

# Marginal abatement cost curves for REDD+

Using recent econometric estimates of costs of avoided deforestation and carbon sequestration from reforestation in tropical countries from Busch et al. (2019), we calculated Business as Usual (BAU) emissions and the corresponding potential abatement supply for the period 2020-2050 as shown in Table 1.

**Table 1: Tropical Deforestation, Reforestation and Net Emissions (Gt CO2), 2020-2050**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Deforestation** | **Reforestation** | **Net emissions from deforestation and reforestation** |
| BAU (emissions) | 257 | -102 | 155 |
| $50/tCO2 (reduced emissions) | -108 | -15 | 32 |
| $100/tCO2 (reduced emissions) | -160 | -36 | -41 |

Note: Emissions reductions (abatement) denoted by a negative sign. Net emissions are the sum of BAU emissions and emissions reductions.

Busch et al. (2019) projected 387.8 million hectares (Mha) of reforestation and 541.5 Mha of deforestation from 2020 to 2050 under a business-as-usual (BAU) scenario. These projected land-cover changes correspond to 102.5 GtCO2 of removals from reforestation, and 256.9 GtCO2 emissions from deforestation from 2020 to 2050 under a BAU scenario. Using the supplementary materials published by Busch et al. (2019), we reconstructed supply curves for the years 2025, 2035 and 2045 (these represent a median estimate of an annual REDD+ supply at given price during corresponding decade (see Figure 1). For a conservative estimate, we selected $100/tCO2 as a cutoff for REDD+ supply.

**Figure 1: Marginal Abatement Cost Curves (MACCs) for Reduced Tropical Deforestation**

 Source: Derived from Busch et al. (2019).

According to Busch et al. (2019), removals from tropical reforestation between 2020 and 2050 could be increased by 5.7 GtCO2 (5.6%) at a carbon price of US$20/tCO2 and progressively more for increasing prices. Based on the Supplementary Materials of Busch et al. (2019), Figure 3 below shows the corresponding supply curves for carbon sequestration from tropical reforestation up to US$100/tCO2.

**Figure 3: Marginal Abatement Cost Curves (MACCs) for Tropical Reforestation**

Source: Derived from Busch et al. (2019) up to $100/tCO2.

The resulting MACC is a linear function of price. We assume no additional supply for a carbon price higher than US$100/tCO2, since (a) we want to be conservative and (b) this exceeds the range documented in Busch et al. (2019). Notwithstanding this conservative assumption on reforestation potential, actual supply could of course be higher at prices above US$100/tCO2. Avoided deforestation offers 7.2–9.6 times as much potential low-cost abatement as reforestation overall (55.1 GtCO2 at US$20/tCO2 or 108.3 GtCO2 at US$50/tCO2).

## Total supply 2020-2100

Since our model covers the period 2020-2100, we include an additional estimate of emissions and removals that take place after 2050. Neither Busch et al. (2019), nor other studies (Gusti et al., 2015) provide data beyond 2050. We apply the assumptions below to obtain a conservative estimate of the mitigation potential from reduced deforestation and reforestation in tropical countries over the second part of the century.

*Reduced deforestation*

The data available from Busch et al. (2019) is not sufficient to estimate BAU emissions beyond 2050 and abatement potential. For the calculation of the corresponding BAU emissions, instead of using the same amount of deforestation as in the period 2020-2050 (257 Gt) from Busch et al. (2019) and thus assuming a flat baseline for deforested area, we apply an extrapolation of Gusti et al. (2015), as shown in Figure 4. This yields a gradually declining deforestation trend over the second part of the century. For the 2051-2100 period, our estimated cumulative BAU deforestation emissions are 109Gt CO2 and estimated abatement at US$100/tCO2 is approximately 90Gt CO2 (see Table 2 below).

**Figure 4: BAU deforestation and REDD+ supply based on Gusti et al. (2015)**

*Reforestation*

We assume no additional areas of tropical reforestation come in as a result of the carbon price after 2050 and include only the continual carbon removal from already reforested land during 2020-2050. We assume that planted forest and forest that is naturally regenerated continue to grow during the period 2050-2100. Additional sequestration is calculated using Figure 1 from the Supplementary Materials of Busch et al. (2019).

We set the average age of planted forest equal to 20 years by 2050 and 70 years by 2100. The carbon density increases from 40-45tC/ha to 80-90tC/ha, i.e. doubles. The naturally regenerated forest is on average about 50 years old (about 70 tC/ha). With 100 tC/ha equal to the upper bound for carbon sequestration per ha of regenerated forest, the additional carbon sequestration is about 40% of the carbon sequestered in the first period (2020-2050). These assumptions yield an additional mitigation potential from reforestation of about 40 GtCO2 over 2051-2100 as shown in Table 2 below.

**Table 2: Summary extrapolation (Gt CO2 during 2051-2100)**

|  |  |
| --- | --- |
|  | **Gusti et al. (2015) for avoided deforestation, Busch et al. (2019) for reforestation** |
| Deforestation | 109 |
| Avoided deforestation @$100/tCO2 | -90 |
| BAU reforestation  | -40 |
| Additional removal attributed to reforested land in 2020-2050 | -36 |

Note: Reduced emissions and removals denoted by a negative sign. Net emissions are the sum of BAU emissions and emissions reductions.

# Scenarios

For numerical simulations, we consider one reference scenario and two removal scenarios.

*Reference scenario*

The reference scenario represents BAU deforestation and BAU reforestation. The net emissions under the reference scenario are 224 Gt CO2 over the modeling period (2020– 2100).

*Reduced deforestation only*

The next scenario (deforestation only) includes only the potential to reduce emissions from deforestation with the minimum of -26 GtCO2 in net emissions (assuming carbon price of $100/t CO2).

*Reduced deforestation plus reforestation*

The third scenario (reduced deforestation plus reforestation) includes an additional supply of emissions removals from reforestation. The realization of this full modelled REDD+ potential yields net tropical forest emissions of -98 GtCO2.

# References

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