METHODS

We established six datasets for potential biomass stocks and seven datasets for actual biomass stocks. All maps were constructed at the spatial resolution of five arc minutes. Datasets were chosen on the basis of their coverage (that is, only maps covering large parts of the globe were included) and their plausibility. Given that most datasets did not cover all land-use types, all regions of the globe, or all relevant biomass stocks, some completion exercises were performed to generate consistently comparable datasets. These relied on different types of evidence, such as land-use information, information from census statistics, remotely-sensed information, and modifications of assumptions on biomass-stock density of different land-use categories and ecozones. The construction of the individual maps is described below.

Actual biomass-stock maps 1 and 2. Actual biomass-stock maps 1 and 2 (based on FRA and ref. 16, respectively; see Extended Data Fig. 3a, b) enabled the isolation of the effect of individual land uses. They were based on a consistent land-use dataset, derived and modified from previous work[30]. The dataset was adjusted to newly available statistical data on the national extent of forests[15] and cropland[31]. Information on cropland types[32] was used to identify permanent crops, other trees within cropland[33] are not included in the cropland layer, complying with FAO definitions[31]. Unused land was identified on the basis of previous assessments (for example, delineating unproductive land with a productivity threshold of $20\,\mathrm{gC\,m^{-2}\,yr^{-1}}$)[19,30], information on permanent snow from a land cover product[34], a thematic footprint map[35] and a map on intact forests[36]. All land not classified as infrastructure, cropland or forestry was defined as grazing land. Grazing land was split into three layers: (1) Artificial grasslands, that is, grasslands on potentially forested areas; (2) natural grasslands with trees, including savannahs and other wooded land; and (3) natural grasslands without trees (for example, temperate steppes), on the basis of land cover information on the extent of land under agricultural management[34], biome maps[37–39]and MODIS data[40] on fractional tree cover, applying a tree cover of 5% at the resolution of 500 m to discern grazing land with and without trees, in fractional cover representation. The final land-use dataset discerns the following classes. Unused land: (1) non-productive and snow; (2) wilderness, no trees; (3) unused forests. Used land: (4) infrastructure; (5) cropland; (6) used forests; (7) artificial grassland; (8) natural grassland, no trees; (9) natural grassland with trees.

To each land-use unit, typical biomass-stock density values from the literature or census statistics were assigned. For forests, the FRA-based map uses national-level data from the global Forest Resource Assessment[15]. By contrast, the map based on ref. 16 uses data from forest inventories and site data. The estimate from ref. 16 is higher, particularly in the tropical forests, but slightly lower in boreal forest biomass stocks, resulting in overall higher total forest biomass stocks (361 PgC in contrast to 298 PgC, for forests only). National forest biomass stock data were downscaled to the grid using information on tree height from a global database[41], following the finding that tree height is among the critical factors determining biomass stocks and it can thus serve as proxy for the spatial allocation of biomass stock densities at large scales[18,42]. Minimum biomass-stock density for forests was set to $3\,\mathrm{kgC\,m^{-2}}$ to discern forests from scrub vegetation and other wooded land. For grassland–tree mosaics, no census data on biomass stocks is available. For some countries, data on wood stocking (in $\mathrm{m^3}$) of other wooded land is available[15], showing a range between 0.4% and 21% (inner 50% quartiles) of forest biomass stocks per unit area, with outliers of >90%. World region aggregates of biomass-stock densities on other wooded land range between 15% and 28% of the values for forests, with a world average of 23%. In order to consider non-woody components, which are of larger importance for other wooded land compared to forests, as well as to produce a conservative estimate, we assumed that biomass stocks per unit area on other wooded land were 50% of the corresponding values for forests at the national level. For herbaceous vegetation units (artificial grassland on potential forest sites, cropland and natural grassland without trees), we assumed that biomass stocks were equal to the annual amount of net primary production[18]. For permanent cropland, we added $3\,\mathrm{kgC\,m^{-2}}$ for tree-bearing systems and $1.5\,\mathrm{kgC\,m^{-2}}$ for shrub-bearing systems to account for woody above- and belowground compartments, in line with estimates in the literature (see Supplementary Table 3). In the absence of data, and owing to the small extent of this land-use type, biomass stocks on infrastructure areas were calculated as one sixth of potential biomass stocks. This assumes one-third of infrastructure to be covered by 50% vegetation with trees and 50% artificial grassland (the latter was assigned no additional biomass, as the potential biomass stocks already provide a progressive estimate). Effects of land degradation on natural grassland (with and without trees) were modelled on the basis of losses in net primary productivity derived from ref. 43.

Actual biomass stock maps 3 and 4. Actual biomass stock maps 3 and 4 were based on refs 6 and 7, respectively, in combination with ref. 8; see Extended Data Fig. 3c, d. Two remote-sensing-based maps were created by combining independent remote-sensing products for tree vegetation (including foliage) and expanding them to account for belowground and herbaceous compartments where necessary. At the global scale, five distinct regions can be discerned with regards to the availability of global remote-sensing-based products. For the northern boreal and temperate forests one product is available[8,44]. A large part of the tropical zone is covered by two datasets[6,7]. These two datasets show pronounced differences, among each other as well as in comparison with *in situ* data[9,10]. A smaller fraction of the tropical zone, including a large part of Australia, South America and South Africa is covered by only one of the remote-sensing datasets[6], whereas a region in China is covered by two datasets[6,8]. For some regions (the southernmost part of Australia, parts of Oceania), no remote-sensing data are available. In these regions, map 1 was used in the compilation of map 3 and 4. Map 3 was constructed by complementing forest biomass stock data for the temperate and boreal zones[8] with data on net primary productivity[18] in order to account for herbaceous vegetation, applying a forest–non-forest mask derived from the GLC2000 land cover map[34]. The resulting map for the northern forests was combined with the biomass stock map for the tropical zone[6]. The latter was also extended with data on net primary productivity[18] to account for the herbaceous fractions. For map 4, we replaced values for woody vegetation from map 3 with data from ref. 7, where available.

Actual biomass stock maps 5 and 6. Grid-cell-based minima and maxima of the remote-sensing maps; see Extended Data Fig. 3e, f. While maps 3 and 4 serve as a best-guess available from remote-sensing products, these two maps were based on a statistical approach, calculating the grid-cell-based minima and maxima of various remote-sensing input data, enabling an assessment of the absolute upper and lower boundaries, breaking up the auto-correlated nature of remote-sensing-derived maps. Maps 3 and 4 were used as input. Furthermore, a modulation was calculated for the area covered only by the map of ref. 8. This map uses a forest mask derived from GLC2000[34]. In order to reflect the uncertainty of this land cover map, we used an alternative forest mask to calculate new values at the grid level. We projected the grid-based biomass stock density (biomass per unit area) values from ref. 8 to the MODIS fractional tree cover dataset[40]. Additionally, alternative maps for net primary productivity were used to complement these biomass stock maps for woody vegetation, derived by a vegetation model[45], a numerical model[46] and from remote-sensing estimates[47]. Map 5 was calculated as the cell-based minima, map 6 as the cell-based maxima of these input layers.

Actual biomass stock map 7. A seventh map was taken from the literature[48]; see Extended Data Fig. 3g.

No robust empirical information is available that would allow resolution of the discrepancies between the two datasets on the basis of consistent, spatially explicit land-use information (maps 1 and 2). The difference between these two estimates was 79 PgC. Both assessments are inventory-based, but in ref. 16 long-term measurements of network plots for the tropical regions were used to compensate for data gaps, whereas FRA reports national data that are often based on remote sensing. The contribution of global remote-sensing data (benchmark maps) to resolve this discrepancy is still limited. The two available high-resolution datasets covering the tropics[6,7] show pronounced differences, between each other and in comparison with *in situ* data[9,10]. The estimate from ref. 16 is situated between these two estimates, whereas the estimate from the FRA is situated below the minimum. However, a study based on alternative site data[11] corrected both maps downwards, close to the grid-based minimum of both accounts, better matching the FRA-based assessment.

Potential biomass stock maps. Potential vegetation refers to a hypothetical state of vegetation, which would prevail without human activities but under current climate conditions[49]. We compiled five maps following an ecozone approach, allocating typical carbon densities of zonal vegetation to state-of-the-art ecozone maps for current climate conditions[37–39], with current coastlines and current permanent ice cover. The carbon-density values refer to landscape-level averages and take effects of age distribution and natural disturbance into account. We used high-resolution data from the ESA GlobCover 2009 Project[50] to exclude small water bodies and small-scale bare areas, with the exception of ecosystems where carbon-stock values already take bare areas into account, for example, steppes and thorn savannahs. Small-scale variability caused by, for example, the spatial variability of edaphic conditions or water availability (azonal vegetation) was neglected. No information is available that allows us to determine whether this omission, or sampling biases in the input data, introduces an upward or downward bias in the maps. Input data could be biased towards high values if sampling favoured undisturbed, old-grown stands, or towards lower values, if the data were derived from human-disturbed vegetation in the absence of natural vegetation remnants for certain ecosystem types. The comparison with other estimates shows that our data are well in line with the literature (Extended Data Fig. 1) and suggest that such biases have a minor role. Furthermore, approximations of upper and lower estimates for potential vegetation were calculated to determine realistic ranges of global biomass stocks.

Potential biomass stock maps 1 and 2. IPCC-based maps, FRA-adjusted or adjusted to ref. 16; see Extended Data Fig. 4a, b. Two maps were constructed to consistently match the actual biomass stock maps 1 and 2. They build from