Supporting Information for

Opportunities for Carbon Sequestration from Removing or Intensifying Pasture-based Beef Production

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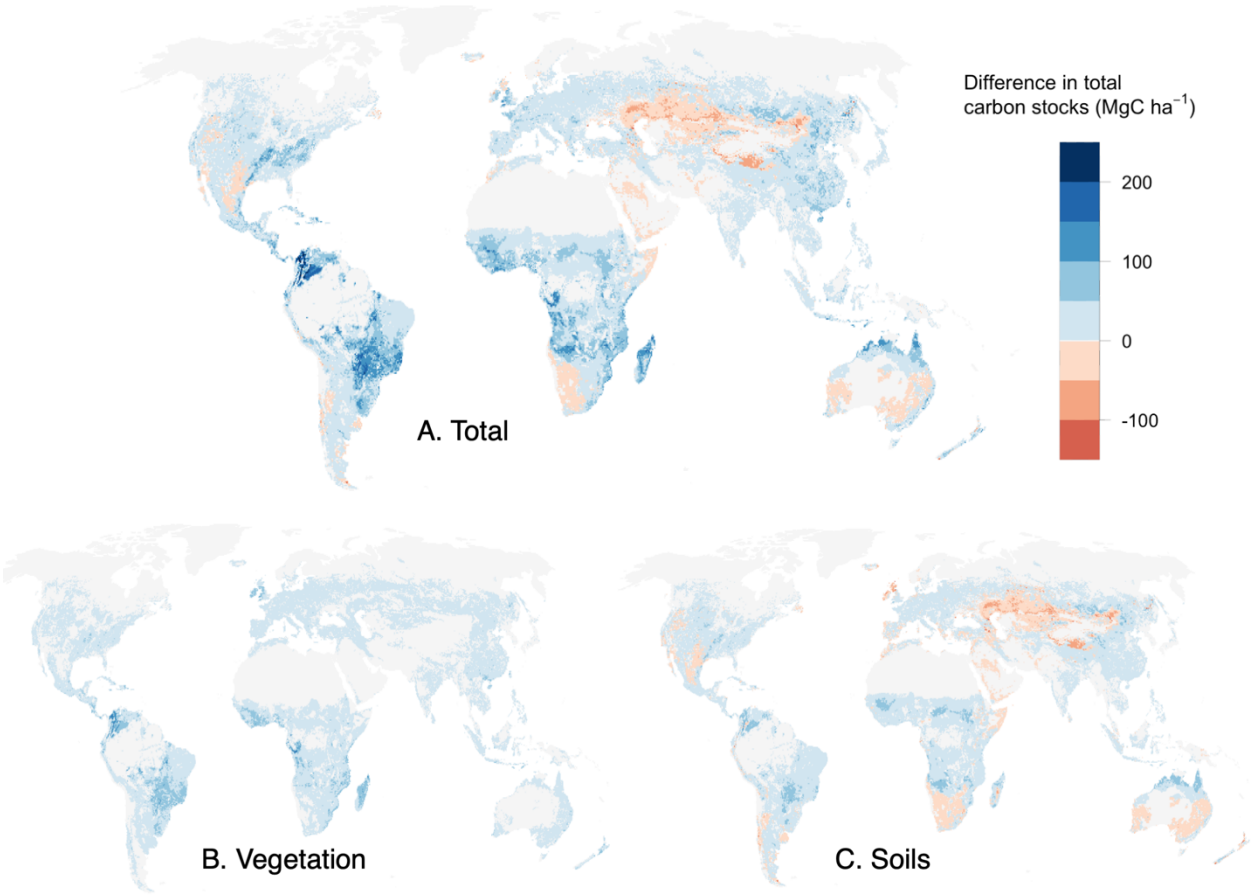

Fig. S1. Carbon opportunity costs of maintaining pastures on the basis of cumulative carbon stock per unit area: difference in potential carbon stocks through 2100 (integrated over 75 years) in A. vegetation + soil combined, B. only vegetation, and C. only soil. Each cell represents the product of the difference in potential and present C stocks in pasture times the area of pasture in that grid cell, divided by the total area in each grid cell.

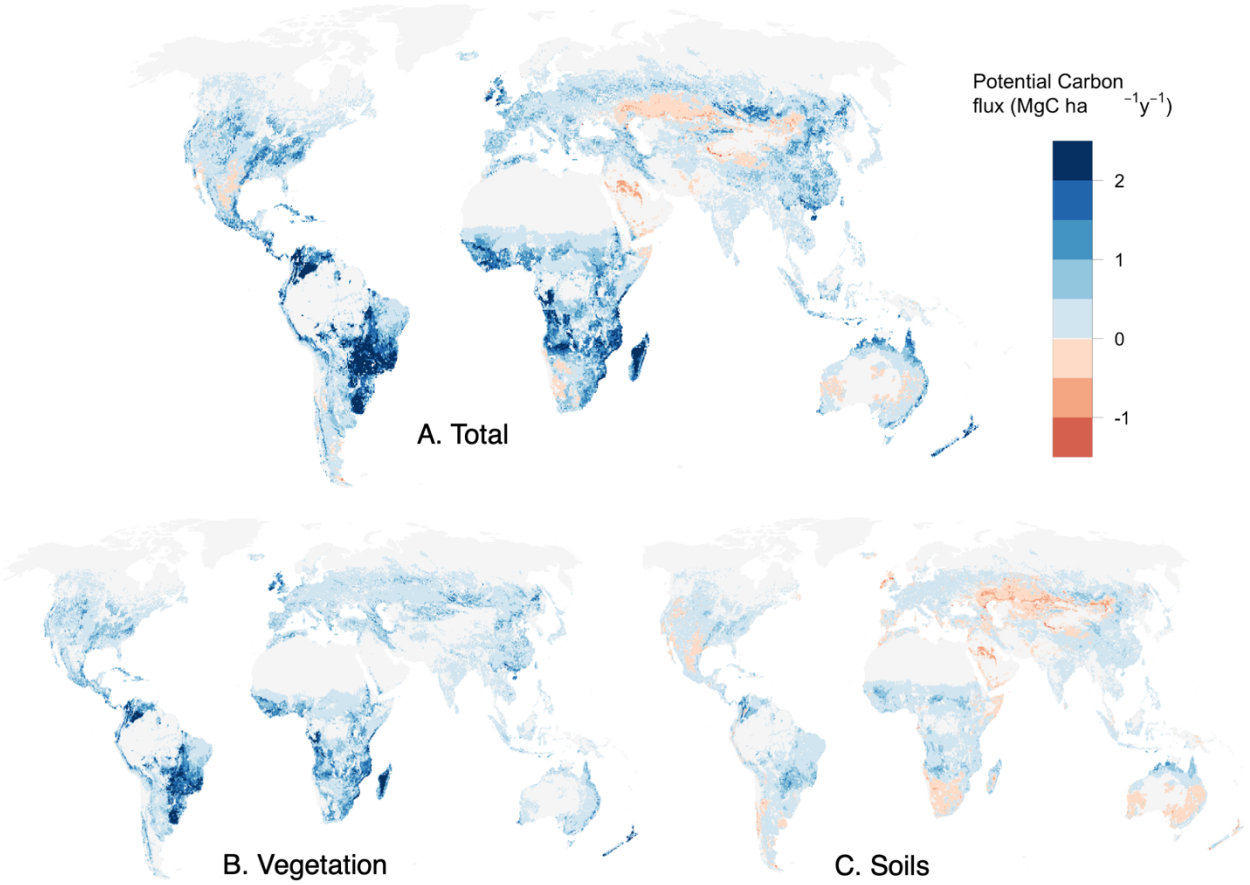

Fig. S2. Carbon opportunity costs of maintaining present-day pastures on the basis of annual carbon flux per unit area, in A. vegetation + soil combined, B. only vegetation, and C. only soil. Each cell represents the product of potential carbon fluxes from regrowing pasture to potential vegetation, times the area of pasture in that grid cell, divided by the total area in each grid cell.

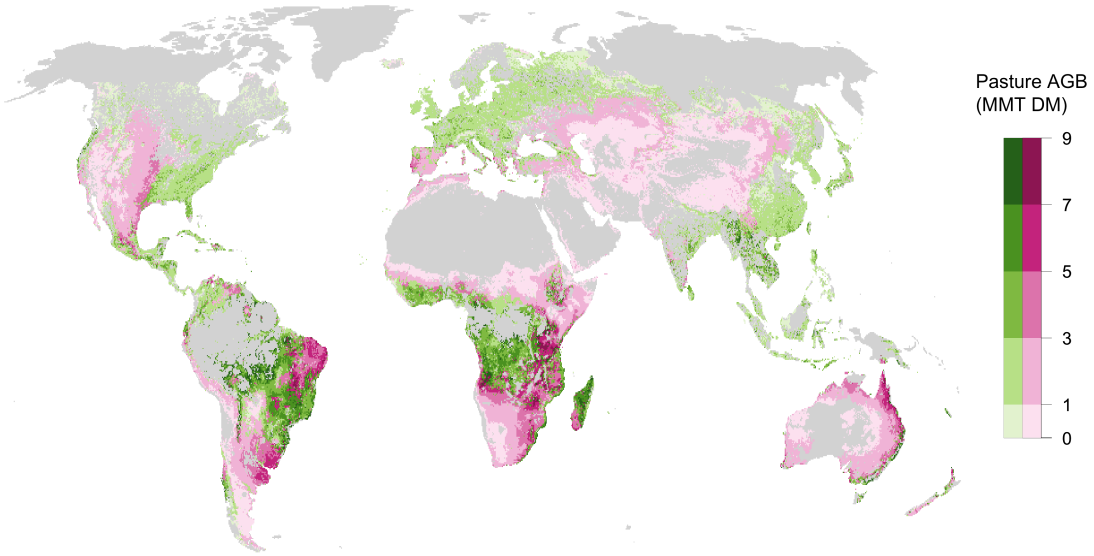

Fig S3. Pasture aboveground biomass (AGB). Green color scale refers to potential forest areas, pink color scale refers to native grassland areas.

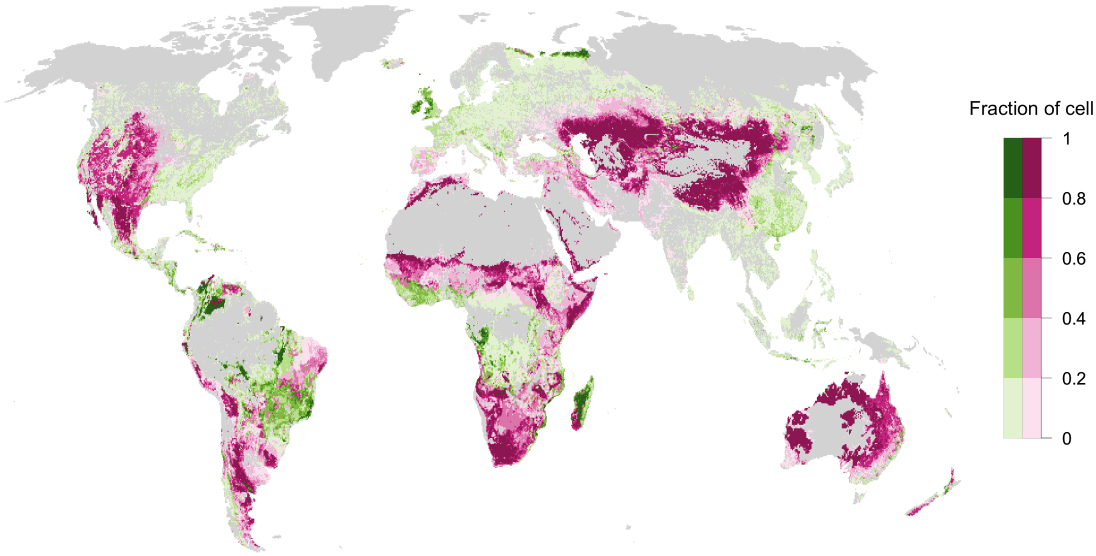

Fig. S4. Fraction of pasture in each grid cell, taken as the sum of all area in pastures plus rangelands, divided by total area of each grid cell. Green color scale refers to potential forest areas, pink color scale refers to native grassland areas.

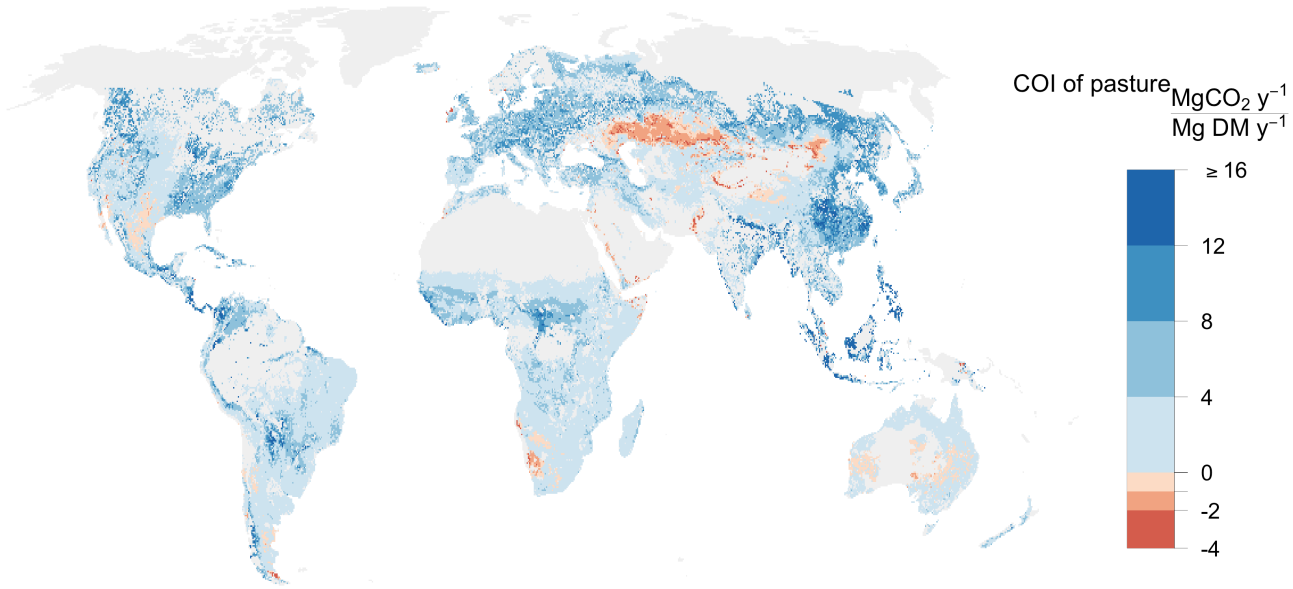

Fig S5. Spatial distribution of COI of pasture production at 5-arcminutes resolution, including negative values.

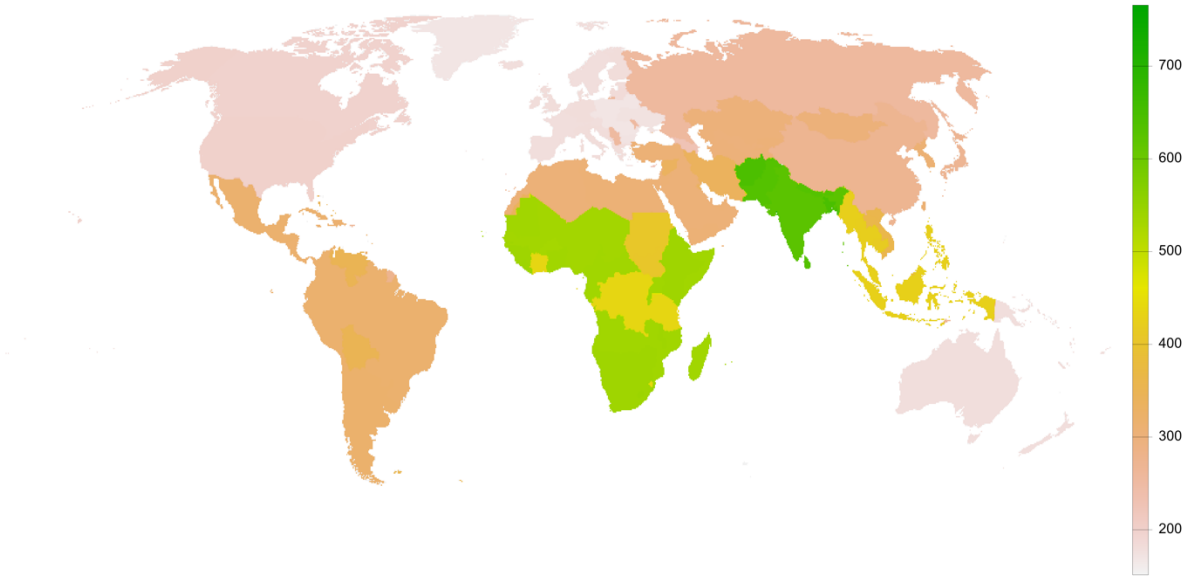

Fig. S6. Feed conversion ratio of pastures to beef in kg Pasture / kg beef protein.

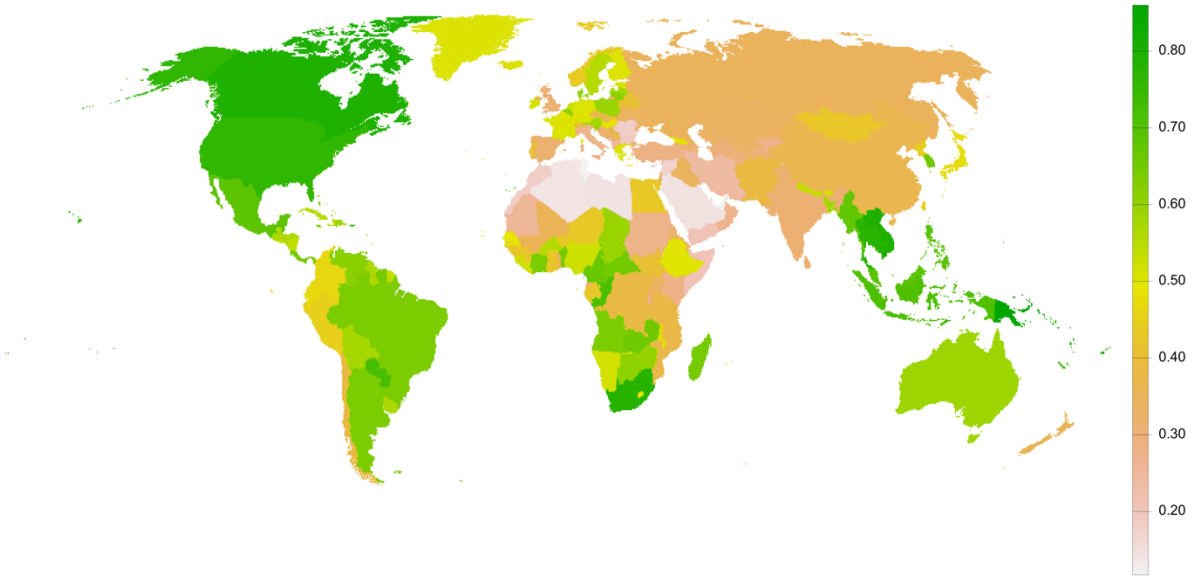

Fig S7. Proportion of pastures producing beef (beef from beef herds and beef from dairy herds combined)

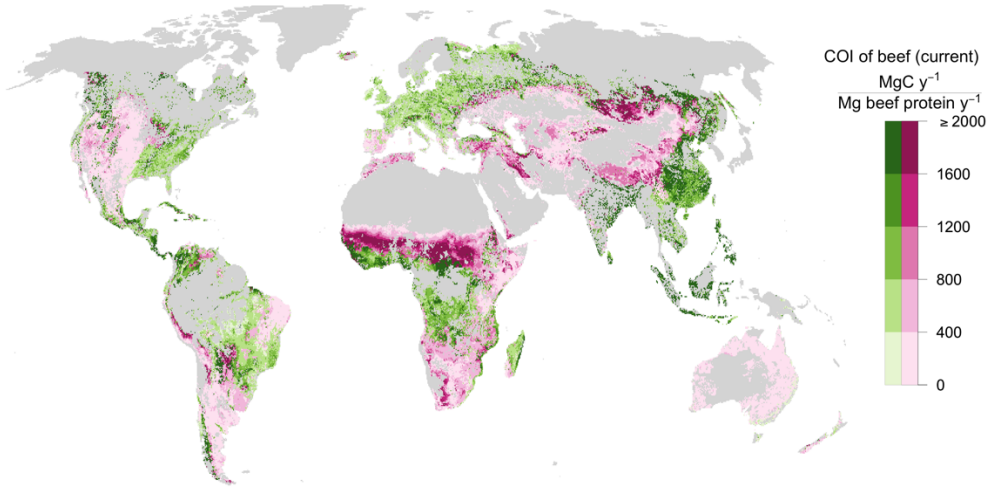

Fig. S8. Carbon Opportunity Intensity of pastured beef at current FCRs. Green color scale refers to potential forest areas, pink color scale refers to native grassland areas.

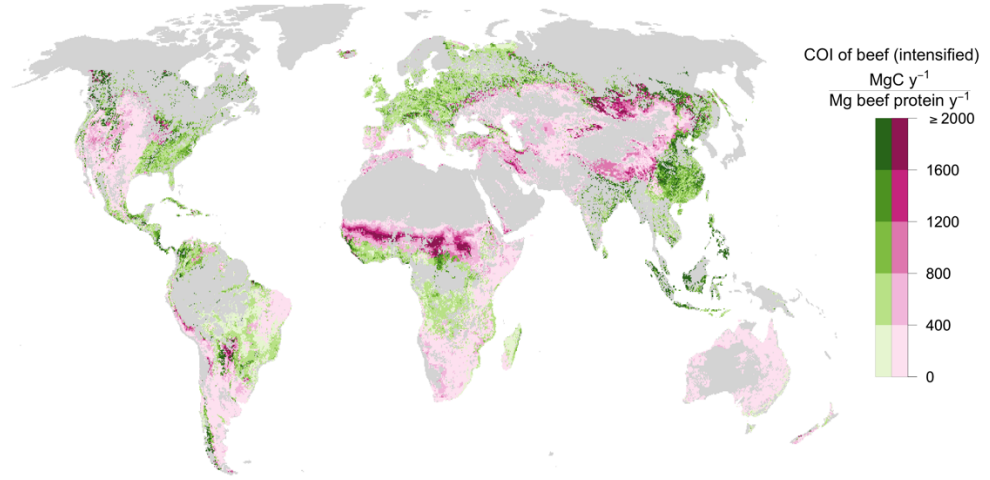

Fig. S9. Carbon Opportunity Intensity of pastured beef at intensified FCRs (90% yield gap closure with OECD countries). Green color scale refers to potential forest areas, pink color scale refers to native grassland areas.

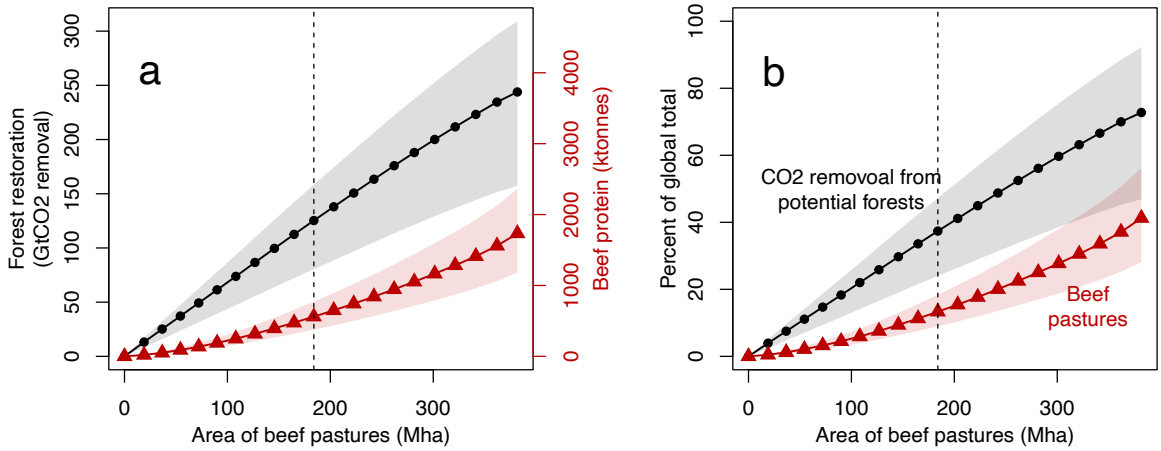

Fig. S10. Total pasture areas in potential forest where high-COI beef production occurs across various thresholds of COI. Each point refers to a 5-percentile point in the distribution of all area-weighted COI values (21 points total). Dashed vertical line corresponds to the area-weighted median COI value (1,974 $kgCO_2$ per kg beef protein) under a scenario of improved FCRs. (a) global CO_2 removal possible from restoring pastures (black dots; 95% confidence intervals in gray) and quantity of pasture-raised beef production forgone (red triangles; 95% confidence intervals in pink). (b) same as a., but demonstrating percentages of the global total.

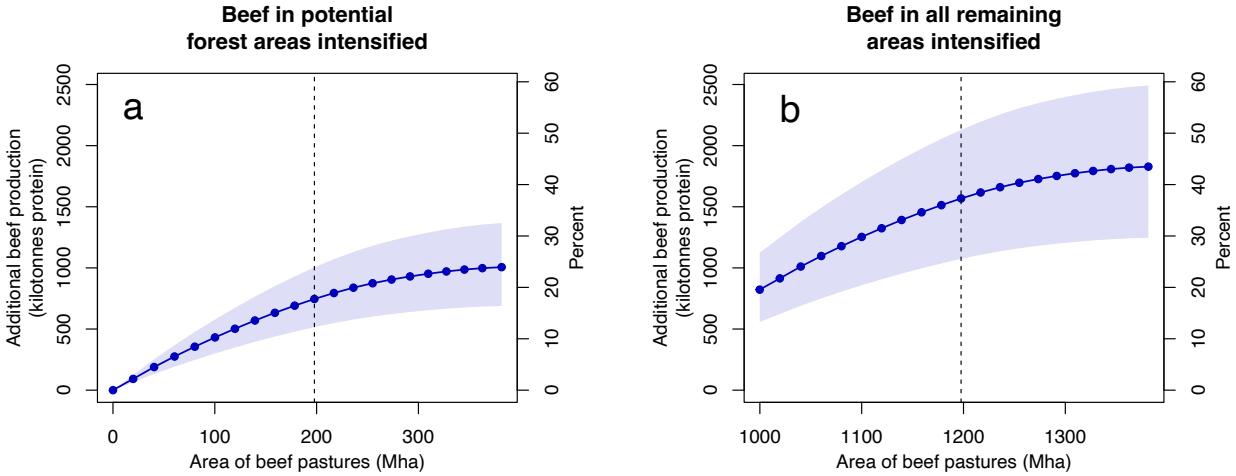

Fig. S11. Total pasture area and additional pastured beef production that could occur through intensification if beef production were removed from high-COI areas (for various COI thresholds of removal, as in Fig. S9) and remaining production areas were intensified. Each point refers to a 5-percentile point in the distribution of all area-weighted COI values (21 points total), above which beef production is removed, and below which pastured beef production is intensified. Current FCRs are intensified to 90% of OECD-average FCRs (202 kg DM per kg beef protein). Dashed vertical line corresponds to pasture area corresponding to the area-weighted median COI value (1,893 $kgCO_2$ per kg beef protein) under a scenario of improved FCRs. (a) quantity of additional beef that could be produced on pastures in areas of potential forests (b) quantity of additional beef that could be produced on pastures in all remaining areas (potential forests + grasslands combined).

A. Removal of beef-producing cattle from high-COI areas		B. Intensification of pastured beef production in remaining potential forest regions		C. Intensification across all remaining regions (potential forests + grasslands)	
Country	Beef removed (tonnes protein y^{-1})	Country	Beef gained (tonnes protein y^{-1})	Country	Beef gained (tonnes protein y^{-1})
USA	80,637	Brazil	148,136	South Africa	47,420
China	44,416	Madagascar	96,399	Madagascar	37,642
Colombia	42,132	Angola	83,662	Angola	35,870
Russia	15,980	Mozambique	34,644	Brazil	28,082
Paraguay	10,242	Zambia	30,502	Argentina	23,694
France	8,250	Tanzania	20,083	Zambia	14,201
Canada	8,070	Republic of Congo	14,339	Tanzania	13,864
Mexico	7,226	South Africa	10,840	Zimbabwe	12,516
Indonesia	7,190	D.R. of the Congo	8,381	Mozambique	12,239
Venezuela	6,758	Gabon	6,021	Kazakhstan	11,898
Germany	5,817	Bolivia	4,861	Mexico	11,290
UK	5,536	Nigeria	4,338	Botswana	10,160
Poland	5,470	Malawi	3,475	Uruguay	9,896
Nicaragua	3,966	Cameroon	3,341	Namibia	9,254
Ireland	3,565	Zimbabwe	3,250	Mongolia	5,897

Table S1. Countries ranked by net quantity of pasture-raised beef production removed or added respectively. A. Removed beef production from potential forested pasture areas that remain higher than the area-weighted median COI (1,893 $kgCO_2$ per kg beef protein) after intensification. B. Beef added by intensifying remaining beef production after high-COI beef removal to 90% of OECD average, in areas of potential forest. C. Beef added by intensifying remaining beef production after high-COI beef removal to 47% of OECD average, in areas of all remaining pastures.