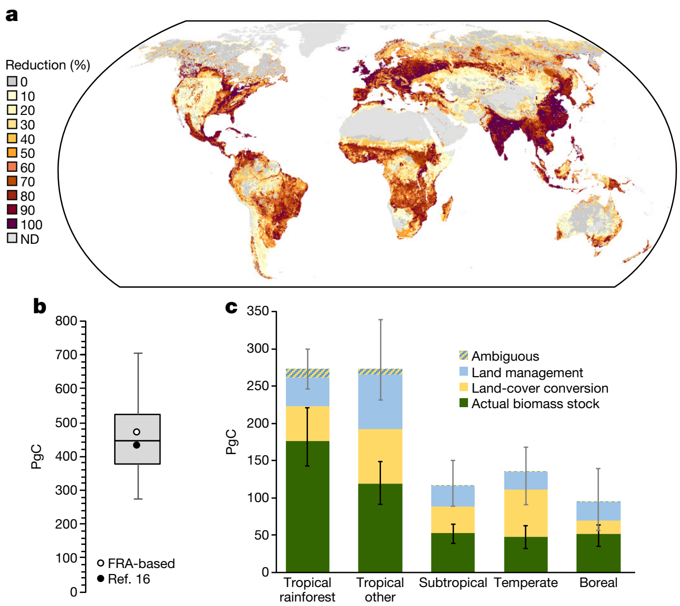

Figure 1 | Differences in biomass stocks of potential and actual vegetation induced by land use. a, Spatial pattern of land-use-induced biomass stock differences (expressed as a percentage of potential biomass stocks), mean of all 42 estimates. **b**, Box plot of all 42 estimates of global potential–actual biomass-stock difference. Whiskers indicate the range, the box shows the inner 50% percentiles, the line indicates the median of all estimates; the two dots represent the results of the two approaches used for the attribution of biomass stock differences to land-cover conversion and land management. **c**, Actual and potential biomass stocks in the world's major biomes (see Extended Data Fig. 5f), and role of land-cover conversion and management in explaining their difference. Error bars indicate the range of the estimates for potential (grey; $n=6$) and actual (black; $n=7$) biomass stocks. 'Ambiguous' denotes cases attributed differently in the assessments based on FRA and ref. 16.

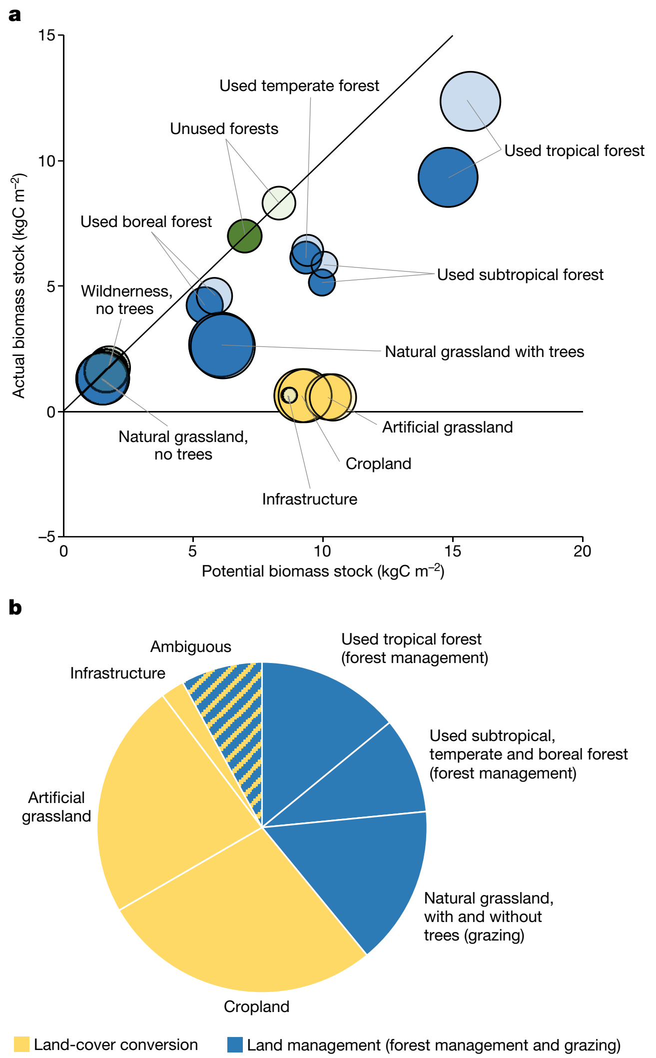

Figure 2 | Contribution of land-use types to the difference between potential and actual biomass stocks. a, Potential and actual biomass stock per unit area per land-use type for the assessment based on FRA (dark colours) and ref. 16 (light colours). Circle size is proportional to the global extent of the individual land use type. The diagonal line indicates the 1:1 relationship between actual and potential biomass stocks (no change, green colour). **b**, Relative contribution of land-cover conversion and land management to the difference between potential and actual biomass stocks, calculated on the basis of the assessments based on FRA and ref. 16. 'Ambiguous' denotes cases attributed differently in the two assessments (for absolute values refer to Extended Data Table 1).

Two of the actual biomass stock maps (based on the Global Forest Resource Assesment (FRA)[15] and ref. 16) were established on the basis of a present-day land-use dataset (Methods) and therefore enabled the systematic separation of land-cover conversion effects, that is, change in the biomass stocks due to conversion of pristine ecosystems into artificial grassland, cropland or infrastructure; and land management effects, that is, management-induced changes that occur within unaltered land-cover types, such as forests, savannahs and other natural grasslands (Extended Data Fig. 2).

At the global scale, the biomass stocks of the currently prevailing vegetation have a mean of 450 petagrams of carbon (PgC; range of the seven estimates: 380–536 PgC, coefficient of variation: 11%). By contrast, biomass stocks of potential vegetation have a mean of 916 PgC (range of the six estimates, individually adjusted to actual biomass stock maps: 771–1,107 PgC, coefficient of variation: 12%). Therefore, our analysis suggests that land use halves the amount of carbon that is potentially stored in terrestrial biomass (Fig. 1). Irrespective of the climate zone, the difference in biomass between potential and actual stocks mostly follows the pattern of global agriculture, with hotspots in South and East Asia, and Europe, as well as the eastern part of North and South America (Fig. 1a). Considerable differences between potential and actual biomass stocks also occur in regions dominated by forest and natural grassland use (Extended Data Fig. 5a, b). Given that biomass stocks are a function of net primary production and turnover time, a 50% reduction in the turnover time[18] and a 10% land-use-induced decrease in net primary production[19] explains the reduced biomass stocks.

The 42 pairs of potential–actual biomass-stock differences have a median of 49%, with the inner quantiles ranging from 43 to 55%, which implies an average impact on biomass stocks of 447 PgC (median; inner quartiles: 375–525 PgC; Fig. 1b).

The approaches based on FRA[15] and ref. 16 enable the separation of effects of land-cover conversion and land management (Fig. 1c). Owing to land-cover conversion (Methods), actual biomass stocks reach only 10% of potential biomass stocks per unit area (Fig. 2a), affecting only a relatively small area of 28 million km^2. By contrast, in an area of 56 million km^2 of managed, but not converted, ecosystems, the actual biomass stocks reach 60 to 69% of the potential biomass stock per unit area. As a consequence, land-cover conversion (53–58%) and land management (42–47%) contribute almost equally to the overall difference between potential and actual biomass stocks. Forest management contributes two-thirds and grazing one-third to the management-induced difference in biomass stocks (Fig. 2b and Extended Data Table 1).

The large impact of land management on vegetation biomass suggests that estimates of historical land-use change emissions are incomplete if only deforestation is considered (Extended Data Table 2). Contextualizing our results with accounts of the global terrestrial