

Supplementary Materials for

**Accelerated forest fragmentation leads to critical increase in
tropical forest edge area**

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Supplementary Materials:

Figures S1-S10

Tables S1-S2

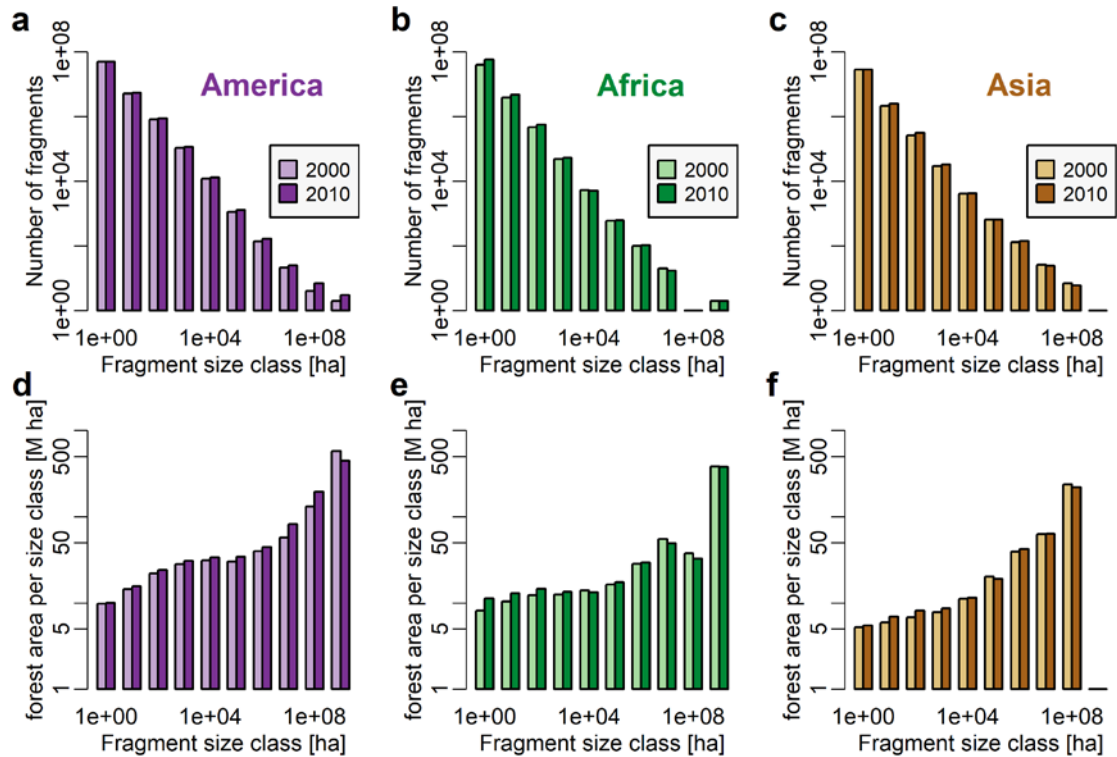


Fig. S1. Fragment size distribution (a-c) and the distribution of forest area (d-f) for the years 2000 and 2010, separately for each continent. Fragment size classes are 0-1, 1-10, 10-100, ... , 10^8 - 10^9 ha. Please note that we used other size classes in Fig.1 to better represent changes in large size classes.

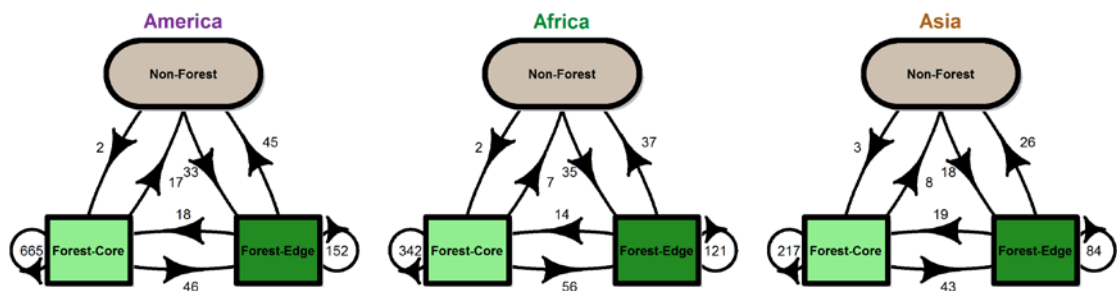


Fig. S2. Transition rates through forest gain and forest loss in the tropics between 2000 to 2010. The numbers next to the arrows indicate the absolute amount of area change over the 10-year period in millions of hectares (Mha). Numbers next to the rectangles indicate the amount of forest area in Mha that has not changed between 2000 and 2010. Forest area is divided into core area and edge area (assuming <100 m distance from forest edge). Shown are gains and losses of forest core area, forest edge area, and non-forest. Results for the whole tropics are shown in Fig. 2.

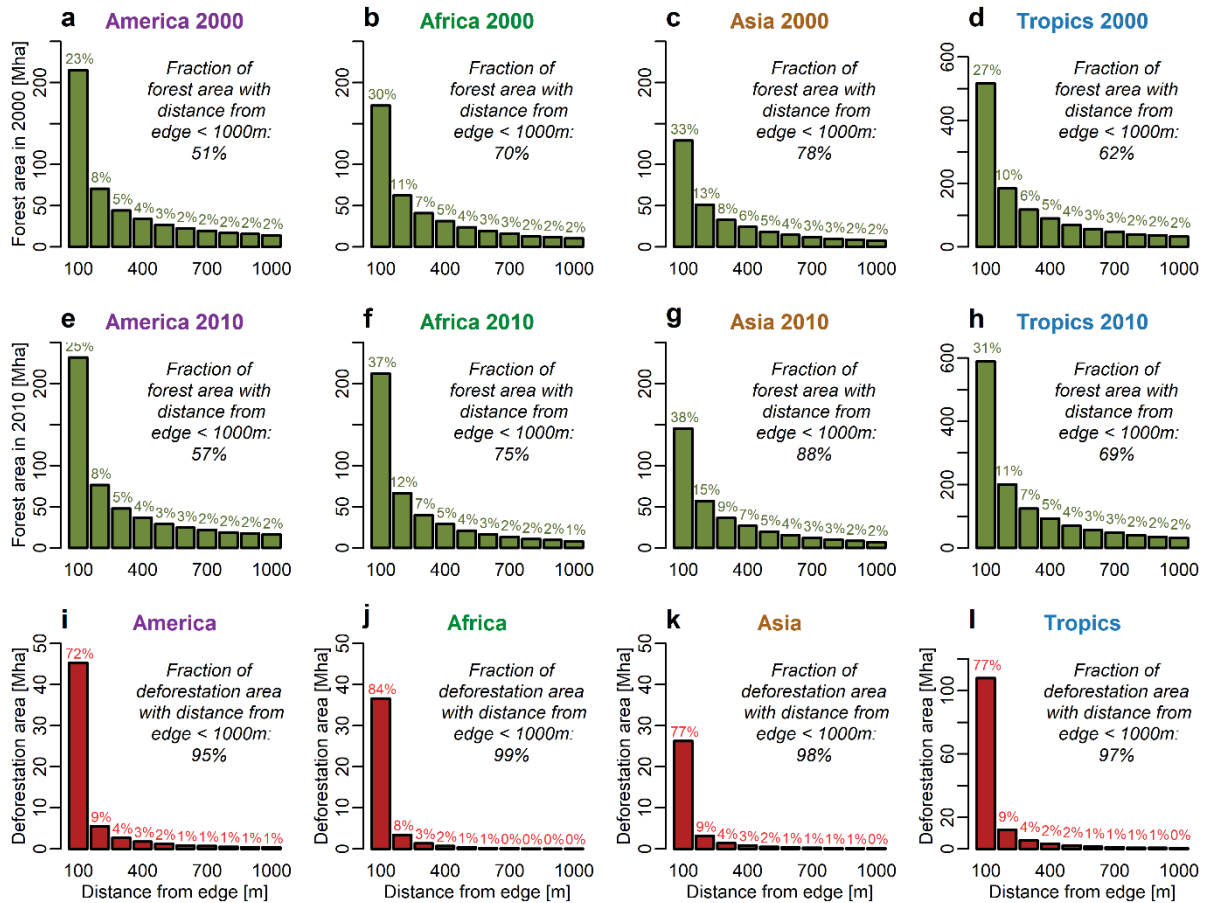


Fig. S3. Amount of forest area in 2000 (a-d), in 2010 (e-h) and deforestation (i-l; gross forest area loss for period 2000 - 2010) as a function of distance from forest edge. Analysis for tropical forests in America, Africa and Asia, and the whole tropics. (a-h) Percentage values indicate the relative amount of forest area per distance class. (i-l) Percentage values quantify the fraction of forest area loss (2000 – 2010) as a function to distance from forest edge.

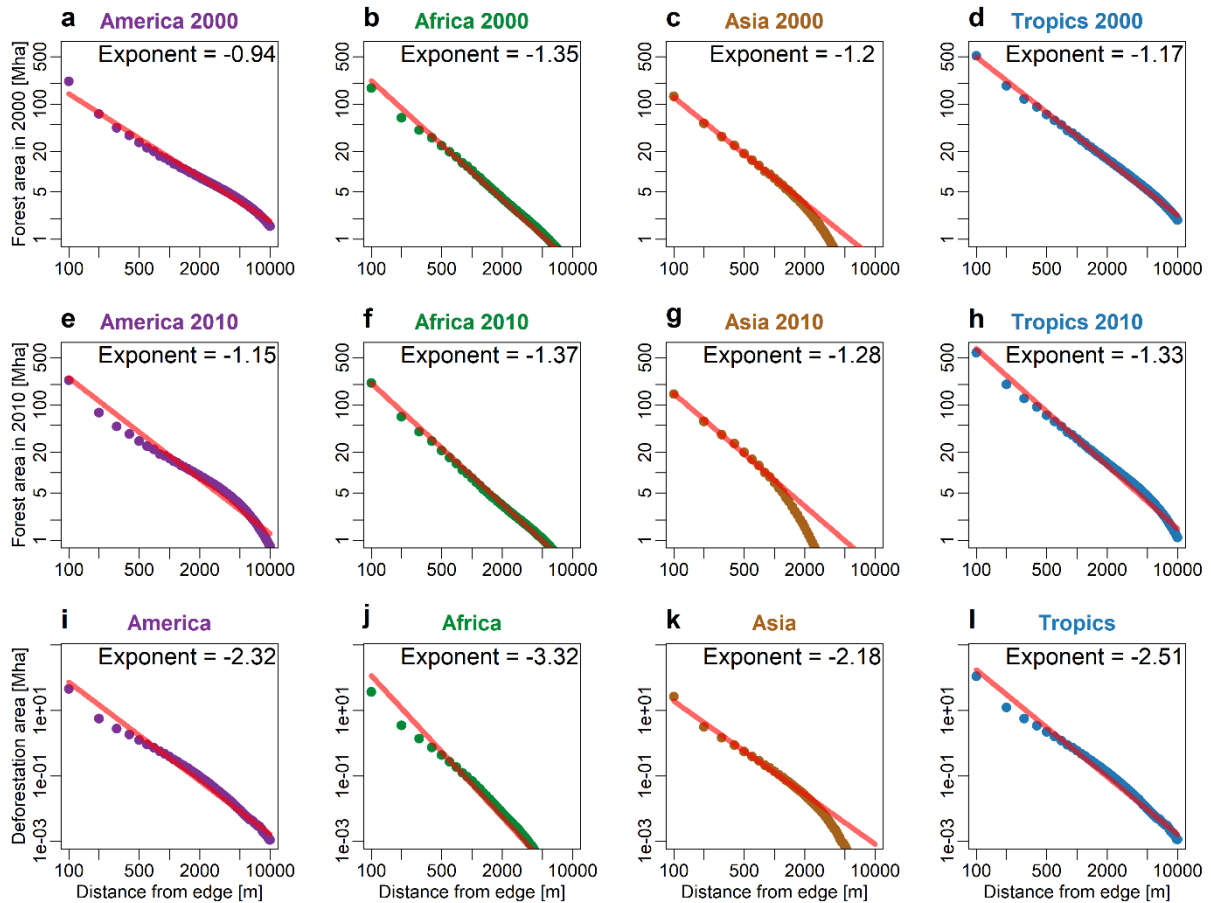


Fig. S4. Same analysis as in Fig. S3. Forest area in 2000 (a-d), forest area in 2010 (e-h) and deforestation (gross forest area loss) from 2000 to 2010 (i-l) as a function of distance from forest edge, but in double logarithmic scaling. Analysis for America, Africa, Asia and the whole tropics. In addition, a power law was fitted to each data set (red line). The power law exponent is shown in each subfigure.

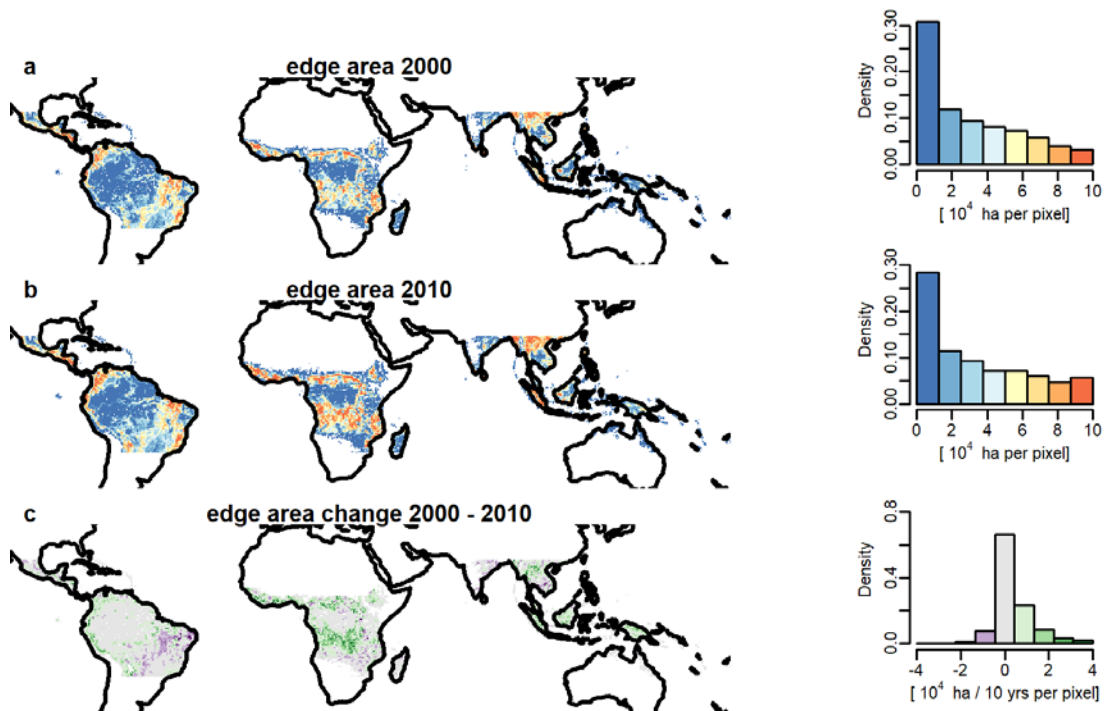


Fig. S5. Maps of forest edge area in 2000, 2010 and edge area change from 2000 to 2010. Only for visualizing these maps, the 30 m edge area data was aggregated to 50 km pixel. For each 50 km pixel the total amount of edge area was summed up. (a) Tropical-wide distribution of edge area for the year 2000 in 10^4 ha per 50 km pixel. (b) Forest edge area for the year 2010 (same as in Fig.3). (c) Change of edge area from 2000 to 2010. The right panels show frequency plots for all maps.

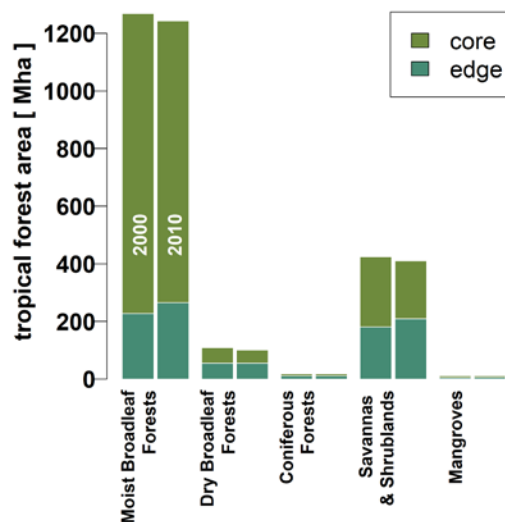


Fig. S6 Amount of forest core and forest edge area for 2000 and 2010 divided among different biomes. Information about the biomes was taken from the Ecoregion map (52). For this purpose, this biome map was aggregated to a resolution of 50 km. During aggregation, each 50km pixel was assigned the dominant biome. For each pixel, the amount of edge and core area is also known (see Fig. 3 and Fig. S5). The 50km resolution results in some mixed pixels consisting of fragmented forest and savannah. This explains the high amount of forest area in biome ‘Savannas and Shrublands’.

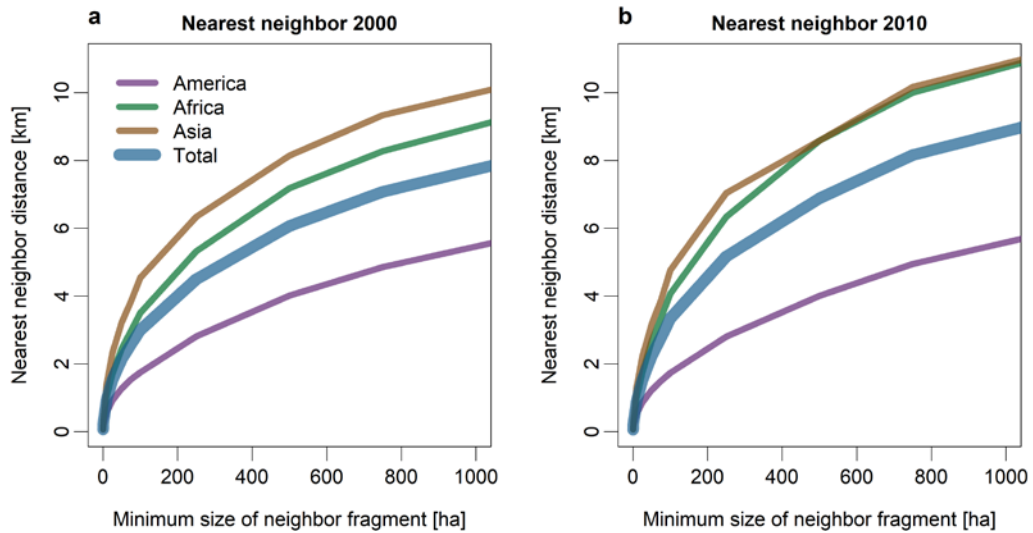


Fig. S7. Analysis of connectivity between forest fragments for the year 2000 (a) and 2010 (b). The panels show the mean distance to the nearest neighbor fragment (averaged over all fragments) as a function of a minimum neighboring fragment size varied along the x-axis. For example, the mean distance to a fragment with a size larger or equal than 250 ha is 5 km for the year 2010.

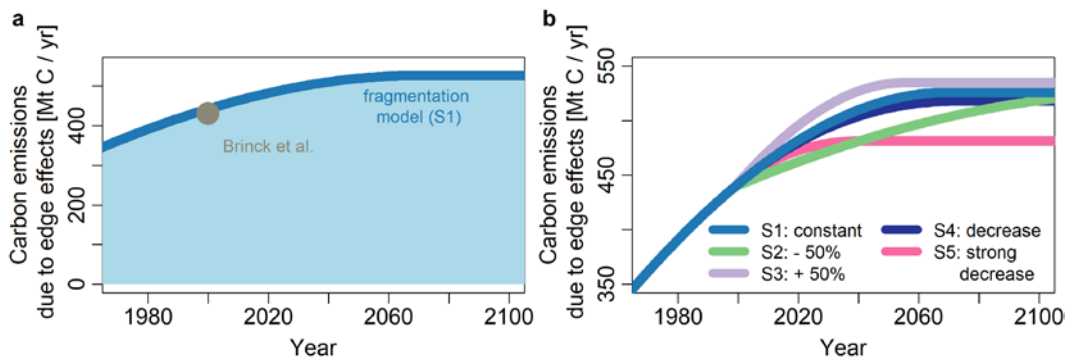


Fig. S8. Projected carbon emissions due to forest fragmentation caused by higher tree mortality in the forest edge. A high-resolution fragmentation model was applied to simulate the patterns of fragmented forests for the whole tropics (for details see methods). In each simulation year, fragmentation was analyzed by applying the same methods as to the forest cover maps derived from remote sensing (including the estimation of edge area in 100 m depth). For each year, the age of edge area is tracked in the simulation. It was assumed that forest areas in the edge lose a total of 50% of their biomass due to higher tree mortality in the first 50 years after edge creation. (a) Estimated carbon emissions due to edge effects assuming constant deforestation rates (scenario S1). Results fit well to the results of the Brinck study (dot; for the year 2000: 429 Mt C / yr; c.f., Table S2 in (22)). (b) Estimated carbon emissions due to edge effects for different scenarios of deforestation rates. The scenarios are described in the section ‘Scenarios of deforestation simulations’ and are shown in Fig. S10.

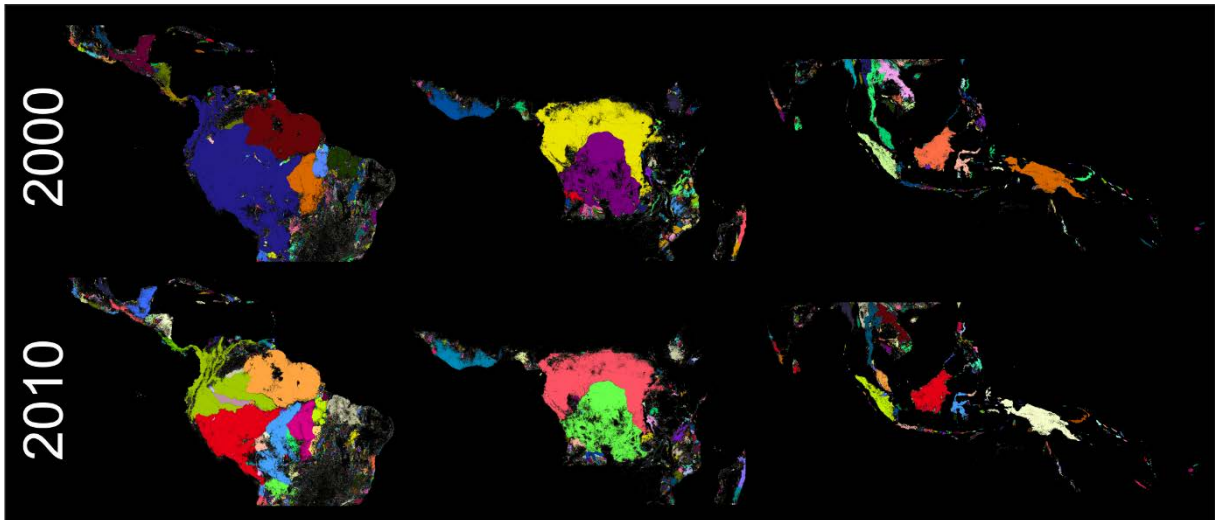


Fig. S9. Development of large forest fragments in the tropics (top row 2000, bottom row 2010, first column Central and Southern America, second column tropical Africa, third column tropical Asia). Please note the colors are not comparable between 2000 and 2010. In South America the large forest fragment (2000, in blue) broke up into several smaller ones. In this area, rivers divided forest areas already before 2000, but until 2000 these forested areas were connected somewhere else; but this connection is missing in 2010 due to deforestation. Please note, rivers are not driving the fragmentation.

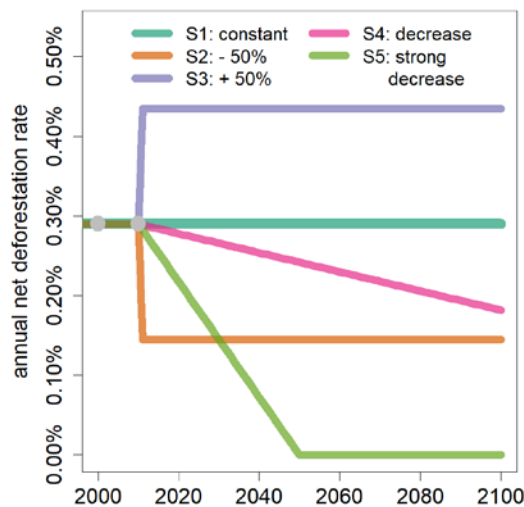


Fig. S10. Scenarios of deforestation. Forest fragmentation was simulated using the model FRAG-B model assuming five different scenarios of deforestation rates. For Scenario S1, the currently observed deforestation rate is assumed to continue through 2100. In scenarios S2 and S3, the deforestation rate is set 50% lower and higher, respectively, than currently observed. In scenarios S4 and S5, the deforestation rate decreases dynamically every year (in S5 more than in S4). The scenarios are described in the section ‘Scenarios of deforestation simulations’. Here, only the scenarios for the continent America are shown, but the scenarios of the other continents are designed in a similar way.

| Parameter | America | Africa | Asia |
|--------------------------------------|---------|--------|------|
| Net deforestation rate r [%/yr] | 0.29 | 0.13 | 0.34 |
| Border deforestation d [%] | 44 % | 27 % | 63 % |
| Deforestation patch size a [pixel] | 8 | 8 | 8 |

Table S1. Parameters of the fragmentation model FRAG-B. Net deforestation rate and border deforestation rate is based on satellite observations (see Table 1 and Fig. S2).

| | Unit | America | | Africa | | Asia | | Total | |
|-----------------------------|--------|------------|------------|------------|------------|------------|------------|------------|------------|
| | | 2000 | 2010 | 2000 | 2010 | 2000 | 2010 | 2000 | 2010 |
| Total forested area | Mha | 865 | 834 | 390 | 376 | 368 | 349 | 1623 | 1559 |
| Net deforestation rate | 1 / yr | | 0.36% | | 0.35% | | 0.53% | | 0.40% |
| Number of fragments | 10^6 | 53.3 | 54.3 | 41.2 | 65.5 | 28.1 | 30.0 | 122.6 | 149.8 |
| Number of fragments < 10 ha | 10^6 | 52.4 | 53.2 | 40.7 | 64.9 | 27.8 | 29.7 | 120.9 | 147.9 |
| Average fragment size | ha | 16 | 15 | 9 | 6 | 13 | 12 | 13 | 10 |
| Core area | Mha | 650 | 602 | 218 | 164 | 239 | 204 | 1107 | 971 |
| Edge area | Mha | 215 | 232 | 172 | 212 | 130 | 145 | 517 | 589 |
| Edge area fraction* | % | 25% | 28% | 44% | 56% | 35% | 42% | 32% | 38% |

Table S2. Tropical forest fragmentation with 50% tree cover threshold. Statistical description of tropical forest fragmentation for each continent and the entire tropics. Same analysis as in Table 1, but with a threshold of 50% tree cover to separate forest and non-forest areas (instead of the 30% threshold used in Table 1). Forest fragmentation was analyzed for the years 2000 and 2010. Edge area was determined by counting every forest pixel with a distance of less than 100 m from the nearest forest edge. Edge area fraction is the ratio between total forest edge area and total forested area per continent (Mha = 10^6 ha). * total edge area divided by total forested area

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