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The blue carbon wealth of nations

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Carbon sequestration and storage in mangroves, salt marshes and seagrass meadows is an essential coastal 'blue carbon' ecosystem service for climate change mitigation. Here we offer a comprehensive, global and spatially explicit economic assessment of carbon sequestration and storage in three coastal ecosystem types at the global and national levels. We propose a new approach based on the country-specific social cost of carbon that allows us to calculate each country's contribution to, and redistribution of, global blue carbon wealth. Globally, coastal ecosystems contribute a mean ± s.e.m. of US$190.67 ± 30 bn yr^{-1} to blue carbon wealth. The three countries generating the largest positive net blue wealth contribution for other countries are Australia, Indonesia and Cuba, with Australia alone generating a positive net benefit of US$22.8 ± 3.8 bn yr^{-1} for the rest of the world through coastal ecosystem carbon sequestration and storage in its territory.

Coastal ecosystems such as mangroves, salt marshes and seagrass meadows are important global carbon sinks[1], sequestering and storing carbon at significantly higher rates than forests per unit area[2,3]; recognition of their importance prompted the invention of the term 'blue carbon' in 2009 (ref. [4]). Consequently, conservation and restoration of such blue carbon ecosystems (BCEs) is considered to be a key contribution of ocean-based activities to climate change mitigation[5,6] and has received considerable attention, for example, in the Research Agenda on Negative Emissions Technologies and Reliable Sequestration of the US National Academy of Sciences[7] and Australia's Emission Reduction Fund[8]. However, there is still substantial uncertainty regarding the spatial extent of BCEs and the factors influencing their carbon sequestration and storage potential. Most important for decision-makers is the absence of reliable, quantitative information on the economic value generated by these ecosystems at the individual country level worldwide[9].

To assess the contribution of BCEs to (inclusive) wealth at the global and national levels, we value the carbon sequestration and storage by their contribution to welfare, that is, we use shadow prices (as opposed to, for example, the United Nations System of Environmental Economic Accounting Ecosystem Accounting standards for national ecosystem accounting which use exchange values for consistency with the overall national accounting framework). Our valuation is based on the economic theory of inclusive wealth and comprehensive investment[10–12]. Among the many services that coastal ecosystems provide, we focus on their sequestration and storage services, which we consider as contributing to blue carbon wealth (Box 1).

Carbon sequestration and storage in BCEs contributes to blue carbon wealth, that is, the value of carbon stored in those ecosystems, which is a particularly relevant component of blue (coastal) wealth, which includes all values of coastal ecosystems[13,14]. Countries contribute differently to blue carbon wealth because they differ in the rates of coastal blue carbon sequestration and storage and in their shadow prices; for example, in their country-specific social cost of carbon (CSCC). We use the global social cost of carbon (SCC), that is, the sum of all CSCCs, to assess how much wealth originates from BCEs, and the CSCC to assess the redistribution of this wealth.

The UN Inclusive Wealth Reports[15–17] follow Arrow et al.[10,18] by using an estimate for the SCC to assess how comprehensive investment, that is, change in inclusive wealth, needs to account for damage caused by carbon emissions. The SCC measures the present value of all climate damage across the globe caused by the emission of an additional tonne of CO_2 into the atmosphere[10]. The high level of aggregation in these studies does not allow, however, assessment of the contribution to comprehensive investments resulting from carbon sequestration and storage via particular sinks and their spatial pattern.

The global SCC is the basis for current global estimates of the contribution of (blue) carbon sequestration and storage[13,19–21] and estimates for specific regions such as the Mediterranean Sea[22]. Focusing on the global aggregates does not help for decision-making at the country level, and neglects that countries differ (1) in their BCE areas and (2) in their valuation of the carbon sequestration and storage potential of these ecosystems. In this article we provide information at the national scale which (1) is relevant for properly assessing the economic value of carbon sequestration and storage in BCEs[23] and (2) can serve to support the development of measures to conserve and restore these coastal habitats by facilitating cost–benefit analysis.

Coastal carbon sequestration potential per country

We calculate the areas covered by three coastal ecosystem types, mangroves, salt marshes and seagrass meadows, in each country's exclusive economic zone (EEZ) based on global spatial data sets[24–28] and combine these data with average annual carbon sequestration rates for mangroves[29,30], salt marshes[31] and seagrass meadows[2], respectively, to obtain estimates for each country's blue carbon sequestration potential. Summing over all countries results in mean ± s.e.m. cumulative sequestration potentials of 24.0 ± 3.2 MtC yr^{-1} for mangroves, 13.4 ± 1.4 MtC yr^{-1} for salt marshes and 43.9 ± 12.1 MtC yr^{-1} for seagrass meadows, totalling 81.2 ± 12.6 MtC yr^{-1} across all BCEs. This is in line with earlier global estimates for mangroves and salt marshes but is lower, and hence more conservative, for seagrass meadows[29]. Australia, the United States and Indonesia are the three countries with the largest annual carbon sequestration potentials aggregated over all three BCE types (10.6 ± 1.6,

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Box 1 | Blue carbon wealth

The concept of inclusive wealth has been developed to assess economically sustainable development, conceptualized as non-declining human well-being, and for project appraisal and cost–benefit analysis of public policies[10]. Inclusive wealth is defined as the aggregate of all natural and human-made capital stocks, valued with their shadow prices, that is, contributions to societal welfare, as opposed to market (or exchange) prices used in national accounting for computing the gross domestic product. Shadow prices reflect (1) the absolute scarcity of resources, which can be quantified by economic–scientific approaches, (2) the expectations about future management of human-made and natural capital stocks and (3) societal objectives captured by a welfare function. The corresponding (weak) sustainability rule requires that inclusive wealth—the productive base of society—does not decline over time. This is equivalent to non-negative comprehensive investment, that is, the aggregate value of investments and disinvestments in all natural and human-made capital stocks[10–12,18].

Natural capital stocks include global commons such as atmospheric carbon, which affects all countries in a differentiated manner as measured by country-specific shadow values[18]. Most countries around the globe will face climate damage costs in the future, captured by a negative shadow price of atmospheric carbon for those countries. When ecosystems or other carbon sinks take up carbon from the atmosphere, their natural capital value increases by the shadow value of the carbon withdrawn from the atmosphere. In general, the various carbon fluxes resulting from emissions and carbon uptake allow the corresponding contributions (net investments) to inclusive wealth to be calculated.

7.5 ± 0.8 and 7.2 ± 0.9 MtC yr^{-1}, respectively, Fig. 1). Among countries that host any BCEs, the smallest absolute annual carbon sequestration potentials exist in Mauritania (2.4 ± 0.3 tC yr^{-1}), Bulgaria (77.3 ± 8.2 tC yr^{-1}) and Saint Vincent and the Grenadines (81.3 ± 10.7 tC yr^{-1}). A full list of national absolute annual carbon sequestration is given in the Supplementary Data 1.

Evidently, the absolute carbon sequestration potential of a country depends on the length of the coastline and the size of that country's EEZ. The three countries with the largest absolute annual carbon sequestration potentials (Australia, the United States and Indonesia) also have the largest areas covered by coastal ecosystems and are among the countries with the largest EEZs. Asian countries, in particular, have large sequestration potentials along with large areas of coastal BCEs (mostly mangroves and seagrasses for tropical and subtropical countries) despite varying EEZ sizes. At the other extreme, many European countries tend to feature low sequestration potentials and small areas covered by coastal ecosystems. Exceptions are France and the United Kingdom, which realize 66% and 42% of their annual sequestration potential within overseas territories, respectively. France also leads in absolute terms the contribution from overseas territories (0.67 MtC yr^{-1}), followed by the United States (0.56 MtC yr^{-1}), although for the latter this provides only 7.4% of its total annual sequestration potential. Overall, overseas territories contribute 1.7% to annual global carbon sequestration potential.

Differences between countries cannot be explained only by different coastal sizes and locations, but are also due to varying sampling efforts across world regions reflected in the spatial data on ecosystem coverage used for the analysis. For example, the extent of tidal marshes is well documented for Canada, Europe, the United States, South Africa and Australia, but remains largely unavailable for northern Russia and South America. Additionally, the spatial data for seagrass meadows are 'geographically and historically biased, reflecting the imbalance in research effort among regions'[9]. Nevertheless, the regional differences in sequestration potentials could also be explained by differing degrees of disturbances, with, for example, seagrass meadows suffering in industrialized countries with strong eutrophication and coastal development but thriving in less-developed, clear-water areas[32].

Blue carbon wealth contributions

We find that global blue carbon wealth generated by carbon sequestration in coastal BCEs amounts to US$190.7 ± 29.5 bn yr^{-1} based on a global mean SCC of US$640.3 ± 4.93 tCO$_2^{-1}$ (s.d. US$188.45 tCO$_2^{-1}$). The SCCs underlying these calculations are derived by averaging across all possible scenario combinations presented in Ricke et al.[33,34], including all five Shared Socioeconomic Pathways (SSP1–5)[35] with possible combinations of the Representative Concentration Pathways (RCPs), RCP4.5, RCP6.0 and RCP8.5 (ref. [36]) (see Methods for details, Extended Data Fig. 1 for CSCC, and Extended Data Fig. 2 and Supplementary Information, section 2 for alternative specifications). Past studies on the global value of coastal ecosystems do not focus on carbon sequestration[13] but include all coastal ecosystem services, estimating their value to be US$31.6 tr yr^{-1} covering seagrass meadows and algae beds as well as tidal marshes and mangroves. In comparison, the carbon sequestration contribution to blue wealth (US$190.7 ± 29.5 bn yr^{-1}) is rather low. However, the management of complex ecology–human interaction as found in many coastal habitats is well-advised to apply the concept of strong sustainability[37], according to which all natural capital assets should be maintained above critical levels. The assessment of blue carbon sequestration, based on the application of (C)SCC, could thus be embedded in an inclusive wealth framework, where the monetary valuation of carbon sequestration is combined with a non-monetary valuation of critical ecosystems services, the latter captured by indicators and corresponding boundary values[38].

Blue carbon wealth redistribution

As each tonne of carbon sequestered has the same value on the global level, the ranking of the country-specific global contribution to blue carbon wealth is the same as for the carbon sequestration potential. Australia is the largest contributor to global blue carbon wealth (US$25.0 ± 3.8 bn yr^{-1}). A full list of national contributions to global blue carbon wealth can be found in Supplementary Data 1. However, only part of the benefit generated by national carbon sequestration remains within the country: this part of blue carbon wealth is represented by the amount of carbon sequestered in the home country multiplied by the CSCC of the respective country. The benefit for all other countries is obtained by valuing the carbon sequestered in the home country with the CSCC of these other countries. We refer to the latter as the 'outbound blue carbon wealth contribution'. In turn, nations also receive blue carbon wealth from carbon sequestration in other countries. Accordingly, the total foreign contribution of global BCEs to domestically avoided climate damage is given by the sum of blue carbon sequestration in all other countries valued with the domestic CSCC. We refer to the latter as the 'inbound blue carbon wealth contribution'. The differences between outbound and inbound blue carbon wealth contributions are net blue carbon wealth redistributions (Fig. 2a; see Methods for more details and Supplementary Information, section 3 for the case of Australia as an example). We denote countries with surpluses as 'blue carbon wealth donor countries' and countries with deficits as 'blue carbon wealth recipient countries'.

The five donor countries that generate the largest blue carbon wealth surpluses are, in addition to Australia: Indonesia, Cuba, Russia and Guinea-Bissau (Fig. 2b). Donor countries are characterized by relatively small—or as in the case of Russia even

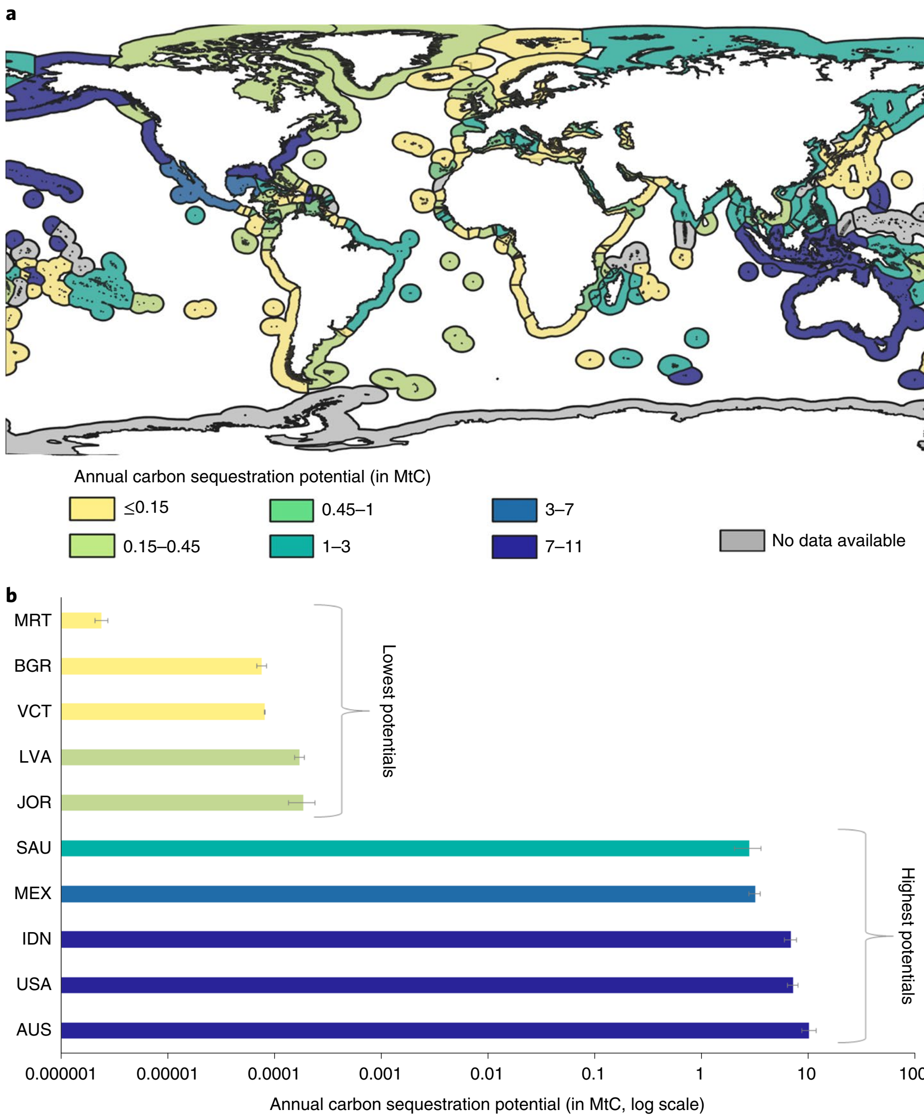

Fig. 1 | Mean annual blue carbon sequestration potentials. a, Global map of mean annual blue carbon sequestration potentials by country. **b**, Bar chart of the five countries with the largest and smallest mean annual blue carbon sequestration potentials. Mean national carbon sequestration potentials are based on spatial ecosystem coverages and mean global net sequestration rates, both per ecosystem type. Error bars in **b** represent ±1 s.e.m. of global carbon sequestration rates. MRT, Mauritania; BGR, Bulgaria; VCT, Saint Vincent and the Grenadines; LVA, Latvia; JOR, Jordan; SAU, Saudi Arabia; MEX, Mexico; IDN, Indonesia; USA, United States; AUS, Australia.

negative—CSCCs and/or a relatively large carbon sequestration potential within the country. Recipient countries with blue carbon wealth deficits, in contrast, are characterized by relatively large CSCCs and/or a relatively small carbon sequestration potential within the country. The five largest recipient countries are India, China, the United States, Pakistan and Japan.

Accordingly, the three countries with the largest CSCCs (the United States, India and China) are also the three largest blue carbon wealth recipient countries. Although the carbon sequestration potential in these countries is not small in absolute terms, their large CSCCs imply that a large share of the global wealth generated by avoided climate damage through carbon sequestration in coastal BCEs accrues to these countries. Based on the CSCC averaged across all scenarios, 17.0% of global SCC is the CSCC of the United States, 15.4% the CSCC of India and 11.7% the CSCC of China. These countries thus benefit substantially from blue carbon sequestration in other countries around the globe. In monetary terms, the net contribution to blue wealth received amounts to US\$26.4 ± 5.0 bn yr^{-1} for India, US\$16.6 ± 3.4 bn yr^{-1} for China and US\$14.7 ± 4.9 bn yr^{-1} for the United States. Blue carbon wealth redistributions aggregated to the continent level are depicted in Fig. 2c. Whereas 53% of Asia's contribution to blue wealth remains in Asia, 99% of Oceania's contribution to blue wealth becomes effective abroad. Note that the classification of blue carbon donor and recipient countries is based on blue carbon sequestration only and includes neither other carbon sinks nor carbon emissions. Accounting also for energy and industrial carbon emissions, only Guinea-Bissau, Belize, Vanuatu, Sierra Leone, Solomon Islands, Guinea, Comoros, Samoa, Madagascar and Papua New Guinea have a positive net blue wealth outbound contribution because their blue carbon sequestration exceeds their emissions (see Extended Data Fig. 1 and Supplementary Information, section 1).

Discussion and conclusions

We extend former analyses and use a novel approach to quantify annual national contributions to global blue carbon wealth as well

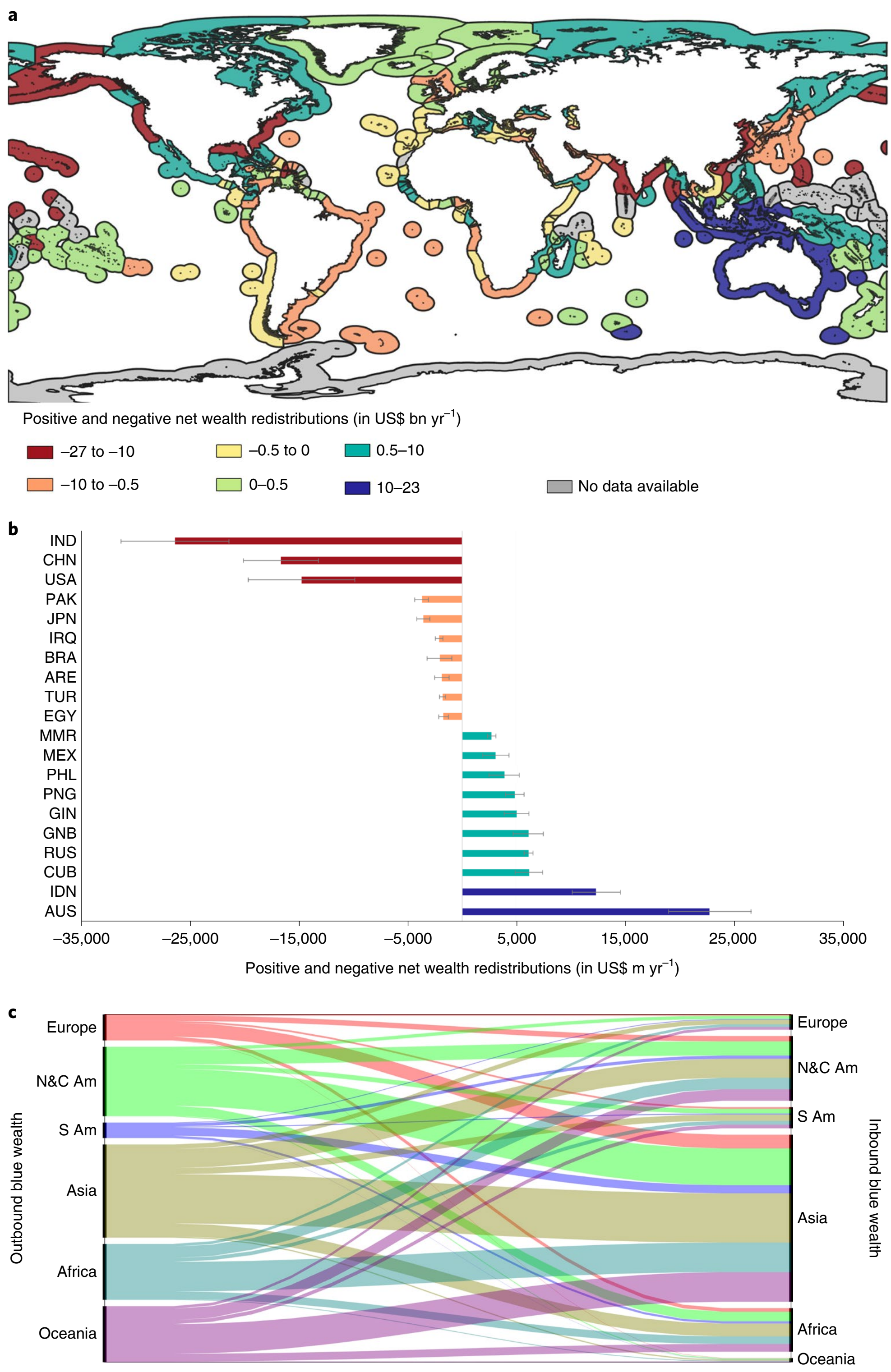

Fig. 2 | Net blue carbon wealth redistributions. a, Global map with positive and negative net blue carbon wealth redistributions (surpluses and deficits). **b**, Bar chart with ten largest donor and recipient countries. Wealth redistributions are calculated using CSCCs averaged across all scenarios. Error bars represent uncertainties in global sequestration rates and estimated CSCCs reflected by standard errors of the mean. IND, India; CHN, China; USA, United States; PAK, Pakistan; JPN, Japan; IRQ, Iraq; BRA, Brazil; ARE, United Arab Emirates; TUR, Turkey; EGY, Egypt; MMR, Myanmar; MEX, Mexico; PHL, Philippines; PNG, Papua New Guinea; GIN, Guinea; GNB, Guinea-Bissau; RUS, Russian Federation; CUB, Cuba; IDN, Indonesia; AUS, Australia. **c**, Blue carbon wealth redistributions on the continent level. N&C Am, North and Central America; S Am, South America; Oceania, Australia and Oceania.

as net donor and recipient countries of blue carbon wealth across the globe. Australia, Indonesia and the United States are the three countries with the largest absolute annual blue carbon sequestration potentials and in turn are the three largest national contributors to global blue carbon wealth, measured by their marginal reduction of global climate change impacts. However, countries are differently affected by climate change and, based on our calibration, the United States benefits the most from global BCE carbon sequestration. In contrast, only a small fraction of the benefits associated with BCE carbon sequestration taking place in Australia are contributing to Australia's wealth. Taking into account these differences in marginal climate damages occurring in each country, we find that Australia, Indonesia and Cuba are the largest blue carbon wealth donor countries, while India, China and the United States are the three largest recipient countries of blue carbon wealth. Considering estimates for country-specific marginal damages (CSCC) makes it possible to identify how benefits generated by carbon sequestration in coastal BCEs are distributed across the globe.

The estimates of national carbon sequestration potentials used in this paper are based on global spatial data sets of BCEs and average global sequestration rates. Both aspects are surrounded by uncertainties, which are partly but not fully covered in the analysis we present. The global spatial data sets used in this paper are based on bottom-up assessments of global ecosystem coverages, which may not be homogeneous across world regions because data are merged from different sources and mapping and documentation of ecosystem occurrences in some world regions can be patchy. While the bottom-up nature of the spatial data used implies that the carbon sequestration estimates derived here are probably conservative, coastal BCEs have also undergone severe losses over the last decades[20,39], with loss rates varying over time; for example, for the case of mangroves, loss rates have declined since the beginning of the 21st century[9,40]. Because we are interested in an economic assessment that is consistent across all nations, we rely on the global spatial data sets available, which allow for a relative comparison of the national blue carbon wealth contributions and redistributions across the globe.

Uncertainties regarding the estimates of global carbon sequestration rates are taken into account here first by using sequestration rates from the most up-to-date reviews, and second by using the standard errors presented in the primary studies. Other factors that influence carbon sequestration potentials, such as disturbances at the site[9], are not taken into account here. Future work could explore the use of differentiated sequestration rates for regions as presented for salt marshes in Ouyang and Lee[31]. The impact of such contextual factors has not yet been quantified on a global scale and broken down to the national level. This is clearly a general data gap that needs to be filled urgently through concerted international effort[41].

Substantial uncertainty also pertains to the estimates of the global SCC, which span from a few tens to a few hundreds of US dollars per tonne of carbon[42]. In particular, Tol[43] has recently challenged the global- and country-specific SCCs estimated by Ricke et al.[33,34], estimating the global SCC to amount to US\$88.0 tCO_2^{-1} in the baseline specification with the pure rate of time preference of 1% per year. This is substantially smaller than the estimates of Ricke et al.[33,34], which are on average mean ± s.d. US\$640.3 ± 188.45 tCO_2^{-1} for the all-scenarios case and US\$358.6 ± 92.87 tCO_2^{-1} for the SSP2/RCP6.0 case with a pure rate of time preference of 2%. Ricke et al.'s estimates are, however, well within the range of other current estimates of the global SCC with mean global SCCs of US\$1,319 and US\$161 tCO_2^{-1} for a pure rate of time preference of 1% and 3%, respectively[42]. Furthermore, accounting explicitly for the impacts of climate change on natural capital, and therefore also (blue carbon) ecosystems, causes SCC estimates to increase[44,45]. For example, Bastien-Olvera and Moore[45] estimate that the SCCs in 2020 increased by more than a factor of five in the standard integrated assessment model DICE when accounting for the various use and non-use values of natural capital. Nevertheless, their integrated assessment model estimate is only about half of the average SCC obtained from considering all the scenarios described by Ricke et al. The rather high SCC obtained by Ricke et al. can be explained by the fact that they assume, in contrast to Tol[43] and Bastien-Olvera and Moore[45], that climate change has a persistent impact on economic growth[46], which has been shown to lead to significantly higher SCCs than previous estimates[47]. While uncertainty about the CSCCs, and in turn on the SCCs, will remain partly irreducible, further research is needed to obtain better estimates of the impacts of climate on various important aspects, such as water resources, energy supply or migration[42].

Current estimates of blue carbon wealth are often based on global averages of SCCs only, neglecting the national perspective. A country-level analysis as presented here offers important perspectives, for example, on the scope for increasing conservation and restoration efforts. We must note, however, that our estimates of carbon wealth redistribution are restricted to blue carbon sequestration only and do not account for the case that, for example, a blue carbon wealth recipient country could be at the same time a large forest carbon wealth donor country, making it overall to a carbon sequestration wealth donor country. Future research can extend our natural capital approach to carbon emissions and all carbon sinks to obtain a more comprehensive estimate for carbon wealth redistribution which, in contrast to existing market-based evaluations, is not affected by the stringency of the underlying climate policy.

Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-021-01089-4.

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Methods

Annual carbon sequestration potential per country. Our calculations of ecosystem area per country are based on the latest available global spatial data sets provided by the United Nations Environment Program World Conservation Monitoring Center (UNEP-WCMC) (Giri et al.[24] for mangroves, Mcowen et al.[25] for salt marshes and UNEP-WCMC[26] and Green and Short[27] for seagrass meadows). The ecosystem areas of all three ecosystem types are allocated to countries based on the spatial coverage of a country's land area as well as a country's EEZ identified by their respective ISO three-digit codes. The combined shapefile of the countries' EEZ and land areas are taken from the Flanders Marine Institute[28]. Subsequently, we prepare the UNEP-WCMC data sets by dissolving overlapping polygons to avoid multiple/double counting in the final area calculation. To calculate the ecosystem area, we use the equal area projection Mollweide. The resulting data set includes the areas of all three coastal BCE types allocated to the countries for the entire globe. Regions covered by coastal BCEs that are located outside national jurisdictions (either land area or EEZ) are not covered by our analysis. However, because mangroves, salt marshes and seagrass meadows occur either on land, in the intertidal zone or in near-shore waters, this effect should be negligible. In total, there are 317,828, 54,662 and 137,682 km^2 seagrass, salt marsh and mangrove BCE areas, respectively. We have 245 countries, of which 165 countries have at least one type of BCE in their jurisdiction (EEZ). In addition, there are 14 areas without ISO code (conflicted areas) which are listed in Supplementary Data 1. These areas contain 762 km^2 seagrass BCEs and 106 km^2 salt marsh BCE areas (representing 0.2% and 0.07% of the total seagrass meadow and salt marsh areas). The contribution to global blue carbon wealth in these areas has been considered. Of the 245 countries, 45 have been assigned to their sovereign country. Overall, the 45 overseas territories contain 8,545 km^2 (2.7%), 60 km^2 (0.1%) and 1,195 km^2 (0.9%) seagrass, salt marsh and mangrove BCEs, respectively, contributing 1.4 MtC to total carbon sequestration, which was assigned to France (0.67 MtC), the United States (0.56 MtC), the United Kingdom (0.11 MtC), Australia (0.05 MtC) and the Netherlands (0.01 MtC). For 31 of the remaining 200 countries there is no information on the CSCC. These countries contain 11,277 km^2 (3.5%), 46 km^2 (0.08%) and 280 km^2 (0.2%) seagrass, salt marsh and mangrove BCE habitat areas, respectively. For those 31 countries without CSCC we have no information on the domestic and inbound contribution of BCE carbon sequestration to blue wealth; however, their outbound contribution of US$3.8 ± 1.0 bn is included in our analysis. Spatial coverages of coastal BCEs per country can be found in Supplementary Data 1.

We calculate the absolute annual carbon sequestration potential ($S_{i,\mathrm{abs}}$) of country i as:

$$S_{i,\mathrm{abs}} = \sum\nolimits_{j=1}^{3} A_{i,j} \times s_j$$

where $A_{i,j}$ is the area of coastal BCE type j allocated to country i and s_j is the annual sequestration rate of ecosystem type j, with mean ± s.e. values of 174 ± 23, 245 ± 26 and 138 ± 38 $\mathrm{tC\,yr^{-1}\,km^{-2}}$ for mangroves[29,30], salt marshes[31] and seagrass meadows[2], respectively.

Global blue carbon wealth and national contributions. We obtained estimates for the CSCCs described by Ricke et al.[31,32], who present estimates for different SSP/RCP scenarios, different discounting scenarios, different climate impact scenarios and different scenarios for estimating the uncertainty of climate change. We obtained for each scenario the median CSCC and then applied a resampling weighted bootstrapping approach to derive a distribution for CSCCs (Supplementary Data 2). The weighted bootstrapping ensured that different climate impact functions have the same probability. In more detail, the impact function provided by Dell et al.[48], used in the analysis of Ricke et al., has a different frequency compared to the impact function of Burke et al.[49], making it necessary to assign a higher weight to Dell et al.'s specifications (that is, each scenario with Dell et al.'s impact function has a weight of 1/15,300, each scenario with Burke et al.'s impact function and with a long-run (lagged) damage model specification has a weight of 1/48,960 and the scenarios with the remaining specifications have a weight of 1/61,200). In addition to the main results which include all scenarios, we present the results for CSCC calculated for the combination of SSP2 and RCP6.0 in combination with one growth-adjusted discount rate (pure rate of time preference per year, $\rho = 2\%$; elasticity of marginal utility substitution, $\mu = 1.5$) (Extended Data Fig. 2 and Supplementary Information, section 2). The contribution to global blue carbon wealth is calculated by multiplying the carbon sequestration potential by the SCC, which is the sum of all CSCCs.

Blue carbon wealth redistribution. We calculate the wealth generated by carbon sequestration in coastal BCEs in one country for all other countries (outbound blue carbon wealth redistribution) as

$$W_{i,\mathrm{out}} = S_{i,\mathrm{abs}} \times \left(\sum\nolimits_{j\neq i} \mathrm{CSCC}_j\right),$$

which measures the marginal economic damages avoided in the rest of the world by carbon sequestration that occurs in country i. We calculate wealth generated within one country by carbon sequestration in all other countries (inbound blue carbon wealth redistribution) as

$$W_{i,\mathrm{in}} = \mathrm{CSCC}_i \times \left(\sum\nolimits_{j\neq i} S_{j,\mathrm{abs}}\right),$$

which measures the marginal economic damages avoided in country i by carbon sequestration occurring in all other countries $j \neq i$. Net blue carbon wealth redistributions are defined as the difference between outbound and inbound blue carbon wealth redistributions. Note that not all countries gain from blue carbon sequestration. Those countries which are estimated to gain from climate change, that is, those having a negative CSCC, experience a wealth reduction from carbon sequestration. Worthy of mention here is above all Russia which has a mean outbound blue carbon wealth contribution of US$4.3 ± 0.4 bn but at the same time experiences a mean inbound blue carbon wealth contribution of –US$1.8 ± 0.4 bn from blue carbon sequestration abroad. Overall, nine countries experience wealth loss via blue carbon sequestration (see Supplementary Data 1).

Data availability

The data on country carbon sequestration potential, country social cost of carbon and wealth restribution resulting from blue carbon sequestration are available within the paper and its Supplementary Information files.

Code availability

The code for estimating the country social cost of carbon via bootstrapping is available within the Supplementary Information files (section 3). The calculation of the ecosystem areas underlying the country carbon sequestration potential is available from the corresponding author upon reasonable request.

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Author contributions

C.B. had the initial idea for the study and developed the concept together with M.Q. and W.R. C.W. and A.T.V. performed the GIS calculations. M.Q. and W.R. performed the bootstrapping of the CSCC. M.Q. and W.R. proposed the concept of blue carbon wealth redistributions. C.B. calculated the carbon sequestration potentials. T.B.H.R. validated the BCE-based data. C.B. and W.R. carried out the economic assessments, interpreted the results and wrote the manuscript. All authors discussed the results and provided input to the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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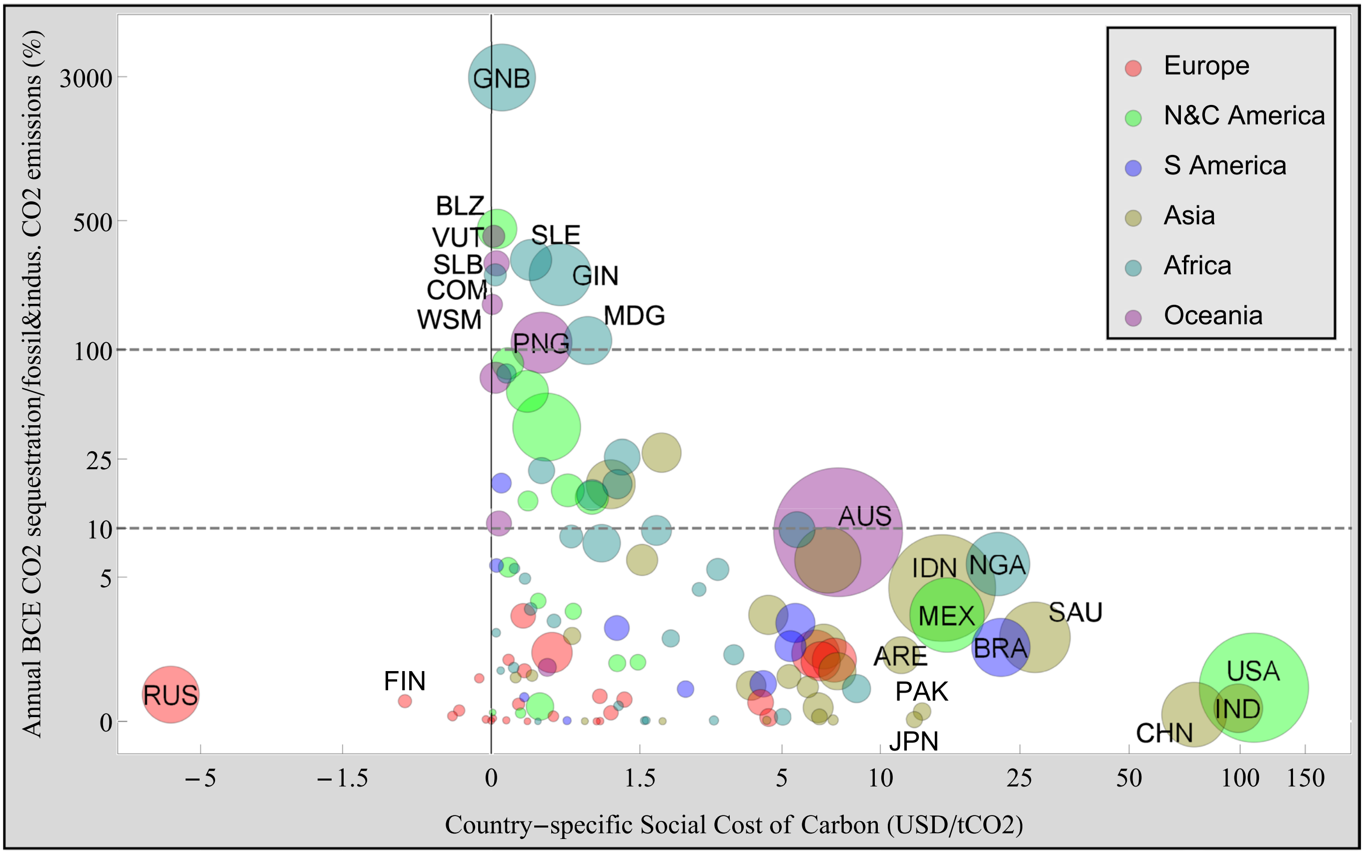
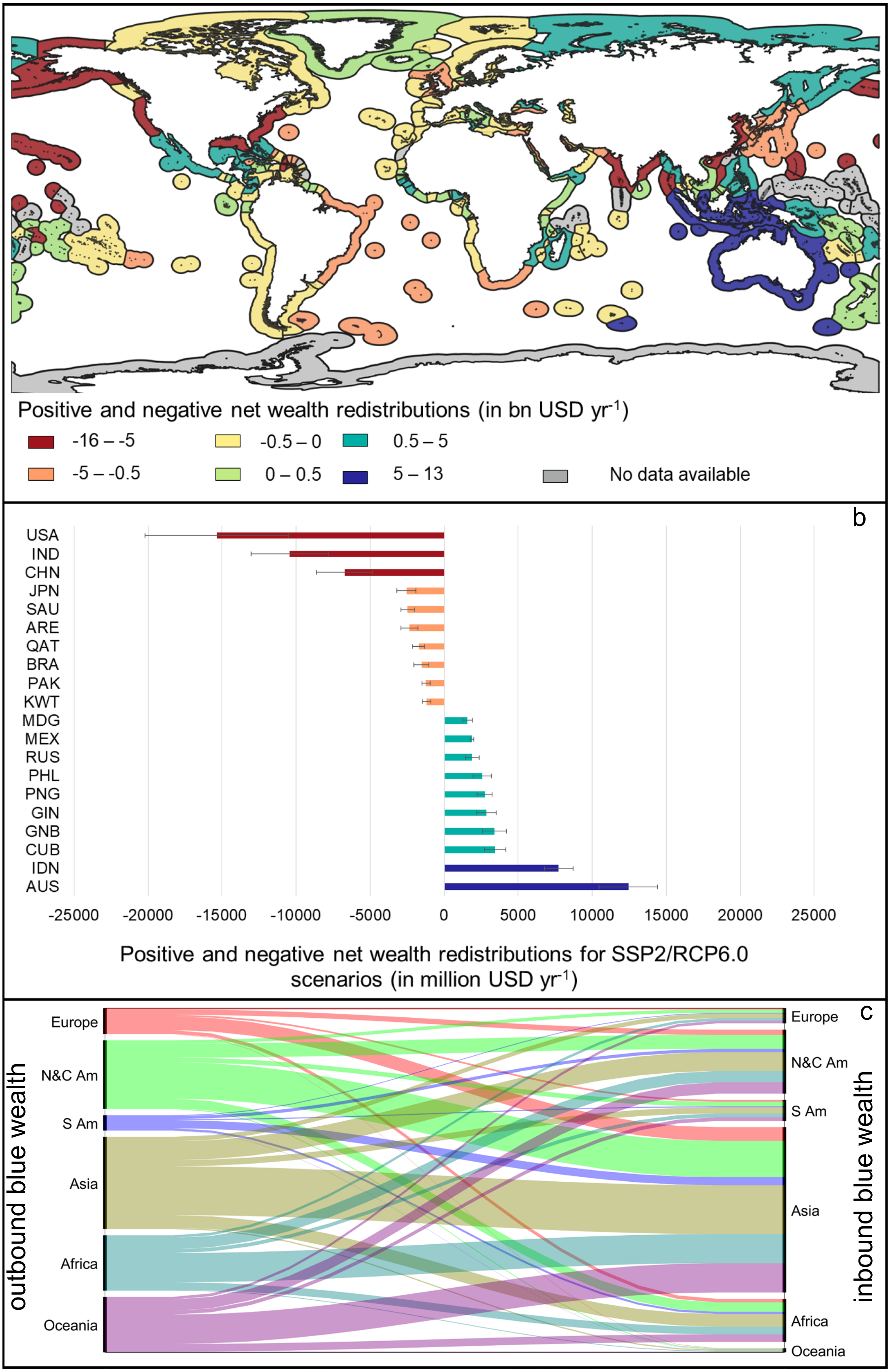


Extended Data Fig. 1 | Relative annual carbon sequestration potential per country in relation to CSCC in double-logarithmic plot. Carbon sequestration potential calculated based on mean global sequestration rates. Carbon emissions relate to CO_2-equivalents emitted from use of fossil fuels in the year 2019. CSCC are averaged over all scenarios presented in Ricke et al.[25,26]. Bubble size reflects absolute carbon sequestration potential in coastal ecosystems (Australia ~10.6MtC yr^{-1}). AUS: Australia, BLZ: Belize, BRA: Brazil, CHN: China, COM: Comoros, FIN: Finland, GIN: Guinea, GNB: Guinea-Bissau, IND: India, IDN: Indonesia, JPN: Japan, MDG: Madagascar, MEX: Mexico, NGA: Nigeria, PAK: Pakistan, PNG: Papua New Guinea, RUS: Russian Federation, WSM: Samoa, SAU: Saudi Arabia, SLE: Sierra Leone, SLB: Solomon Islands, ARE: United Arab Emirates, USA: United States of America, VUT: Vanuatu.



Extended Data Fig. 2 | See next page for caption.

Extended Data Fig. 2 | Net blue carbon wealth redistribution for SSP2/RCP60. Global map with positive and negative net blue carbon wealth redistributions (surpluses and deficits). **b**, Bar chart with ten largest donor and recipient countries. Wealth redistributions are calculated using CSCC averaged over all damage functions for the scenario combinations SSP2/RCP6.0 with one growth-adjusted discount rate (pure rate of time preference per year, $\rho = 2\%$; elasticity of marginal utility substitution, $\mu = 1.5$). Error bars represent uncertainties in global sequestration rates and estimated CSCC reflected by standard errors. USA: The United States of America, IDN: Indonesia, CHN: China, JPN: Japan, SAU: Saudi Arabia, ARE: United Arab Emirates, QAT: Qatar, BRA: Brazil, PAK: Pakistan, KWT: Kuwait, MDG: Madagascar, MEX: Mexico, RUS: Russian Federation, PHL: Philippines, PNG: Papua New Guinea, GIN: Guinea, GNB: Guinea-Bissau, CUB: Cuba, IDN: Indonesia, AUS: Australia. **c**, Blue carbon wealth redistributions on the continent-level. N&C Am: North and Central America, S Am: South America, Oceania: Australia and Oceania.