Supporting Information for “Tropical deforestation drivers and associated carbon emission factors derived from remote sensing data”

Contents
Supporting information S1: Bias adjustment 30m AGB map .................................................. 2
  General approach .................................................................................................................. 2
  Input Data .............................................................................................................................. 2
  Error stratification ................................................................................................................. 3
  Validation ................................................................................................................................ 3
  Downscaling bias adjustment .................................................................................................. 5
  Additional references .............................................................................................................. 5
Supporting information S2: Spatial distribution of follow-up land uses .................................. 7
Supporting information S3: Emission factors at eco-zone and national level ............................ 9
Supporting information S4: Comparison with IPCC Tier 1 and alternative Tier 1 values .......... 13
Supporting information S5: IPCC Tier 1 refinement for annual crop and grasslands ............... 14
Supporting information S1: Bias adjustment 30m AGB map

General approach
The methodology follows closely the error stratification approach described by Avitabile et al. (2016). The stratification approach aims to identify regions with homogenous error structure in the input map (these regions are referred to as error strata). A first stratification is based on geographical location, i.e. Asia, Africa, Central and South America to consider the different allometric relationships between AGB and tree diameter and height (Feldpausch et al., 2011, 2012). The errors of the input AGB map were derived by comparing the map with a reference field AGB database. Next, the error map of the input map (AGB Baccini) was predicted using the AGB map itself, its uncertainty layer and various other maps related to the uncertainty of the AGB map (land cover, tree height, tree cover) with a Random Forest model calibrated on the basis of reference data. This error map was then clustered (stratified) using the K-means approach in 6 or 8 homogenous error strata (depending on number of reference data per continent). Per stratum the average bias was calculated and used to correct the bias of the input map. A validation was then performed to estimate the remaining bias in the new AGB map.

The bias estimation and removal, and the map calibration and validation was done on the 1km scale as this was the scale of the reference plots. In order to combine this map with other spatial datasets (i.e., Hansen et al., 2013), we used the original resolution (30 m) of the AGB Baccini map, downsampling the results of the bias estimation using a correction factor. This correction factor was calculated by dividing the original 1km AGB map by the new (bias adjusted) 1km AGB map. This correction factor map was then downscaled to 30m and used to correct the 30m AGB map.

Input Data
- AGB map: Baccini, downloaded from Global forest Watch. Resampled to 1 km to align to the reference data.
- Reference data: This dataset comprised of individual field data (AGB) independent of the other input maps - 1 km pixel forest plots screened, up-scaled and consolidated by Avitabile et al (2016). Data can be found at: http://lucid.wur.nl/storage/downloads/high-carbon-ecosystems/Avitabile_AGB_RefData.zip
- Covariate maps (see also Avitabile et al, 2016 + suppl. materials).
  - Land cover: derived from ESA CCI 2000 land cover map (ESA, 2000), reclassified into eight classes (Evergreen Forest, Deciduous Forest, Woodland, Mosaic vegetation, Shrub land, Grassland, Cropland, Other land) and then resampled (majority criterion) from its original resolution (330 m) to 1 km.
  - Tree cover: derived from the annual MODIS VCF tree cover composites for the years 2000 – 2010 (DiMicelli et al., 2011). The annual datasets were averaged over this period and spatially aggregated to 1km.
  - Height: directly derived from the global Vegetation Height map at 1km resolution (Simard et al., 2011)
  - Uncertainty: Uncertainty of AGB map (downloaded from Global Forest watch) taking into account the errors from allometric equations, the LiDAR based model, and the
randomForest model. All the errors are propagated to the final biomass estimate. Resampled to 1 km to align to the reference data.

**Error stratification**

For Central America and Africa 8 strata were used while for Asia and South America only 6 strata were used because less samples were available (Table 1). This compromises a trade-off between homogeneity of the strata and number of samples per strata.

| # plots |
|---------|
| Africa 287 |
| Asia 120 |
| C. America 2303 |
| S. America 135 |

The following tables provide the performance of the error model (Table 2) and the importance of the variables for the error model (Table 3).

| Africa | Asia | C. America | S. America |
|--------|------|------------|------------|
| RMSE 84.5 | 98.9 | 25.9 | 76.1 |
| Rel. RMSE 0.38 | 0.51 | 0.34 | 0.31 |
| R2 0.35 | 0.13 | 0.56 | 0.29 |
| Error Rate (%) 17.26 | 27.74 | 26.91 | 34.31 |

| AGB Baccini 2,305 | 1,123 | 4,159 | 760 |
| Uncertainty 2,107 | 899 | 2,692 | 777 |
| Height 1,808 | 994 | 1,956 | 678 |
| VCF 2,733 | 923 | 2,064 | 1,087 |
| Land cover 592 | 96 | 262 | 19 |

**Validation**

For the validation, 30% of the reference plots were kept apart, only 70% were used for the error model calibration. Figure 1 compares RMSE per region for the original and bias adjusted AGB map. Figure 2 compares the bias for the original and bias adjusted AGB map. In Figure 3, the validation reference data are plotted against the predictions of the original map (Baccini) and the bias adjusted map (Final). Values are binned (10 Mg ha⁻¹).
Figure S1.1: RMSE of the original and bias adjusted AGB map per region.

Figure S1.2: Bias of the original and bias adjusted AGB map per region.
Downscaling bias adjustment

In order to translate the bias adjustment from a 1 km to a 30 m scale, a correction factor map was calculated by dividing the bias adjusted map by the original AGB map.

The correction factor had some extreme outliers, so it was capped using the interquartile range with the following formula:

- Lower limit = $Q1 - k(Q3 - Q1)$
- Upper limit = $Q3 + k(Q3 - Q1)$

The correction factor map was resampled to a 30m resolution and used to adjust the bias of the original 30m AGB map. This resulted in the bias adjusted 30 m AGB map used in this study.

Additional references

Di Miceli CM, Carroll ML, Sohlberg RA et al. (2011) Annual Global Automated MODIS Vegetation Continuous Fields (MOD44B) at 250 m Spatial Resolution for Data Years Beginning Day 65, 2000–2010, Collection 5 Percent Tree Cover. University of Maryland, College Park, MD, USA.
ESA (2000) Global land cover map for the epoch 2000. Available at: http://www.esa-landcover-cci.org/

Feldpausch TR, Banin L, Phillips OL et al. (2011) Height-diameter allometry of tropical forest trees. Biogeosciences, 8, 1081–1106.

Feldpausch TR, Lloyd J, Lewis SL et al. (2012) Tree height integrated into pantropical forest biomass estimates. Biogeosciences, 9, 3381–3403.

Simard M, Pinto N, Fisher JB, Baccini A (2011) Mapping forest canopy height globally with spaceborne lidar. Journal of Geophysical Research: Biogeosciences, 116, 1–12.
Supporting information S2: Spatial distribution of follow-up land uses

Figure S2.1 Forest area loss (ha) per follow-up land use from 1990 to 2000

Figure S2.1 shows the distribution of follow-up land uses across the study area. As mentioned in De Sy et al. (2015), pasture is particularly dominant as follow-up land use in South America, especially in the Brazilian arc of deforestation, the Brazilian Pantanal, the Brazilian Cerrado, Western Paraguay and the Argentinian Chaco. Deforestation followed by large-scale cropland was more prevalent in the Brazilian Mato Grosso State, Eastern Paraguay, Central Bolivia and Northern Argentina, while small-scale cropland expansion mainly occurred in the Andean countries. In Central America, deforestation is mostly followed by pasture and small-scale cropping.
Among the African countries, extensive deforestation can be found in Mozambique, Democratic Republic of the Congo, Angola, Tanzania, Madagascar, Zambia, Nigeria, Cote d’Ivoire and Cameroon, mainly due to small-scale cropland expansion and other land use. In Angola, pasture is also an important follow-up land use, while in Zambia and Nigeria hotspots of large-scale agriculture can be found. Small-scale cropland is also the most dominant follow-up land use in Burkina Faso, Central African Republic, Chad, Congo, Ethiopia, Gabon, Guinea, Liberia, Malawi, Mali, Sierra Leone, Uganda and Zimbabwe. Deforestation followed by pasture is predominant in Botswana, Kenya and South Africa but also occurs to a lesser extent in Chad, Ethiopia, Guinea, Mali, Namibia, Uganda and Zimbabwe. Large-scale cropland is a less common follow-up land use in this region, but some hotspots of large-scale cropland expansion can be found in Southern Zambia, Nigeria, Kenya, Namibia and South Africa. Tree crops are the dominant follow-up land use in Ghana, and are also important in Sierra Leone.

In the Asian region, most deforestation between 1990 and 2000 occurred in Indonesia, mostly in northern Sumatra and southern Kalimantan. Tree crop is an important follow-up land use in Indonesia, as well as other land use and small-scale cropland. In Malaysia and Thailand tree crop is the dominant follow-up land use, while in the Philippines both tree crop and small-scale crop are important. In Bangladesh, Cambodia, India, Lao PDR, Myanmar, Nepal, Papua New Guinea, Sri Lanka and Vietnam most deforestation is followed by small-scale cropland. Small-scale cropland is also important in Thailand. Pasture is not a common follow-up land use in this region, and can only be found in Lao PDR, India, and Thailand.
Supporting information S3: Emission factors at eco-zone and national level

Table S3.1 Mean emission factor (EF) estimates (Mg C ha⁻¹) aggregated to eco-zone and continental levels. Values are mean (S.E.).

| Region          | Continent | Pasture | Large-scale crop | Small-scale crop | Other land use | All land uses ~
|-----------------|-----------|---------|------------------|------------------|----------------|----------------|
| Africa          |           |         |                  |                  |                |                |
| Tropical rainforest |          | 8 (6)   | 8 (4)            | 49 (68)          | 16 (23)        | 37 (59)        |
| Tropical moist deciduous forest | 9 (7)     | -       | -                | 102 (91)         | 72 (77)*       | 93 (90)        |
| Tropical dry forest | 8 (5)     | -       | 16 (10)          | 14 (8)           | 14 (9)         |
| Tropical mountain system | 16 (10)   | 10 (3)* | 12 (12)          | 11 (11)          | 11 (10)        |
| Tropical shrub land | 5 (5)     | -       | 8 (4)            | 8 (8)            | 6 (5)          |

| Region          | Continent | Pasture | Large-scale crop | Small-scale crop | Other land use | All land uses ~
|-----------------|-----------|---------|------------------|------------------|----------------|----------------|
| Latin America   |           |         |                  |                  |                |                |
| Tropical rainforest |          | 83 (43) | 74 (24)          | 96 (56)          | 78 (38)        | 82 (42)        |
| Tropical moist deciduous forest | 110 (35) | 86 (31) | 111 (59)         | 102 (36)         | 108 (36)       |
| Tropical dry forest | 54 (20)  | 68 (18) | 68 (39)          | 58 (18)          | 57 (21)        |
| Tropical mountain system | 34 (24)  | 62 (17) | 31 (7)*          | 38 (18)          | 38 (25)        |
| Tropical shrub land | 103 (62) | 60 (21)*| 85 (50)          | 80 (46)          | 91 (53)        |
| Subtropical humid forest | 84 (11)  | 86 (11) | -                | 72 (7)*          | 85 (11)        |
| Subtropical mountain system | 40 (7)*  | -       | -                | 32 (4)*          | 39 (8)         |

| Region          | Continent | Pasture | Large-scale crop | Small-scale crop | Other land use | All land uses ~
|-----------------|-----------|---------|------------------|------------------|----------------|----------------|
| Asia            |           |         |                  |                  |                |                |
| Tropical rainforest |          | 86 (27) | 98 (22)          | 115 (60)         | 118 (61)       | 115 (59)       |
| Tropical moist deciduous forest | 90 (28)* | -       | -                | 115 (63)         | 117 (63)       | 114 (61)       |
| Tropical dry forest | 82 (31)* | 99 (13)*| 93 (19)          | 91 (25)          | 93 (23)        |
| Tropical mountain system | 79 (19)* | 85 (9)* | 86 (37)          | 98 (59)          | 88 (40)        |
| Tropical shrub land | 94 (61)* | -       | 138 (64)*        | -                | 139 (61)       |

* less than ten sample units present

~ All land uses is the combination of pasture, large-scale crop, small-scale cropland and other land use
Table S3.2 Mean fraction of initial carbon lost (\(\text{Clost}\)), aggregated to eco-zone and continental levels. Values are mean (S.E.).

| Ecozone                      | Continent                     | Tropical rainforest | Tropical moist deciduous forest | Tropical dry forest | Tropical mountain system | Tropical shrub land | All land uses* |
|------------------------------|-------------------------------|---------------------|--------------------------------|--------------------|------------------------|-------------------|---------------|
| *Latin America*              |                               |                     |                                |                    |                        |                   |               |
| Continent                    | 0.96 (0.04)                   | 0.96 (0.05)         | 0.93 (0.05)                    | 0.92 (0.07)        | 0.96 (0.05)            |                   | 0.96 (0.05)   |
| Tropical rainforest          | 0.96 (0.03)                   | 0.97 (0.04)         | 0.94 (0.05)                    | 0.93 (0.06)        | 0.96 (0.03)            |                   | 0.96 (0.03)   |
| Tropical moist deciduous forest | 0.96 (0.04)               | 0.94 (0.06)         | 0.92 (0.05)                    | 0.90 (0.07)        | 0.95 (0.06)            |                   | 0.95 (0.06)   |
| Tropical dry forest          | 0.92 (0.05)                   | 0.96 (0.02)         | 0.96 (0.04)*                   | 0.92 (0.06)        | 0.93 (0.04)            |                   | 0.93 (0.04)   |
| Tropical mountain system     | 0.92 (0.07)                   | 0.95 (0.05)*        | 0.92 (0.08)                    | 0.94 (0.07)        | 0.92 (0.07)            |                   | 0.92 (0.07)   |
| Subtropical humid forest     | 0.93 (0.04)                   | 0.96 (0.03)         | -                              | 0.83 (0.09)*       | 0.94 (0.04)            |                   | 0.94 (0.04)   |
| Subtropical mountain system  | 0.96 (0.04)                   | -                   | -                              | 0.93 (0.06)*       | 0.96 (0.05)            |                   | 0.96 (0.05)   |
| *Asia*                       |                               |                     |                                |                    |                        |                   |               |
| Continent                    | 0.97 (0.03)                   | 98 (22)             | 0.93 (0.06)                    | 0.93 (0.06)        | 0.92 (0.07)            |                   | 0.92 (0.07)   |
| Tropical rainforest          | 0.96 (0.02)*                  | -                   | 0.91 (0.07)                    | 0.92 (0.05)        | 0.91 (0.07)            |                   | 0.91 (0.07)   |
| Tropical moist deciduous forest | 0.98 (0.01)*                | 0.98 (0.02)*        | 0.96 (0.02)                    | 0.96 (0.03)        | 0.96 (0.03)            |                   | 0.96 (0.03)   |
| Tropical dry forest          | 0.94 (0.06)*                  | 0.97 (0.01)*        | 0.96 (0.04)                    | 0.94 (0.05)        | 0.96 (0.04)            |                   | 0.96 (0.04)   |
| Tropical mountain system     | -                             | 0.95 (0.02)         | 0.96 (0.02)                    | 0.95 (0.02)        | 0.95 (0.02)            |                   | 0.95 (0.02)   |
| Tropical shrub land          | 0.98 (0.02)*                  | 0.97 (0.01)*        | -                              | 0.98 (0.01)        |                        |                   | 0.98 (0.01)   |

* less than ten sample units present

~ All land uses is the combination of pasture, large-scale crop, small-scale cropland and other land use.
Table S3.3: Mean emission factor estimates (EF) (Mg C ha⁻¹), aggregated to national level. Values are mean (S.E.).

| Country   | Pasture | Large-scale crop | Small-scale crop | Other land use | All land uses*~ |
|-----------|---------|------------------|------------------|----------------|-----------------|
| Angola    | 11 (6)* | 12 (5)           | 14 (5)*           | 12 (5)         | 12 (5)          |
| Argentina | 64 (17) | 77 (11)          | -                | 69 (10)*       | 72 (14)         |
| Bolivia   | 95 (33) | 85 (39)*         | 105 (34)*        | 91 (28)        | 93 (31)         |
| Brazil    | 90 (41) | 77 (27)          | 139 (34)         | 93 (40)        | 90 (40)         |
| Chad      | 14 (6)* | -                | 10 (3)*          | 11 (5)*        | 12 (4)          |
| Colombia  | 96 (29) | 150 (28)         | 108 (25)         | 105 (32)       |                 |
| Cote d'Ivoire | 134 (124)* | 16 (7)*       | 125 (121)       |                 |                 |
| DRC       | 128 (55)* | -              | -                | 130 (54)*      |                 |
| Ethiopia  | 11 (13)* | 19 (29)*         | 11 (14)*         | 17 (25)        |                 |
| India     | 98 (34)* | 114 (45)*        | 95 (34)          | 108 (44)       | 102 (37)        |
| Indonesia | -       | 180 (61)         | 118 (66)         | 130 (69)       |                 |
| Kenya     | 7 (9)   | 17 (8)*          | 10 (11)*         | 8 (7)*         | 9 (9)           |
| Lao PDR   | 97 (16)* | 113 (31)        | 116 (32)         | 112 (30)       |                 |
| Madagascar| 4 (10)* | 95 (55)          | 40 (26)*         | 74 (61)        |                 |
| Malawi    | 27 (14)* | -              | -                | 27 (14)*       |                 |
| Malaysia  | -       | 152 (88)         | 150 (88)         |               |                 |
| Mexico    | 37 (9)  | 43 (19)          | 33 (5)           | 37 (11)        |                 |
| Mozambique| 5 (4)*  | 14 (9)           | 13 (6)           | 14 (8)         |                 |
| Myanmar   | -       | 71 (41)          | 76 (23)          | 73 (37)        |                 |
| Nigeria   | 8 (1)*  | 15 (13)          | 11 (4)*          | 11 (11)        |                 |
| PNG       | -       | 124 (63)         | 166 (37)*        | 133 (59)       |                 |
| Paraguay  | 27 (22) | 73 (4)*          | -                | 41 (29)        |                 |
| Peru      | 157 (33)* | -             | 143 (39)         | 147 (33)       |                 |
| Philippines| -       | 101 (24)         | 104 (26)*        | 100 (22)       |                 |
| Tanzania  | 9 (5)   | 13 (6)           | 13 (6)           | 12 (6)         |                 |
| Thailand  | -       | 87 (9)*          | 82 (13)          | 84 (13)        |                 |
| Venezuela | 58 (17) | 41 (11)*         | 79 (48)*         | 83 (41)        | 57 (26)         |
| Viet Nam  | -       | 108 (30)         | 110 (43)         | 108 (32)       |                 |
| Zambia    | 10 (4)* | 11 (2)*          | 18 (13)          | 16 (12)        |                 |
| Zimbabwe  | 4 (3)*  | 15 (31)          | 14 (18)          | 12 (22)        |                 |

* less than ten sample units present

~ All land uses is the combination of pasture, large-scale crop, small-scale cropland and other land use
Table S3.4: Mean fraction of initial carbon lost (Clost), aggregated to national level. Values are mean (S.E.).

| Country     | Pasture | Large-scale crop | Small-scale crop | Other land use | All land uses~ |
|-------------|---------|------------------|------------------|---------------|----------------|
| Angola      | 0.95 (0.09)* | -                | 0.89 (0.08)       | 0.94 (0.04)*   | 0.91 (0.08)    |
| Argentina   | 0.90 (0.05)  | 0.95 (0.04)      | -                | 0.85 (0.07)*   | 0.92 (0.06)    |
| Bolivia     | 0.95 (0.03)  | 0.97 (0.02)*     | 0.88 (0.10)*     | 0.92 (0.06)    | 0.95 (0.04)    |
| Brazil      | 0.97 (0.03)  | 0.98 (0.02)      | 0.92 (0.08)      | 0.93 (0.07)    | 0.97 (0.03)    |
| Chad        | 0.97 (0.02)* | -                | 0.93 (0.03)      | 0.86 (0.21)*   | 0.94 (0.07)    |
| Colombia    | 0.93 (0.04)  | -                | 0.97 (0.02)      | 0.94 (0.12)    | 0.94 (0.04)    |
| Cote d’Ivoire | -         | -                | 0.97 (0.08)*     | 0.92 (0.06)*   | 0.97 (0.07)    |
| DRC         | -        | 0.79 (0.26)*     | -                | 0.80 (0.26)*   |
| Ethiopia    | 0.90 (0.06)* | -                | 0.84 (0.16)*     | 0.57 (0.57)*   | 0.84 (0.21)    |
| India       | 0.96 (0.04)* | 0.98 (0.02)*     | 0.97 (0.02)      | 0.93 (0.06)    | 0.96 (0.04)    |
| Indonesia   | -        | -                | 0.95 (0.04)      | 0.92 (0.05)    | 0.91 (0.07)    |
| Kenya       | 0.92 (0.06)  | 0.98 (0.01)*     | 0.89 (0.05)*     | 0.84 (0.20)*   | 0.91 (0.06)    |
| Lao PDR     | 0.96 (0.02)* | -                | 0.97 (0.02)      | 0.94 (0.05)    | 0.96 (0.03)    |
| Madagascar  | 0.85 (0.05)* | -                | 0.88 (0.11)      | 0.83 (0.12)*   | 0.87 (0.10)    |
| Malawi      | -        | -                | 0.86 (0.18)*     | -             | 0.85 (0.19)*   |
| Malaysia    | -        | -                | -                | 0.94 (0.05)    | 0.95 (0.04)    |
| Mexico      | 0.93 (0.04)  | 0.91 (0.05)      | 0.94 (0.04)      | 0.93 (0.05)    | 0.93 (0.04)    |
| Mozambique  | 0.82 (0.17)* | -                | 0.75 (0.19)      | 0.83 (0.08)    | 0.77 (0.09)    |
| Myanmar     | -        | -                | 0.88 (0.08)      | 0.94 (0.05)    | 0.90 (0.08)    |
| Nigeria     | 0.57 (0.29)* | -                | 0.73 (0.24)      | 0.85 (0.17)*   | 0.77 (0.23)    |
| PNG         | -        | -                | 0.89 (0.08)      | 0.94 (0.04)*   | 0.90 (0.07)    |
| Paraguay    | 0.91 (0.05)  | 0.90 (0.06)*     | -                | 0.92 (0.08)    | 0.91 (0.05)    |
| Peru        | 0.93 (0.04)* | -                | 0.93 (0.03)      | -             | 0.93 (0.03)    |
| Philippines | -        | -                | 0.93 (0.02)      | 0.93 (0.04)*   | 0.92 (0.04)    |
| Tanzania    | 0.84 (0.12)  | -                | 0.87 (0.05)      | 0.87 (0.87)    | 0.87 (0.07)    |
| Thailand    | -        | 0.97 (0.01)*     | 0.97 (0.01)      | 0.97 (0.01)    | 0.97 (0.01)    |
| Venezuela   | 0.92 (0.07)  | 0.96 (0.03)*     | 0.96 (0.04)*     | 0.94 (0.03)    | 0.89 (0.12)    |
| Viet Nam    | -        | 0.96 (0.03)      | 0.95 (0.05)      | 0.96 (0.03)    | 0.96 (0.03)    |
| Zambia      | 0.80 (0.19)* | 0.80 (0.09)*     | 0.76 (0.12)      | 0.75 (0.19)    | 0.76 (0.12)    |
| Zimbabwe    | 0.82 (0.18)* | -                | 0.88 (0.25)      | 0.82 (0.09)    | 0.85 (0.18)    |

* less than ten sample units present

~ All land uses is the combination of pasture, large-scale crop, small-scale cropland and other land use
### Supporting information S4: Comparison with IPCC Tier 1 and alternative Tier 1 values

Table S4.1 IPCC default carbon stock values, mean carbon stock estimates (Mg C ha\(^{-1}\)) from Langner et al. (2014), and mean carbon stock estimates (Mg C ha\(^{-1}\)) for all forests from this study. Values are mean (standard error).

| Region                         | IPCC\(^1\)  | Langner et al (2014)\(^1\) | This study\(^2\) |
|--------------------------------|--------------|-----------------------------|-------------------|
| **Tropical rainforest**        |              |                             |                   |
| Africa                         | 195/84-318   | 130 (45)                    | 155 (81)          |
| America\(^3\)                  | 189/77-251   | 153 (28)                    | 155 (44)          |
| Asia (Ins.)                    | 177/77-421   | 154 (39)                    |                   |
| Asia (cont.)                   | 220/177-324  | 158 (34)                    |                   |
| **Tropical moist deciduous forest** |            |                             |                   |
| Africa                         | 164/102-269  | 50 (15)                     | 24 (18)           |
| America\(^3\)                  | 140/134-177  | 79 (35)                     | 76 (50)           |
| Asia (Ins.)                    | 115/7-348    | 125 (39)                    |                   |
| Asia (cont.)                   | 183          | 106 (37)                    |                   |
| **Tropical dry forest**        |              |                             |                   |
| Africa                         | 77/77-84     | 42 (15)                     | 13 (14)           |
| America\(^3\)                  | 134/127-257  | 51 (16)                     | 41 (23)           |
| Asia (Ins.)                    | 84/65-102    | 96 (36)                     | 83 (32)           |
| Asia (cont.)                   | 102          | 94 (33)                     |                   |
| **Tropical mountain system**   |              |                             |                   |
| Africa                         | 27-121       | 78 (36)                     | 83 (84)           |
| America\(^3\)                  | 39-146       | 124 (38)                    | 118 (55)          |
| Asia (Ins.)                    | 33-140       | 167 (32)                    | 199 (57)          |
| Asia (cont.)                   | 33-226       | 160 (21)                    |                   |
| **Tropical shrubland**         |              |                             |                   |
| Africa                         | 46/14-127    | 30 (15)                     | 12 (7)            |
| Asia (Ins.)                    | 39           | 69 (26)                     |                   |
| Asia (cont.)                   | 46           | 107 (24)                    | 152 (67)          |
| **Subtropical humid forest**   |              |                             |                   |
| America\(^3\)                  | 140/134-177  | 71 (34)                     | 90 (16)           |
| **Subtropical mountain system**|              |                             |                   |
| America\(^3\)                  | 39-146       | -                           | 35 (4)            |

1 AGB values from Table 2c in sup. Mat. of Langner et al. (2014), converted to total biomass with Eq 1, assuming carbon stock is 50% of total biomass
2 Values for All forests from Table 3
3 For this study, values are for forests in Central and South America

Table S4.1 gives an overview of estimates of mean forest carbon stock of all forests within an ecozone from this study, IPCC Tier 1 values and alternative Tier 1 values by Langner et al. (2014). Langner et al. (2014) provide alternative Tier 1 values, based on pan-tropical AGB maps and other remote sensing data. Both IPCC Tier 1 and alternative Tier 1 values are converted from AGB to total biomass and then to carbon stock according to our methodology.
Supporting information S5: IPCC Tier 1 refinement for annual crop and grasslands

Table S5.1: Default carbon stock of (woody) above-ground biomass (tonnes C ha\(^{-1}\)) present on land converted to annual crops.

| Region                        | Mean | SD  |
|-------------------------------|------|-----|
| Tropical and subtropical Africa | 3.4  | 6.8 |
| Tropical and subtropical Latin America | 3.0  | 3.6 |
| Tropical and subtropical Asia  | 5.3  | 4.0 |

Table S5.2: Default above-ground woody biomass (tonnes d.m. ha\(^{-1}\)) present on land converted to grassland.

| Region                        | Mean | SD  |
|-------------------------------|------|-----|
| Tropical and subtropical Africa | 2.2  | 3.1 |
| Tropical and subtropical Latin America | 4.7  | 5.2 |
| Tropical and subtropical Asia  | 3.5  | 3.4 |