

Fair Effort Sharing in the Global Biodiversity Framework: An Approach for Assessing Fair and Proportional Contributions

Author: Liam O'Connor

Supervisors: Thomas White & E.J. Milner-Gulland

Acknowledgements:

Thank you to Nell, Liam, Emilie, George, Luca, Tai, and the entire BCNR cohort for your love and laughs.

Thank you to my incredible supervisors and the NATURE Impacts team, and especially Éilish for your tireless support and encouragement.

This research was supported and funded by the Oxford School of Geography and the Environment, as well as the Oxford Interdisciplinary Centre for Conservation Science and WWF-UK through the NATURE Impacts initiative.

Abstract

The Kunming-Montreal Global Biodiversity Framework (KMGBF) asks Parties to contribute to addressing global biodiversity loss in accordance with national circumstances, priorities, and capabilities, but offers no method for judging what a fair and proportional contribution would be. At present, country contributions to implementing the KMGBF are voluntary commitments, meaning that contributions are unlikely to align either with the total effort required to fulfill the framework, or with fair allocation principles. Here, we present an approach and accompanying tool that make the fairness choices behind contributions explicit by varying the weight given to each principle, for three targets: biodiversity finance (Target 19), protected areas (Target 3), and sustainable consumption (Target 16). We apply fairness principles including economic capacity, impact on biodiversity, and development need, drawn from effort-sharing literature and a survey of international conservation researchers. The proportion of total effort a country is asked to bear depends heavily on the principles considered: moving between single principles relocates 47–49% of the total. Counting only the impacts a country drives overseas is almost as consequential, reallocating 36% and raising the share attributed to high-income countries from 21% to 44%. For Target 3, more than half of the cost of protected area expansion is allocated to countries that would not host the new protection. Rather than prescribing a single fair allocation, this approach makes explicit the trade-offs among fairness principles, offering a basis for Parties to situate their own priorities and consider how they might contribute most effectively and fairly to global biodiversity recovery.

1. Introduction

The Kunming-Montreal Global Biodiversity Framework (KMGBF) commits Parties to the Convention on Biological Diversity (CBD) to halt and reverse biodiversity loss by 2030 (CBD, 2022). If its targets are to be met, countries will need to substantially change how they finance conservation, protect and restore ecosystems, and address underlying systemic drivers of loss through a ‘whole of society’ approach, e.g., reducing the impacts of their consumption (IPBES, 2019; WWF, 2024). These changes carry direct, indirect, and opportunity costs which fall

unevenly across countries (Deutz et al., 2020; Booth et al., 2024; Zurell et al., 2025). The KMGBF states that to meet its targets, countries “would contribute to attaining the goals and targets of the Framework in accordance with national circumstances, priorities and capabilities” (CBD, 2022), but beyond this statement, no method is established for determining what a fair and proportional contribution should be for a given country (Tomoi et al., 2022; Lehmann et al., 2025). This raises a question which is central to the implementation of the KMGBF: how should effort required to meet global biodiversity targets be shared among countries?

Currently, significant costs fall upon countries without the capacity to bear them. Considering just one target of the KMGBF, Target 3, Waldron et al. (2020) estimate that most of the cost of implementing the 30% protected area (PA) goal falls on low- and middle-income countries, stretching far beyond their domestic public spending budgets. A similar disparity arises under Target 16, which calls for reducing the footprint of consumption. Demand in wealthy countries drives habitat loss in the biodiverse countries that supply them (Lenzen et al., 2012), and if responsibility is assigned where the loss occurs rather than where the demand originates, the cost falls on poorer, more biodiverse nations (Sun et al., 2022). Meeting the goals of the KMGBF therefore depends on distributing these costs fairly. Who causes loss and who can afford to act are two of several grounds on which the costs of addressing biodiversity loss could be divided.

Effort sharing in climate and biodiversity governance

Effort here refers to the work towards meeting an international target, expressed as a quantity that can be divided between countries such as money, land area, or material use. The question of how to divide effort towards global environmental commitments has been examined extensively in climate change policy since 1992, when the United Nations Framework Convention on Climate Change (UNFCCC) included the principle of Common but Differentiated Responsibilities and Respective Capabilities in Article 3 (UNFCCC, 1992). This principle has since been operationalized by literature which asks how global climate mitigation goals should be divided among countries with varying emissions histories and different capacities to act, drawing on the fairness principles of *responsibility*, *capability*, *equality*, and *need* (Ringius et al., 2002; Baer et al., 2009; Höhne et al., 2014). Studies comparing multiple approaches and models

in climate research have demonstrated that different fairness principles generate substantially different national allocations of responsibility for climate mitigation (van den Berg et al., 2020). However, it is difficult to apply these same frameworks directly in the context of biodiversity governance. Biodiversity loss cannot be represented by a single global stock pollutant such as cumulative carbon emissions, given that the drivers and consequences of biodiversity loss are location-specific and vary sharply in their intensity between different biodiversity components (Purvis, 2025).

Despite this barrier, recent work has assessed the need and possibility for a fair effort sharing framework within the biodiversity treaty regime. Methods for dividing global environmental limits are numerous, with Bai et al. (2024) identifying eleven sharing approaches, including *legacy, responsibility, sovereignty, capability, equality, and development rights*. Within biodiversity, the literature converges on a common set of principles that are relevant for conservation: contribution to the problem, capacity to act, and the benefit received from conservation. Armstrong (2019) argues that cost-sharing must consider more than one of these principles, and Lehmann et al. (2025) extend all three to specific KMGBF targets to derive normative guidance on where the costs of implementation should fall. Booth et al. (2024) establish methods for operationalizing these principles, framing the avoidance of biodiversity impacts as a claims problem for which rules of fair division could be used to assign proportional contributions towards KMGBF goals. However, existing work has not yet produced an operational approach for determining proportional country shares, in part because data gaps prevent precise distributive recommendations (Lehmann et al., 2025). While these limitations mean that there may be limited scope for producing precise quantitative estimates of fair country-level contributions, it is still possible to explore the consequences of different approaches to effort allocation.

Quantifying fair shares of biodiversity effort

Here we develop and apply an approach to quantifying what different fairness principles imply for the allocation of effort between countries. We distribute three separate pools of effort, each representing the total sum of effort needed to meet three KMGBF targets: biodiversity finance (Target 19), ecosystem protection (Target 3), and sustainable

consumption (Target 16). An allocation depends on two choices: the mechanism or “rule” used to divide a pool, and the weight given to each fairness principle within the mechanism. Here, we hold the rule fixed as weighted proportionality and vary the weights, so differences between the resulting allocations are attributable to which fairness principles are invoked.

Because the choice of weighting is inherently subjective, we complemented the exploration of the effect of using each principle alone and in set combinations through an exploratory elicitation exercise with international conservation researchers and practitioners. By asking this expert group to weight different fairness principles, we were able to derive an expert-weighted effort allocation scenario and explore the judgements underpinning their weightings.

Fairness choices are already made implicitly in the process of determining national contributions, as well as during CBD deliberations. By developing this framework, we hope to provide a tool that makes these decisions explicit, and to show how different fairness assumptions translate into country-level responsibilities under the KMGBF.

We address three questions regarding how biodiversity conservation and recovery effort should be shared between Parties to the KMGBF:

1. How much does the choice of fairness principle (capacity, impact on biodiversity, population, development need) change what each country is asked to contribute across the three targets of finance, protected areas, and consumption?
2. How much do choices around measuring impact change allocations (for example, in relation to domestic vs overseas impacts, and cumulative vs current impacts)?
3. For Target 3, how much of the allocated effort would need to flow across borders for countries to meet their 30 by 30 goal, and what does that imply for implementation of the target?

Box 1. Glossary for fair-sharing terms used to describe our methodology.

Term	Definition
Effort	The work of meeting a KMGBF target, expressed as a quantity that can be divided between countries: money, area, or material use.
Effort pool	The total quantity of effort to be divided under one target. For example, USD 200 billion per year for Target 19.
Theme	One of the three KMGBF targets to which we apply the approach: biodiversity finance, ecosystem protection, and sustainable consumption.
Basis (plural bases)	A measurable indicator used to calculate a country's share of the pool, such as economic capacity, population, or impact on biodiversity. We use 'bases' as the plural throughout.
Weight	The extent to which a basis counts when calculating a share. Weights sum to one within any single scenario.
Allocation rule	The mechanism by which a pool is divided between countries once the bases and their weights are set.
Weighted proportionality	Each country's share is a weighted average of its proportional shares under each basis, so a country holding 10% of global GDP receives 10% of the weight placed on capacity.
Claims problem	A term from economics for the division of a fixed quantity between agents whose claims to it compete.
Scenario	One combination of bases and weights applied to a pool.

2. Methods

2.1 Conceptual Framework

Meeting the goals of the KMGBF requires far more effort than countries have collectively committed to (WWF, 2024; Bell-James & Watson, 2025, Milner-Gulland et al., 2026). We framed the division of that effort between countries as a claims problem, in which a quantity, in this case effort towards targets, is divided between agents according to competing claims (O'Neill, 1982; Ju et al., 2007; Herrero et al., 2010). Booth et al. (2024) apply this framing to biodiversity-impact avoidance, and we extended it to the allocation of effort across KMGBF targets, where each country's share can be justified on different grounds, such as its economic capacity, population, or impact on biodiversity.

Within this framing we distinguished between three components: (i) the **effort pool** to be distributed between countries; (ii) the **basis of the claim**, or the measurable indicator used to

justify a country's share (e.g. economic capacity, cumulative impact, etc.); and (iii) the **allocation rule**, or the mechanism by which effort is divided. Most contention around “fairness” is disagreement about one of these components, and separating them clarifies what stage of the process is disputed. We then developed an approach which allows users to adjust the weights or “dials” on different factors, and we analyzed the impact these adjustments have on a range of potential allocations of effort.

Our analysis fixed the allocation rule as **weighted proportionality** (Young, 1994; Booth et al., 2024), where each country's share reflects a weighted average of its proportional shares under the selected bases. We varied the bases considered and their weights, drawing on the methodology established in climate effort-sharing literature (Holz et al., 2018; van den Berg et al., 2020; Jagu Schippers & Lowing, 2026). Different weighting combinations were referred to as **scenarios**, and we attributed the differences between them to competing fairness assumptions. We applied this methodology to three themes based on three KMGBF targets: biodiversity finance (Target 19), ecosystem protection (Target 3), and sustainable consumption (Target 16). This quantitative analysis was complemented by an exploratory expert consultation.

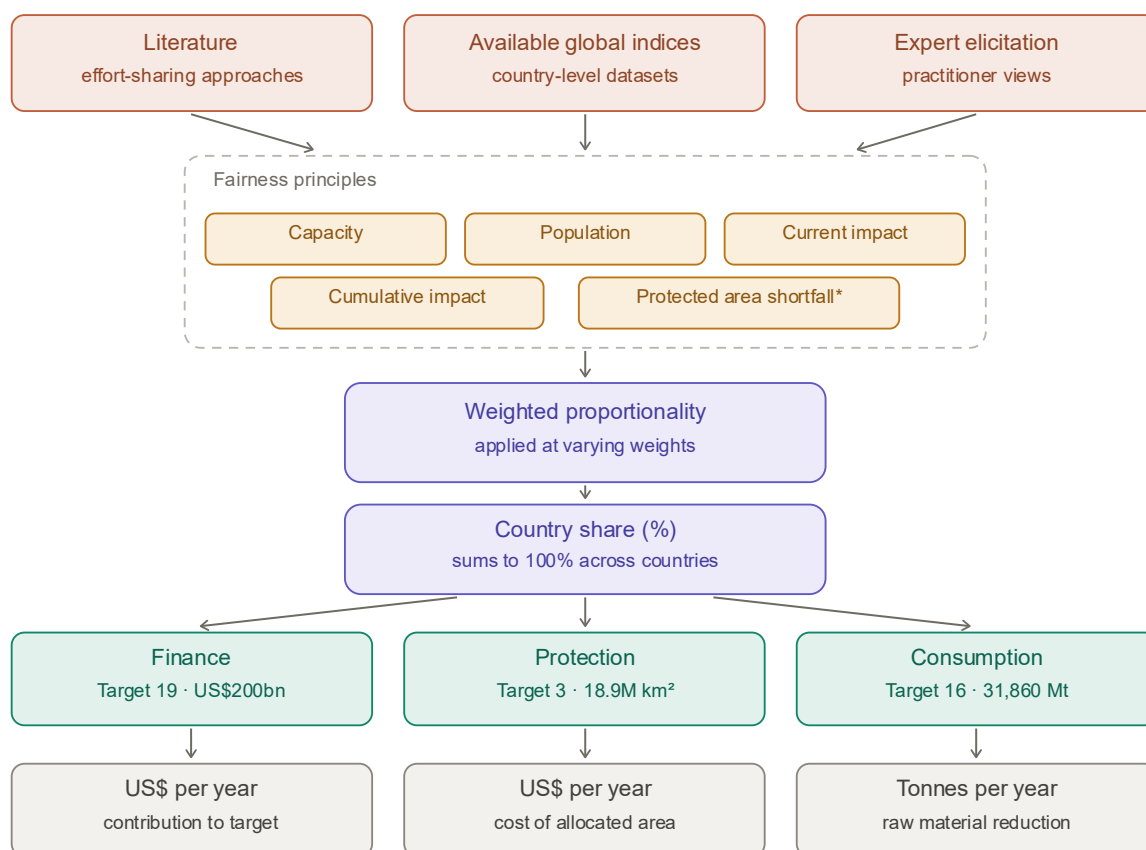


Figure 1: Conceptual framework for allocating effort towards Global Biodiversity Framework targets. Fairness bases are drawn from effort-sharing literature and available indices with global coverage, and further informed by an expert elicitation. Selected principles are assigned weightings across various scenarios, determining country shares (%) of a global effort distribution. That share is applied to the effort pool we determine for three KMGBF targets to determine country contributions given different weighting scenarios. *Distance from 30% protected area coverage applies only to the protected area target.

2.2 Rule for Allocating Effort: Weighted Proportionality

Each country's share of the global effort pool was calculated as a weighted average of its share of each indicator used to judge a fair allocation, such as GDP or current impact on species. For example, if a country holds 10% of global GDP and is responsible for 4% of global current biodiversity impact, then under an equal weighting of capacity and current impact its share is 7% for that scenario. This methodology is derived from the weighted indicator approach used in climate effort-sharing tools such as the Responsibility-Capability Index of the Greenhouse

Development Rights framework, which allocates a global total in proportion to a weighted index of fairness indicators with adjustable weights (Baer et al., 2019; Holz et al., 2018).

The equation used to derive our shares is expressed, for the example above, as follows:

Simplified: country's allocation = effort pool $\times$ [(weight on capacity $\times$ country's share of global GDP) + (weight on impact $\times$ country's share of global impact) + ...]

Formal: Let $N = \{1, \dots, n\}$ be the set of countries and let E represent the total effort pool to be divided for a given KMGBF target theme. For each basis k in the set of admissible bases K , let $x_i^k \geq 0$ be country i 's value for basis k where i and j both index countries in N . Given a weight vector $w = (w_k)_{\{k \in K\}}$ with $w_k \geq 0$ and $\sum_{\{k \in K\}} w_k = 1$, the effort allocated to country i is

$$a_i = E \cdot \sum_k w_k \left(x_i^k / \sum_j x_j^k \right)$$

where $x_i^k / \sum_j x_j^k$ is country i 's normalized share on the basis k . All allocated shares sum up to the total effort pool so that nothing is left unallocated.

We used proportionality as our underpinning rule because it is well suited to dividing a single uniform pool, is straightforward to check and reproduce, and already underpins the language of “proportional contributions” in KMGBF discourse (Booth et al., 2024).

2.3 Effort Themes Based on KMGBF Targets

We conducted our scenario analysis across three KMGBF themes. Each theme relates to a specific KMGBF target and is defined by a distinct effort pool to be allocated. We treated these totals as illustrative and focused on the distribution mechanisms produced, rather than absolute figures.

Biodiversity Finance (Target 19)

The effort pool for this theme is the headline resource-mobilization figure in KMGBF Target 19, which calls for at least USD 200 billion per year by 2030 from all sources (CBD, 2022). Shares of this pool were expressed in proportions and USD amounts. Target 19 is a good theme to illustrate our approach because it is distribution-sensitive; the target sets a yearly global sum which all Parties should contribute to, but does not specify how this should be divided to achieve the target.

Ecosystem Protection (Target 3)

For this theme, we distributed the total additional terrestrial area required for the world to reach a key element of Target 3, a 30% coverage of terrestrial protected areas, computed as a sum of each country's current terrestrial PA coverage shortfall compared to the 30% goal. This totaled 18,924,821 km², based on national PA coverage data from Protected Planet (UNEP-WCMC & IUCN, 2026). This total does not include an assessment of management effectiveness, which Target 3 also requires, and excludes area-based conservation that is not formally designated as a protected area.

A country's share of this pool represents its allocated responsibility for supporting global progress towards 30% coverage, either within its own borders or beyond them. Because shares were determined by varying fairness factors depending on the scenario, a country's allocated responsibility can exceed its own national shortfall to its 30% target. For example, a country with high economic capacity that is close to meeting its national target may still be allocated a large share of global effort. Shares were reported in US dollars to be easily understood, using estimated management cost of PAs per km² from Yang et al. (2026) to convert the area gap into required funding (**Appendix S1**). The estimated total costs we divide are USD 27.97 billion per year.

We restricted this theme to terrestrial coverage (**Appendix S1**) and chose Target 3 both because it is a high-profile and important target, and because it is distribution-sensitive: both the land that requires protection, and the capacity to pay for protecting it, are unevenly distributed (Waldron et

al., 2020), so meeting the target globally requires effort to be shared across borders rather than being delivered domestically by each country.

Sustainable Consumption (Target 16)

For the sustainable consumption theme we defined the pool as 30% of the total global raw material consumption: 31,860 million tonnes (UNEP, 2024). KMGBF Target 16 calls on Parties to reduce the footprint of consumption, but this reduction goal is not quantified. We therefore defined our pool as an illustrative target to explore distribution mechanisms, which can then be adjusted if global goals are quantified. Target 16 is distribution-sensitive because consumption in one country can drive biodiversity loss in another, separating where impact occurs from the demand that drives it (Sun et al., 2022).

Table 1. *The three effort themes, their associated KMGBF targets, and their effort pools*

Theme	KMGBF target	Target language (abridged; CBD, 2022)	Effort pool	Value	Pool source
Biodiversity finance	Target 19	“Substantially and progressively increase the level of financial resources from all sources ... mobilizing at least \$200 billion per year by 2030”	Annual resource mobilization, all sources	USD 200 bn yr ⁻¹	CBD (2022)
Ecosystem protection	Target 3	“Ensure and enable that by 2030 at least 30 per cent of terrestrial and inland water areas ... are effectively conserved and managed”	Additional terrestrial area to reach 30% global coverage	18,924,821 km ² (USD 27.97 bn yr ⁻¹ to manage)	Protected Planet (UNEP-WCMC & IUCN, 2026); management costs from Yang et al. (2026)
Sustainable consumption	Target 16	“... by 2030, reduce the global footprint of consumption in an equitable manner ...”	Illustrative reduction in global raw-material consumption	31,860 Mt yr ⁻¹ (30% of 106,200 Mt)	SCP-HAT (UNEP, 2024)

2.4 Expert Elicitation

To inform our approach, we conducted an expert elicitation to provide additional input into the design, and assess which factors academics and policy experts specializing in nature conservation considered fair when allocating global biodiversity effort.

A survey was conducted during two workshops at the World Biodiversity Forum in June 2026. Participants were asked to select which factors should carry the greatest weight when distributing effort towards the KMGBF targets, from a list corresponding to the potential factors included in our approach. Respondents were predominantly researchers and academics engaged with biodiversity loss, and they spanned a range of career stages and nationalities (**Appendix S2**). The responses in these workshops informed the choice of the fairness bases we included in our approach (**Section 2.5**), and weightings for a survey-informed scenario we applied to each of the three effort themes (**Section 2.6**). Although the sample was small, deliberations around country contributions often involve a similar subset of experts and decision-makers, and their input was valuable given the spaces we hope to engage with our fair-sharing approach.

Ethics: This research received ethical approval from the University of Oxford’s Central University Research Ethics Committee (CUREC reference 3413441).

2.5 Fairness Bases and Indicators

The country attributes that determined each share were drawn from the input from our expert elicitation, available indices with global coverage, and an established set of sharing approaches and fairness principles. The sharing approaches catalogued by Bai et al. (2024) are distinguished by their temporal orientation: responsibility looks to accumulated impact, capability and equality to present-day ability and status, and development rights to a forward-looking entitlement. These approaches correspond to the fairness principles established in the climate effort-sharing and distributive-justice literatures: *responsibility* or the *polluter-pays* principle, *capacity* or *ability-to-pay*, *equality*, and *need* (Ringius et al., 2002; Armstrong, 2019; Lehmann et al., 2025).

We drew the bases we used in our approach from this set. Capacity, population, cumulative impact and current impact were applied across all three themes, drawing on various global indices (**Table 2**). Country coverage varies slightly across bases, and a proxy procedure was used for countries absent from the impact datasets (**Appendix S3**). Development need was also considered in each of the three themes but was implemented as a discount rather than a direct weighting basis (**Section 2.6**). The protected area theme contains an additional base as well: each country's distance from its own 30% coverage target. Allocating on this basis follows from the sovereignty principle (Bai et al., 2024), or a country's responsibility for biodiversity within its jurisdiction, as outlined in the Convention on Biological Diversity's Article 3 (CBD, 2022).

Table 2. *Fairness bases, their indicators, their corresponding fairness principle drawn from literature, and what each indicator attempts to measure. The source for the indicator is included in the right-most column.*

Fairness basis	Indicator	Fairness principle	What the indicator measures	Data source
Capacity	GDP (current US\$)	Capability / ability to pay	National economic output.	World Bank
Population	Total population	Equality (equal per capita)	National population size.	World Bank
Current impact	LIFE (2023)	Responsibility (present)	Expected terrestrial vertebrate extinctions caused by land-cover change, attributed through supply chains.	SEI/JNCC (2025) Commodity Footprints Dashboard
Cumulative impact	SCP-HAT, summed 1990–2023	Responsibility (historical)	Potential species loss from land use, accumulated over the period.	UNEP (2024)
Protection shortfall	Distance from national 30% goal	Sovereignty	Additional terrestrial area needed to reach 30% coverage of a country's own land.	Protected Planet (UNEP-WCMC & IUCN, 2026)
Development need	HDI	Need / development rights	Composite index of life expectancy, education and income.	UNDP (2024)

Current and cumulative biodiversity impact capture two temporal dimensions of responsibility. To measure current impact, we used the LIFE metric, which quantifies the marginal change in the expected number of terrestrial vertebrate extinctions caused by land-cover change (Croft et

al., 2025; Eyres et al., 2025; SEI/JNCC, 2025). For current impact, we used the variant which attributes this impact to countries' consumption through their international supply chains in 2023. For cumulative impact, we used SCP-HAT (UNEP, 2024), which measures potential species loss from land-use derived from widely used characterization factors and summed over its 1990–2023 reporting period. Both metrics capture land-use driven biodiversity loss, and neither account for overexploitation or invasive alien species, which remain largely absent from multi-regional input–output and life cycle assessment approaches such as these (Marques et al., 2017)

For both responsibility metrics, we included a version of the indicators which exclude domestic flows to test how share allocations respond when only the impact of international consumption is considered. This follows consumption-based accounting approaches that reattribute environmental responsibility from producing countries to the final consumers whose demand drives the resulting impact (Sun et al., 2022), and allows us to test how allocation scenarios respond when only impact driven by consumption overseas is considered.

Both current impact (LIFE) and cumulative impact (SCP-HAT) are used as proxies for responsibility and are strongly correlated across countries according to our calculations (Pearson $r \approx 0.89$ and $R^2 \approx 0.80$ on a log–log scale; Spearman $\rho \approx 0.80$). However, we retain both metrics because they contribute distinct signals of the responsibility basis (current vs. cumulative impact).

2.6 The Development Floor

While GDP is used to represent capacity within our models, some may argue that this does not fully reflect the varying development need between countries and its impact on their ability to pay/act. To express this, we apply an option to discount the capacity indicator that scales down the contribution expected for a given country depending on their level of development, using the Human Development Index (HDI) as a proxy. This mechanism follows the Greenhouse Development Rights (GDR) framework, which exempts countries with incomes below a development threshold from their allocation model on the principle that countries whose priority is their own development should not be expected to fund a global public good (Baer et al., 2009; Holz et al., 2018). Our choice to use HDI rather than per-capita income as the development

measure follows Sun et al. (2022), who adopt HDI as the weighting parameter in an environmentally just accounting of global biodiversity loss. The threshold is set at 0.70, the UNDP marker for high human development (UNDP, 2024). Effort discounted from countries below this threshold is redistributed across those above it (see **Appendix S4** for details, alongside our analysis of the effect of the floor on share distribution).

2.7 Scenario Construction

We developed allocation scenarios using different weightings of the fairness bases (Table 3). Four bases were applied to the scenarios for every theme: capacity, population, current impact, and cumulative impact. Scenarios that were built only from these inputs produce identical proportional shares across themes, differing solely in the pool distributed. We refer to these as the core scenarios. In addition, we developed theme-specific scenarios using thematically-relevant effort units. We explore single-principle scenarios (weighted only by one fairness base), and hybrid scenarios where equal weights are given to multiple fairness bases. We also provide a survey informed scenario, where practitioner preferences in the survey are used to inform weightings (**Table 3**).

Table 3. Scenarios evaluated in our analysis and their respective weightings of fairness bases. Includes our four categories of scenario: single-principle, equal-weight hybrid scenarios, theme specific scenarios, and the survey-informed scenario. In the themes column, *F* refers to finance, *P* to protected areas, and *C* to consumption.

Scenario	Capacity	Population	Current impact	Cumulative impact	Protection shortfall	Development floor	Impact counted	Themes
Single principle: all weight on one basis, so the allocation isolates the effect of that principle. Core scenarios, run on all three themes.								
Capacity	1	–	–	–	–	–	–	F, P, C
Capacity (development considered)	1	–	–	–	–	✓	–	F, P, C
Cumulative impact	–	–	–	1	–	–	Total	F, P, C
Current impact	–	–	1	–	–	–	Total	F, P, C
Population	–	1	–	–	–	–	–	F, P, C
Equal-weight hybrid: weight divided evenly between the bases considered, following the 50/50 default of the Climate Equity Reference Calculator (Athanasίου et al., 2014). Core scenarios, run on all three themes.								
Capacity + cumulative impact	0.5	–	–	0.5	–	–	Total	F, P, C
Capacity + current impact	0.5	–	0.5	–	–	–	Total	F, P, C
Theme-specific: scenarios using bases that are applied only for specific themes in our analysis, although the tool permits any basis to be applied to any theme.								
Own PA gap only	–	–	–	–	1	–	–	P
PA gap + capacity	0.5	–	–	–	0.5	–	–	P
PA gap + capacity + cumulative	0.33	–	–	0.33	0.33	–	Total	P
PA gap + cumulative impact	–	–	–	0.5	0.5	–	Total	P
PA gap + current impact	–	–	0.5	–	0.5	–	Total	P
Capacity + cumulative impact overseas	0.5	–	–	0.5	–	–	Overseas	C
Capacity + current impact overseas	0.5	–	0.5	–	–	–	Overseas	C
Cumulative footprint (overseas)	–	–	–	1	–	–	Overseas	C
Current footprint (overseas)	–	–	1	–	–	–	Overseas	C
Survey-informed: weights derived from practitioner rankings.								
Survey-informed	.38	.02	.33	.27	–	✓	Overseas	F, P, C

Our choice to include single-principle and equal-weight hybrid scenarios is derived from the methodology used in climate fair effort allocation models such as The Climate Equity Reference Calculator (CERc), which offers default weightings ranging from 100% capacity and 100%

responsibility to 50/50 hybrid scenarios (Athanasίου et al., 2014). Our hybrid scenarios extend this framing to three factor equal-weighting by adding protected area gap to 30 by 30 as an additional factor for one of our target 3 specific scenarios, where weightings are $\frac{1}{3}$ each alongside capacity and cumulative impact.

The **survey-informed scenario** used a mix of weightings determined by the survey responses in our expert elicitation (**Section 2.4**). Responses in our two workshops to the question of which factor they consider most important in the fair allocation of biodiversity effort were combined and ranked by selection frequency across the four additive bases. These frequencies were converted into normalized weightings after excluding the unused bases: 38% capacity, 33% current impact, 27% cumulative impact, and 2% population. Development need was selected frequently, and the development floor was applied to express this. Additionally, participants in the breakout sessions of the workshops frequently raised concerns that biodiverse countries should not be disproportionately punished for consumption of their own domestic production, so the scenario only counts current and cumulative impact from overseas consumption. Survey results and demographics can be found in **Appendix S2**.

The scenarios developed for our analysis are used to illustrate the fair allocation approach, rather than specific positions this paper defends. Reporting across a range of weightings rather than a single figure follows the “equity band” approach of Holz et al. (2018), in which two agreed-upon benchmarks marked a range of settings a civil-society coalition considered “plausibly defensible as fair”.

2.8 Analysis of share allocations

We present the share allocations for different nations under the different weighting scenarios for each relevant theme. Allocations were then compared in three ways:

Divergence:

We measured the distance between each combination of pairs of scenarios as the total variation distance (TVD) between their share vectors, calculated as half of the sum of the absolute differences between each country’s share in two separate scenarios. This is interpreted as the

proportion of a pool which must be redistributed to convert one allocation to another. A TVD of 0 indicates an identical allocation while 0.5 indicates that half of the pool changes hands. For example, this would mean USD 100 billion of the 200 billion in the finance pool being reassigned between countries.

Rank Agreement

We also report Spearman rank correlation between pairs of scenarios. This indicates how much countries switch places across rankings. Because TVD can be driven primarily by movement among the biggest contributors, rank correlation shows whether the order of countries changes, or just the amounts allocated to them.

Continuums

Recognizing that the results only show one weighting in the multi-factor scenarios, we also visualize the effect of weightings of different fairness bases in multi-factor scenarios on a continuum between 0 and 1. We display these sweeps for different countries alongside one another to show how rankings change along the continuums.

2.9 Interactive Tool

All scenarios, weightings and additional settings described above were implemented in an interactive tool that enables the user to alter weightings and develop their own scenarios. This tool is available <https://natureimpacts.github.io/Fair-Effort-Sharing-in-the-Global-Biodiversity-Framework/>. (Figure 2).

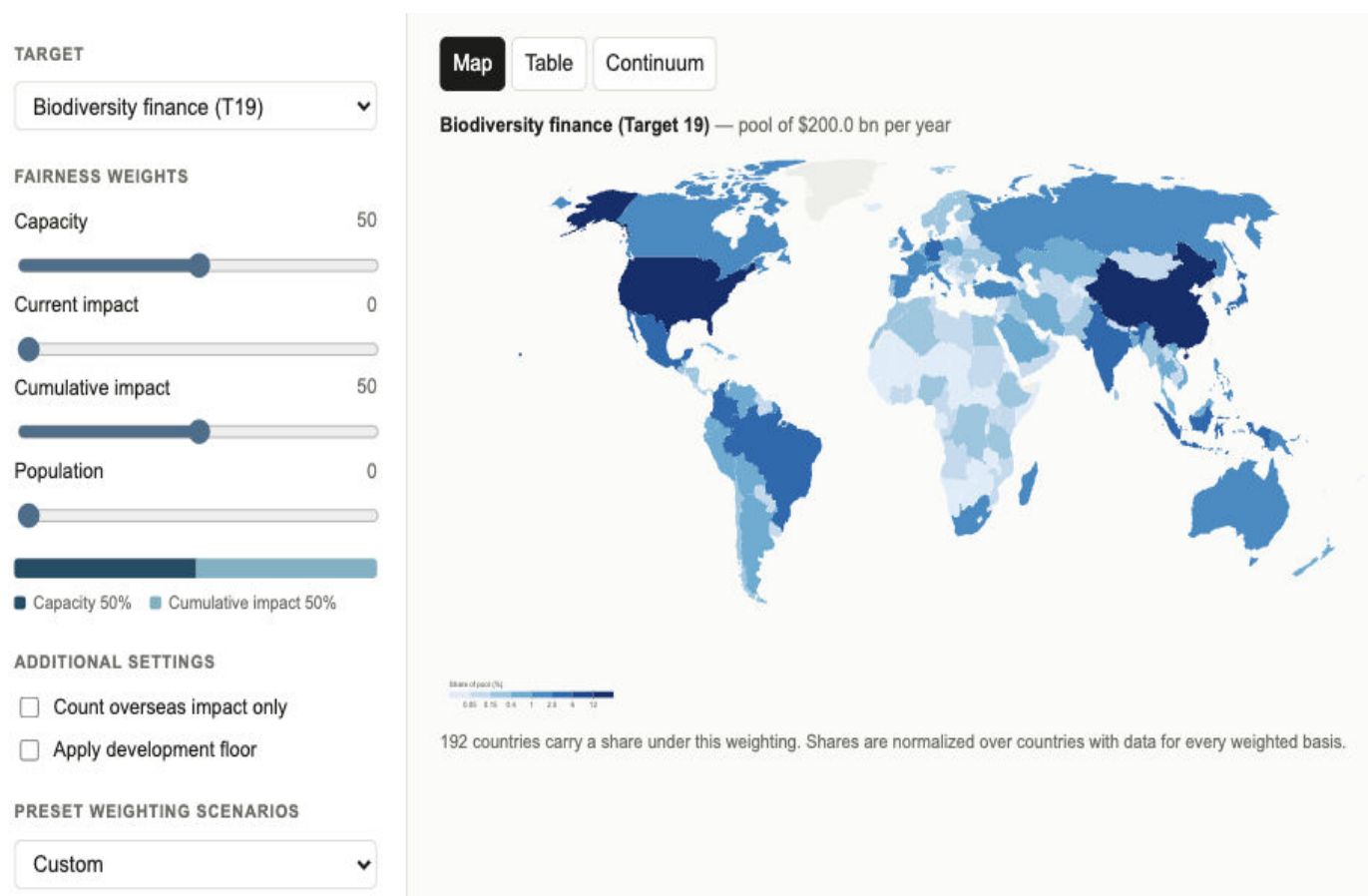


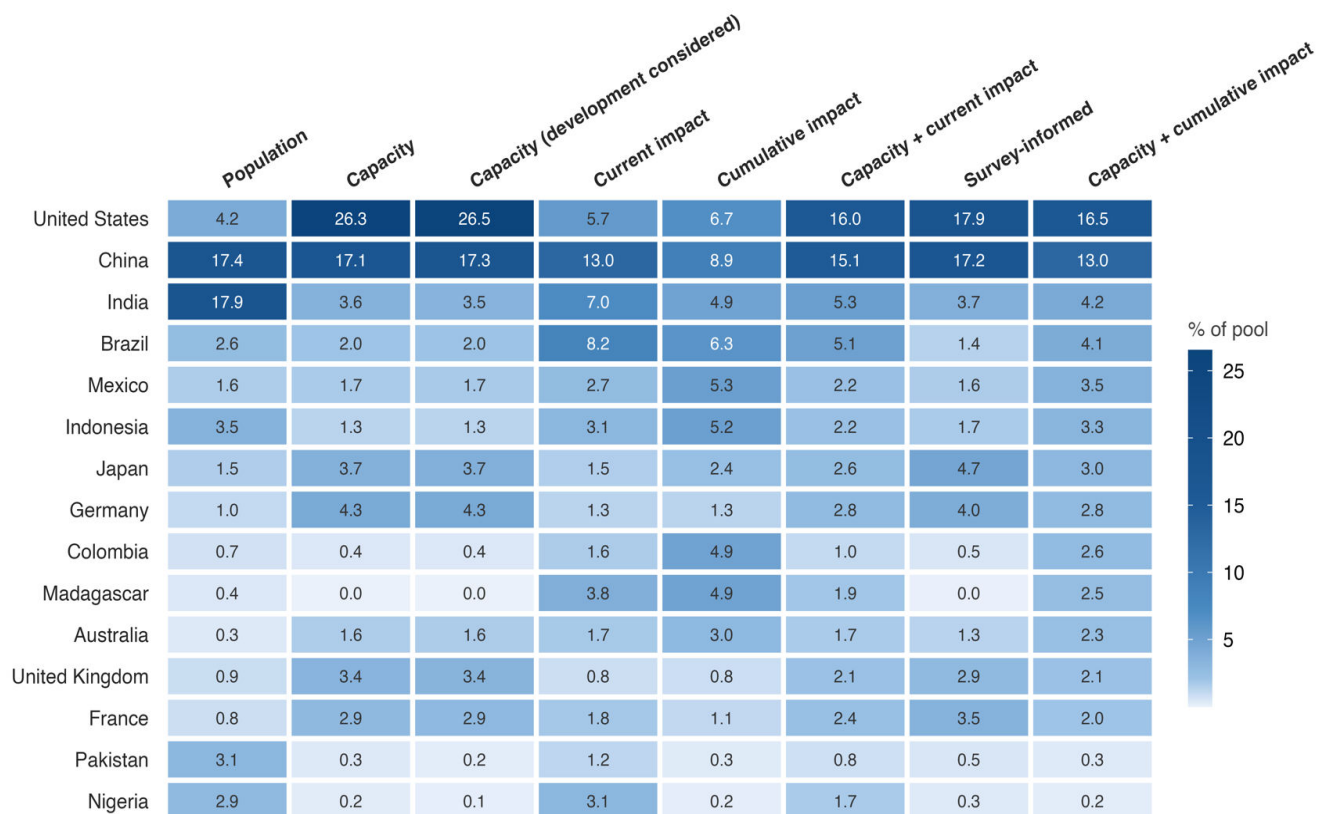
Figure 2. Interactive tool implementing the approach described above. Users select a target and their weightings across the five fairness bases, with the option to apply the overseas impact only setting and the development floor. Results are shown as an effort distribution map, a downloadable country table, and a continuum view tracking how a country's share moves as weightings shift between two bases. Users can choose between pre-set scenarios that we included in our analysis. Prototype is available at: <https://natureimpacts.github.io/Fair-Effort-Sharing-in-the-Global-Biodiversity-Framework/>

3. Results

3.1 Allocation Scenarios Analysis

The distribution of effort was highly sensitive to the principles of fairness applied in different scenarios (**Figure 3 & Table 3**). The Finance theme analyses included only the core fairness scenarios that were applied consistently across all three themes. Consequently, **Figure 3 (a)** and **Table 3 (a)** carry the full set of core allocation scenarios. For Protected Areas and Consumption, we examined additional bases, such as a country's remaining distance from 30% protected area coverage, and their biodiversity impacts associated solely with their overseas consumption, respectively (**Figure 3b & c**) (**Table 3b & c**).

a). Core allocation scenarios



b) Protected Area (Target 3) scenarios



c) Sustainable consumption (Target 16) scenarios

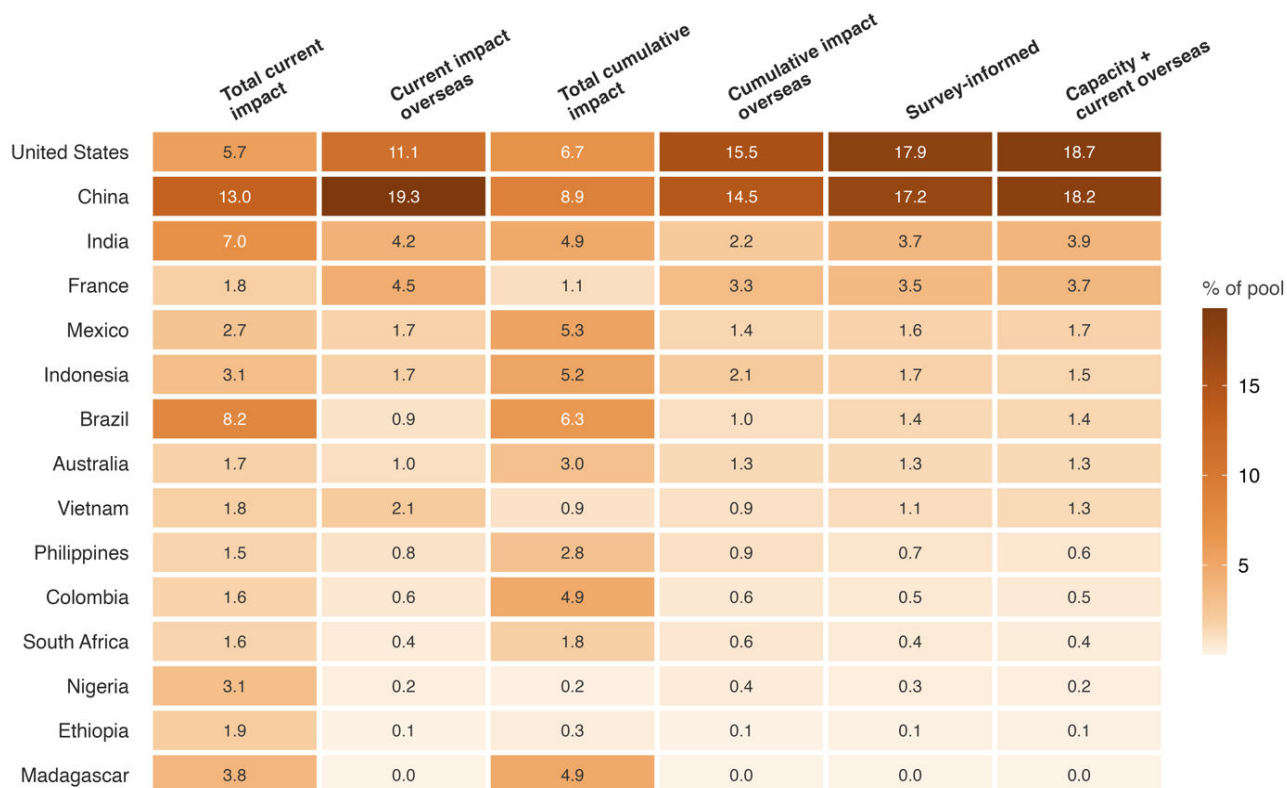


Figure 3. National shares of the global biodiversity effort pool under alternative fairness principles. Share (%) of the pool distributed across the 15 largest contributors. Darker cells denote larger national shares. Hybrid scenarios combining more than one basis assign equal weightings to each factor. **(a)** 8 core allocation scenarios applied across all three effort themes. **(b)** 6 protected area allocation scenarios for Target 3. **(c)** 6 sustainable consumption allocation scenarios for Target 16.

Table 3 . Allocated shares applied to the three effort pools corresponding to the three KMGBF target themes we analyzed. Shares and scenarios are derived from **Figure 3 (a,b & c)**, and the 10 largest contributors are presented in each table, listed in order of the left-most allocation. Darker shaded boxes represent larger shares. Hybrid scenarios combining more than one basis assign equal weightings to each factor. **(a)** Allocation of the biodiversity finance pool (USD 200 billion per year). **(b)** Allocated share of the cost of closing the global 30×30 shortfall (USD 27.97 billion/year). **(c)** Allocation of the consumption reduction effort pool 31,860 Mt/year.

a). Allocation of the biodiversity finance pool (USD 200 billion/year)

Country	Capacity	Current impact	Cumulative impact	Survey-informed	Cap + cumulative
United States	\$52.55 bn	\$11.39 bn	\$13.47 bn	\$35.88 bn	\$33.01 bn
China	\$34.26 bn	\$26.00 bn	\$17.83 bn	\$34.41 bn	\$26.05 bn
India	\$7.15 bn	\$14.01 bn	\$9.80 bn	\$7.40 bn	\$8.48 bn
Brazil	\$3.99 bn	\$16.34 bn	\$12.53 bn	\$2.76 bn	\$8.26 bn
Mexico	\$3.39 bn	\$5.37 bn	\$10.62 bn	\$3.25 bn	\$7.01 bn
Indonesia	\$2.55 bn	\$6.22 bn	\$10.45 bn	\$3.38 bn	\$6.50 bn
Japan	\$7.36 bn	\$3.02 bn	\$4.71 bn	\$9.40 bn	\$6.03 bn
Germany	\$8.56 bn	\$2.56 bn	\$2.53 bn	\$8.05 bn	\$5.55 bn
Colombia	\$0.77 bn	\$3.28 bn	\$9.76 bn	\$1.00 bn	\$5.26 bn
Madagascar	\$0.03 bn	\$7.69 bn	\$9.89 bn	\$0.07 bn	\$4.96 bn

b). Allocated share of the cost of closing the global 30 by 30 shortfall (USD 27.97 billion/year)

Country	PA gap + capacity	Gap + current impact	Gap + cumulative	Survey-informed	Gap + cap + cumulative
United States	\$4.87 bn	\$1.99 bn	\$2.14 bn	\$5.02 bn	\$3.87 bn
China	\$3.39 bn	\$2.82 bn	\$2.25 bn	\$4.81 bn	\$3.09 bn
Russian Federation	\$2.60 bn	\$2.42 bn	\$2.45 bn	\$0.47 bn	\$1.82 bn
India	\$0.99 bn	\$1.47 bn	\$1.18 bn	\$1.03 bn	\$1.12 bn
Canada	\$1.54 bn	\$1.35 bn	\$1.33 bn	\$0.50 bn	\$1.08 bn
Mexico	\$0.46 bn	\$0.60 bn	\$0.97 bn	\$0.45 bn	\$0.80 bn
Indonesia	\$0.43 bn	\$0.69 bn	\$0.98 bn	\$0.47 bn	\$0.77 bn
Brazil	\$0.28 bn	\$1.15 bn	\$0.88 bn	\$0.39 bn	\$0.77 bn
Australia	\$0.68 bn	\$0.70 bn	\$0.87 bn	\$0.37 bn	\$0.73 bn
Colombia	\$0.16 bn	\$0.34 bn	\$0.79 bn	\$0.14 bn	\$0.56 bn

c). Allocation of the consumption reduction effort pool (Mt)

Country	Cumulative impact overseas	Current impact overseas	Cap + cumulative overseas	Survey-informed	Cap + current overseas
United States	4,934 Mt	3,544 Mt	6,657 Mt	5,722 Mt	5,962 Mt
China	4,617 Mt	6,149 Mt	5,041 Mt	5,488 Mt	5,806 Mt
India	707 Mt	1,342 Mt	923 Mt	1,180 Mt	1,241 Mt
Germany	1,543 Mt	1,034 Mt	1,455 Mt	1,284 Mt	1,200 Mt
Japan	2,387 Mt	1,209 Mt	1,781 Mt	1,498 Mt	1,191 Mt
France	1,048 Mt	1,445 Mt	985 Mt	1,118 Mt	1,183 Mt
United Kingdom	1,025 Mt	682 Mt	1,050 Mt	916 Mt	878 Mt
Korea, Rep.	748 Mt	807 Mt	647 Mt	681 Mt	677 Mt
Italy	987 Mt	548 Mt	841 Mt	716 Mt	621 Mt
Spain	623 Mt	652 Mt	563 Mt	580 Mt	578 Mt

The largest contributors changed depending on the scenario (**Figure 3 & Table 3**). The United States bore the greatest share when just capacity (GDP) was considered, being allocated 26.3% of the pool (or USD 52.5 billion of the annual finance total). Alternatively, when current impact, or cumulative impact were considered, China held the highest allocation, with 13% (USD 26

billion) and 9% (USD 18 billion) respectively. Finally, when only population was taken into account, India bore the highest burden, at 17.9% (USD 35.8 billion).

The theme-specific bases also changed which countries appeared among the largest contributors. When only progress towards national 30 by 30 protected area goals was considered (Target 3), effort was concentrated on large states with low PA coverage, such as Russia (16%), Canada (9%) and Algeria (3%; **Figure 3b**). These countries did not rank within the top 10 when only capacity or either impact metric was considered. Instead, they were replaced by high-capacity, high-income countries such as the United States, China, Japan, Germany, and France, as weighting shifted towards capacity and impact.

The consumption theme (Target 16) showed a similar pattern. When considering total current footprint, responsibility was high for both high consuming nations and biodiverse producer countries: China 13%, Brazil 8.2%, India 7.0% ranked highest, followed by the United States, Madagascar, Nigeria, and Indonesia. When the scenario was switched to consumption that excluded domestic flows, highly biodiverse countries with a greater proportion of domestic consumption flows such as Madagascar dropped markedly, while large, high-import economies took their place. China (19.3%), United States (11.1%) were the largest contributors followed by France, Japan, Germany, South Korea, the United Kingdom, and Spain. Overall, six of the ten largest contributors were replaced.

Hybrid and survey-informed scenarios

The two capacity and impact hybrids, using current and cumulative impact respectively, generated similar distributions, with the United States accounting for approximately 16% of the total, and China 13–15%. Large biodiverse countries which produce a lot of agricultural commodities, such as Brazil and Indonesia, retained substantial shares across both.

Interestingly, the survey-informed hybrid produced markedly different results. By weighting the factors based on practitioner preference, including solely considering internationally driven impact, it concentrated responsibility on high-consuming economies such as the United States (17.9%) and China (17.2%), followed by Japan, Germany, France, and the United Kingdom.

Consequently, countries such as Brazil, Indonesia, and Madagascar no longer featured among the large contributors to consumption reduction efforts.

Figure 4 displays a plausible hybrid scenario for each theme alongside the survey-informed scenario, showing the full distribution of effort allocation beyond the fifteen largest contributors displayed in **Figure 3**.

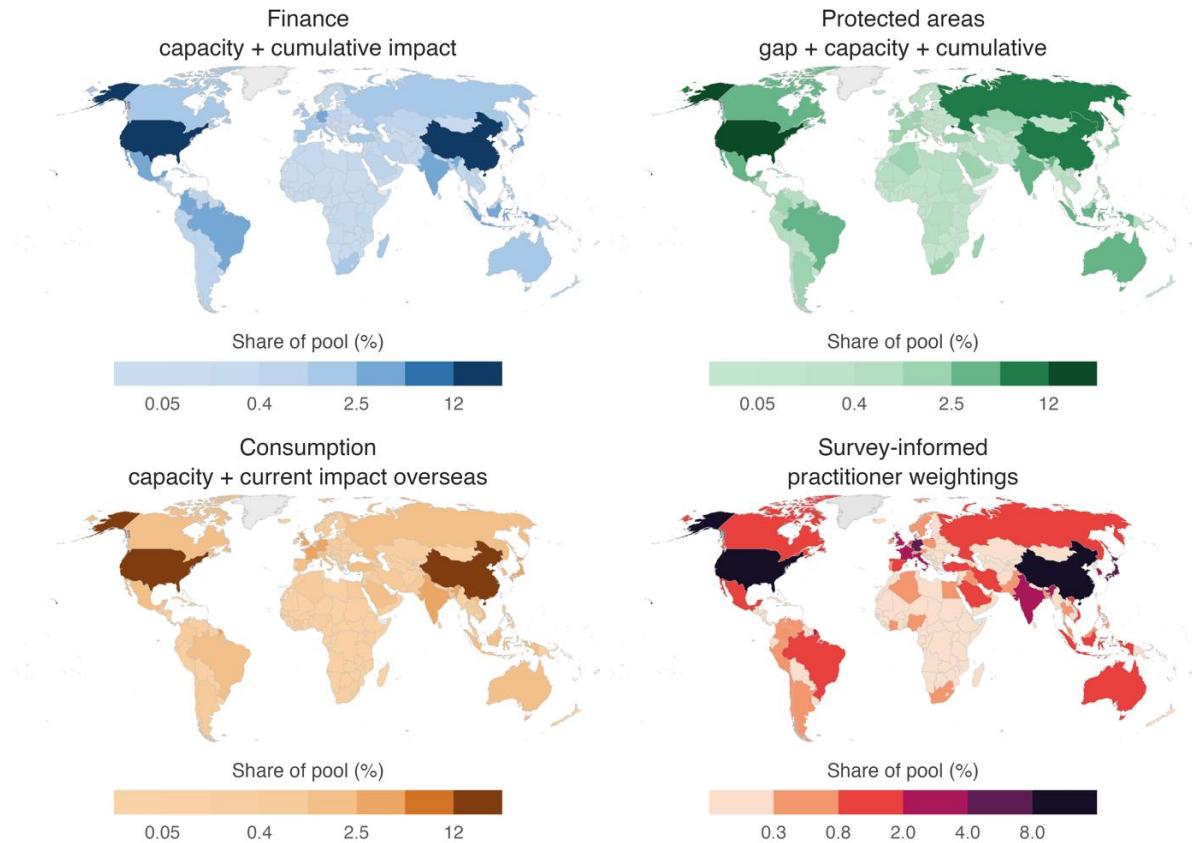


Figure 4. Map displaying the balanced allocation scenarios for each of the three KMGBF target themes, as well as the survey-informed scenario. Included is the capacity + cumulative hybrid scenario applied to finance (**Figure 3a**), the PA gap + capacity + cumulative impact scenario (**Figure 3b**), capacity + current impact overseas (**Figure 3c**), and the survey-informed scenario (**Figure 3a**).

Sensitivity of allocations to fairness principles

Sensitivity between allocation scenarios was substantial, such that moving between some of the single-principle allocations shifted almost half of the pool. Total variation distance (TVD)

between the capacity-based allocation, and those based on current impact, cumulative impact, and population hovered between 0.47 and 0.49 (**Table 4**). This indicated that almost half of all allocated effort would need to be redistributed depending on which single principle was adopted. In absolute terms these shifts are large. For example, the United States' annual obligation ranged from USD 52.5 billion when just capacity was considered, to USD 13.5 billion under the cumulative impact allocation scenario, while Brazil's increased from USD 4.0 to 12.5 billion.

Table 4: Divergence between core allocation scenarios (those in **Figure 3 (a)**). Values represent Total Variation Distance (TVD), defined as the share of the pool that would need to be redistributed among countries to convert one allocation into another (0 = identical allocations, 1 = completely different allocations). Darker boxes represent larger variations.

Scenario	Population	Capacity	Current impact	Cumulative impact	Capacity + cumulative	Capacity + current
Capacity	0.47					
Current impact	0.28	0.48				
Cumulative impact	0.45	0.49	0.28			
Capacity + cumulative impact	0.42	0.24	0.30	0.24		
Capacity + current impact	0.33	0.24	0.24	0.33	0.14	
Survey-informed	0.40	0.12	0.41	0.44	0.21	0.18

This reshuffling appeared more clearly when considering changes in the magnitude of a country's effort compared to changes in their relative rankings. Rank agreement between core scenarios remained high, with Spearman's rank correlation coefficient staying between $\rho = 0.74$ and 0.96. The lowest agreement occurred between the capacity-based allocation and the other single-principle scenarios ($\rho = 0.74$ –0.79), where differences in allocation magnitude were greatest. This suggests that countries' relative positions changed less than the amount of effort allocated to them.

Relative burden across income groups

For the finance theme, we expressed each allocation as a share of the country's own GDP. When just capacity (GDP) was considered, every country was allocated the same fraction of its GDP, 0.18%. Under the other bases this varied substantially. Low-income countries were allocated a

median 2.48% of their GDP when only current impact was considered and 2.91% under population, compared with 0.07% for high-income countries under both. Madagascar and Burundi, the most extreme cases, were allocated 44.1% and 18.9% of their GDP respectively under current impact, reflecting the very high levels of biodiversity and also of biodiversity loss in these two countries.

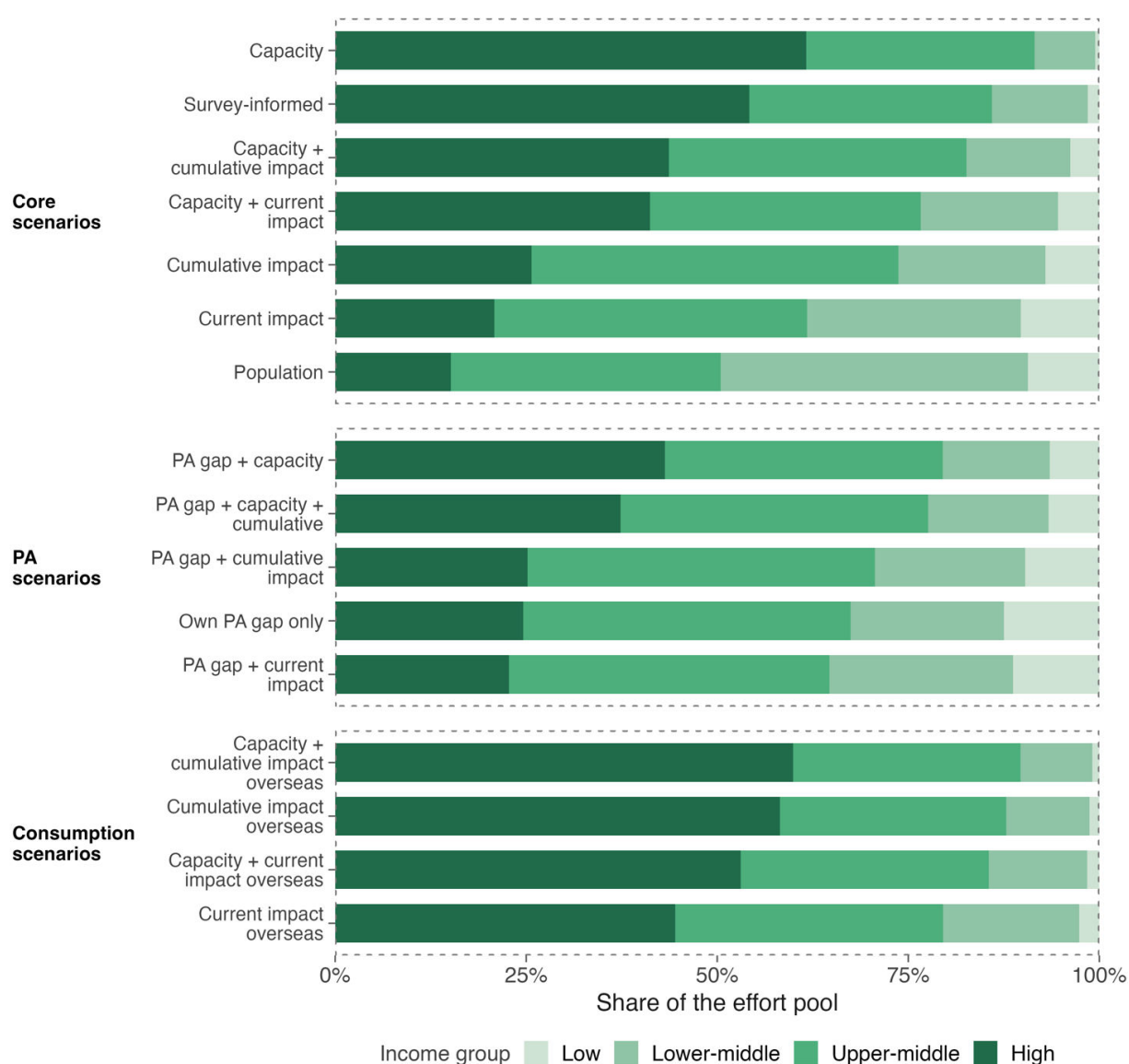


Figure 5: Distribution of allocation shares by World Bank income group under each allocation scenario. Bars show the percentage of effort pools across all three themes allocated to countries in each group, with scenarios ordered by the share borne by high-income countries. Capacity-based allocations concentrate the pool in high-income countries, while allocations weighted on current or cumulative impact shift a substantial portion towards middle- and low-income countries.

The share of effort distribution borne by each income group shifted correspondingly across core and themed scenarios (**Figure 5**). Shares for high-income countries ranged from 15% under population to 62% under capacity (**Figure 5**). Allocating by protected-area shortfall placed more burden on low-income countries than any other scenario tested, at 12.5%. Counting just cumulative impact overseas rather than including both overseas and domestic impact raised the high-income share from 26% to 58%, reflecting their large overseas footprints from international trade.

Assessing the impact of consumption metric decisions

Some high biodiversity countries retain almost all of their current consumption-related biodiversity footprint (represented by the LIFE score) domestically: only 4% of Brazil's footprint occurred overseas, 3% for Nigeria, Ethiopia 2%, and Madagascar 0% (**Figure 6**). This reflects the fact that most consumption in these countries is supplied by domestic production. In contrast, import-reliant economies showed the reverse pattern, with 97% of France's consumption impact occurring overseas, 76% for the United States and 58% for China. This is why switching between these attribution metrics relocated responsibility between these two different groups of countries, shifting 36% of the current consumption pool, and 45% for cumulative impact.

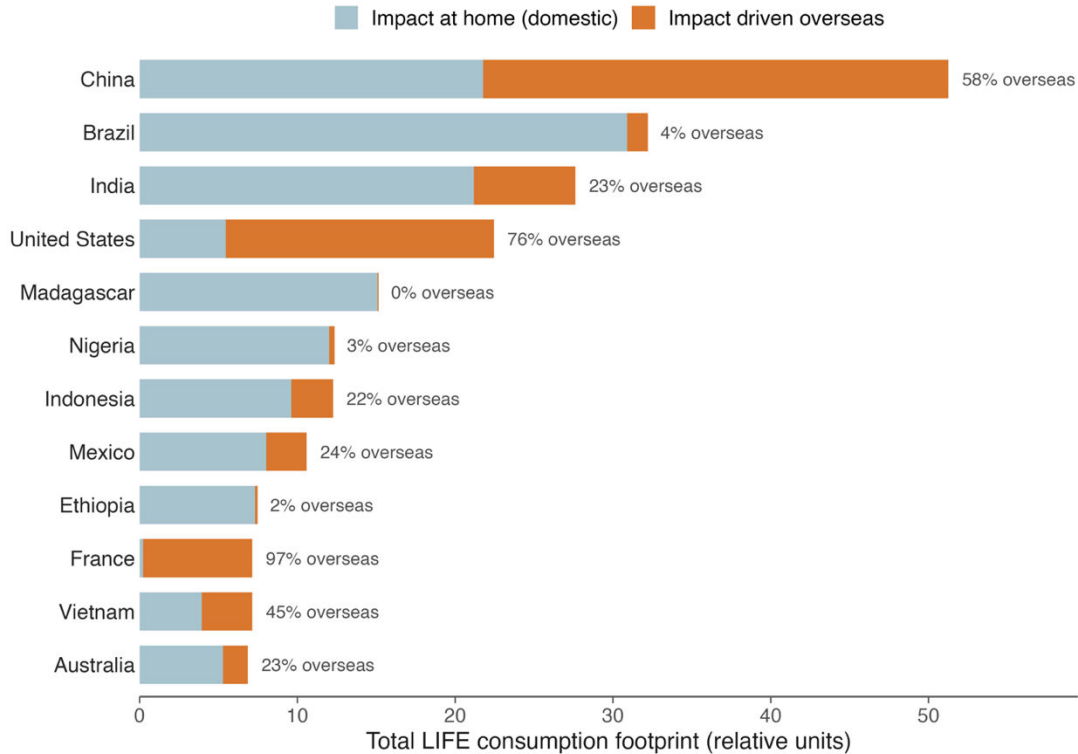


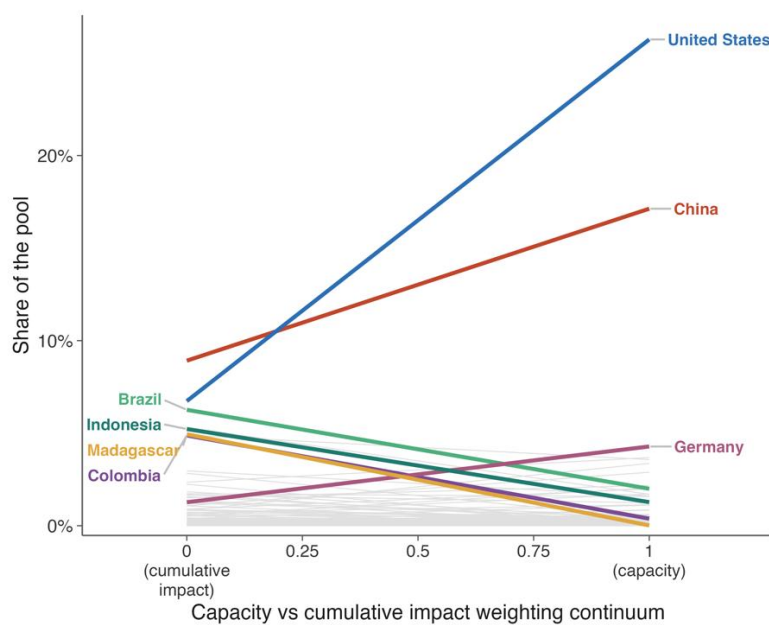
Figure 6: Domestic vs. overseas share of national consumption footprints. Each bar represents a country's total current consumption based on LIFE scores in 2023 (Croft et al., 2025; SEI/JNCC, 2025), split into the share of impact that falls within its own borders (domestic) and the impact its consumption drives abroad (overseas).

The effect of weighting cumulative versus current impact was more limited. To assess this, we varied current vs past impact while holding the metric constant. Current and cumulative impact are measured with different metrics in the primary analysis, LIFE and SCP-HAT respectively, so comparing them directly would confound the metric with the time period. Because of this, we used only SCP-HAT here. Current and cumulative allocations differed by only 9% in TVD for total impact and 17% when excluding domestic flows. Therefore, the more consequential fairness choice appears to be whether domestic flows are included or excluded. However, the temporal framing does change the balance of responsibility between fast-growing consumers and long-industrialized economies. Counting only impact driven overseas, China's share decreases substantially from 23.5% to 14.5% when switching from current to cumulative impact, allowing the United States to overtake China as the largest contributor (15.5% vs. 14.5%). India's share roughly halves from 4.4% to 2.2%, whereas Japan's increases from 4.3% to 7.5%.

3.2 Weighting continuums

Rankings changed at identifiable points along the continuum, while the slope of each country's allocation trajectory indicates sensitivity to different fairness choices (**Figure 7**).

a). Continuum between capacity and cumulative impact for largest contributors



b). Continuum between capacity and cumulative impact for low- and middle-income countries

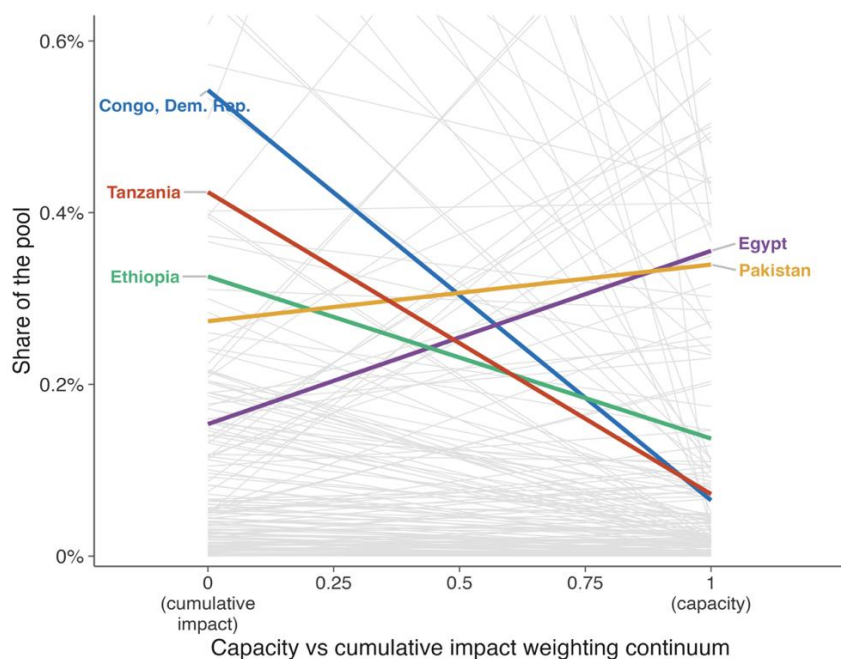


Figure 7: National shares of the effort pool along a weighting continuum from cumulative impact to capacity, where 1 on the x-axis represents a weighting of 1 for Capacity and 0 for cumulative impact. (a) All countries, with the largest contributors labelled. (b) The same continuum cropped to 0.6% of the pool, showing low- and middle-income countries. Grey lines are all other countries in both panels.

Sweeping from cumulative impact towards capacity, China remained the largest contributor until the weighting for capacity surpassed approximately 0.19 (**Figure 7a**). Following this, the United States became the largest contributor. The producer economies fell steadily across the same range: Madagascar decreased from 4.9% to almost 0%, Colombia from 4.9% to 0.4%, and Brazil from 6.3% to 2.0%. Among low- and middle-income countries the direction of movement along the continuum varied (**Figure 7b**). Egypt more than doubled its share from capacity to cumulative impact, while the Democratic Republic of the Congo lost close to 90% of its share across the same range. Low- and middle-income countries did not move as a bloc, and no weighting was universally favorable to all of them.

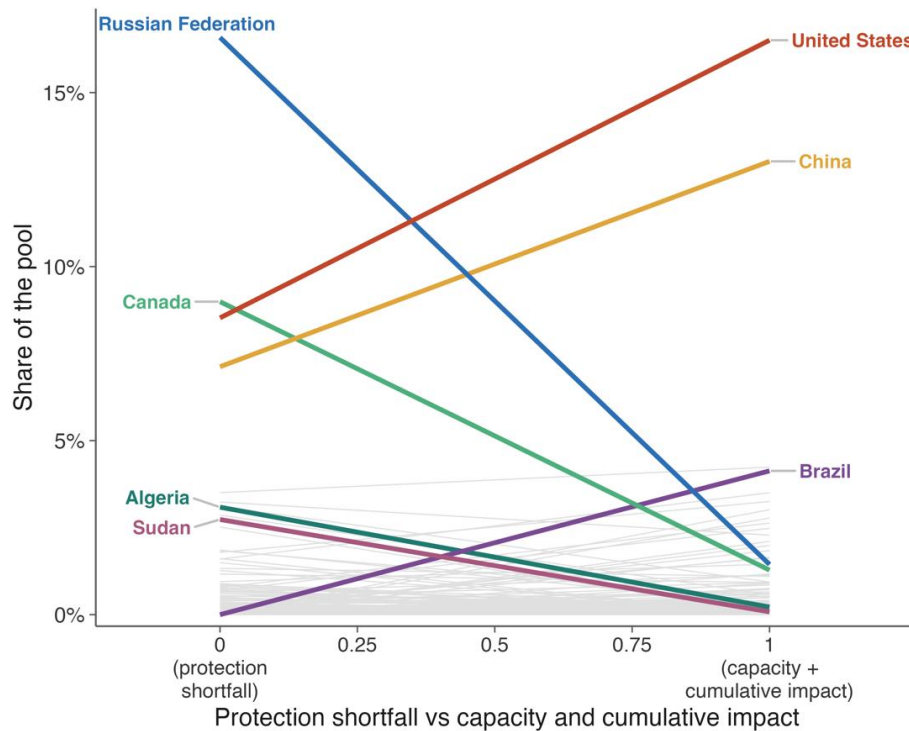


Figure 8: The responsibility allocation as a continuum between a country's protection shortfall and a capacity and cumulative impact 50/50 hybrid weighting, where 1 on the x-axis represents a weighting of 1 for Capacity/cumulative impact and 0 for own protection gap.

Protected area shortfall must receive a relatively high weighting before territory-rich states such as Russia begin to show large increases in their shares (**Figure 8**). Russia held 16.6% of the allocation under a full weighting for protection shortfall, compared with just 1.4% under the capacity + cumulative impact weighting. As the weighting shifted away from protected area shortfall, Russia was overtaken by the United States at $w = 0.35$ and by China at $w = 0.45$.

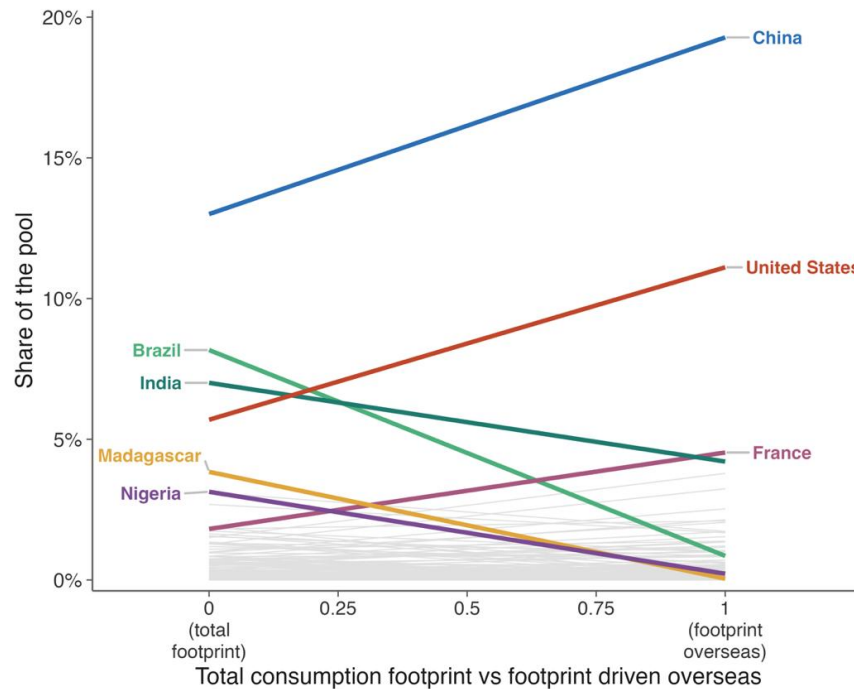


Figure 9: The allocation as a continuum between total current footprint (LIFE) and current footprint where domestic flows are excluded, where 1 on the x-axis represents a weighting of 1 for total current consumption footprint overseas and 0 for total current consumption footprint.

The left end of the consumption-based sweep represents total current footprint, the right end consumption overseas only (**Figure 9**). China had the largest share at both weighting endpoints (13.0% and 19.3% respectively), so no rank crossings occurred at the top of the distribution. However, the United States overtook India at $w=0.16$, and Brazil at $w = 0.19$. These early rank crossings show that producer economies are displaced quickly, in favor of consumer economies; even a modest shift toward assigning responsibility only for consumption impacts overseas was enough to substantially alter allocations of responsibility. Presented this way, the framework provides a continuous spectrum of allocations, allowing the effects of different weighting choices on country responsibilities to be assessed explicitly.

3.3 Protected area domestic targets and cross-border support

For the protected-area theme, the allocation of the total cost of reaching the global 30 by 30 target can be compared directly with the estimated cost of closing each country's own 30 by 30 gap for a given scenario. This analysis distinguished net supporters of global 30 by 30 effort from net recipients (**Figure 10**).

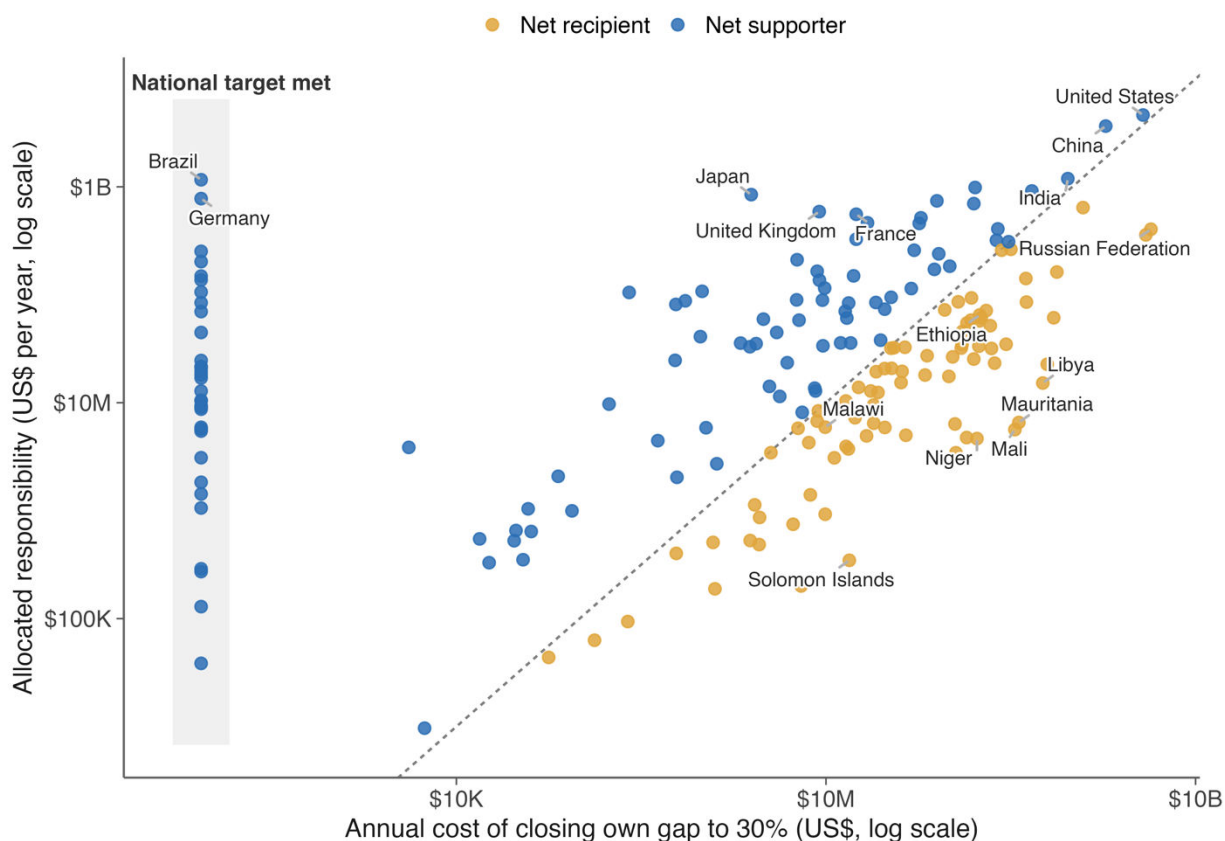


Figure 10. *Allocated protected-area responsibility versus the annual cost of closing each country's own gap to the 30 by 30 target. Each point represents a country. The vertical axis shows each country's allocated share of the global 30 by 30 shortfall under the capacity + cumulative impact 50:50 hybrid scenario, a core scenario which excludes the protection shortfall basis. The dashed 45° line marks where allocated effort equals the cost of meeting a country's own domestic target. Countries above the line are net supporters, with allocated responsibility exceeding their domestic funding needs, and those below are net recipients, with domestic funding needs exceeding their allocated responsibility.*

Of the 187 countries included in this analysis, 113 were allocated a contribution to the global funding pot that is larger than the cost of closing their domestic protected area gap. The most

distinct examples are the 32 countries which have already reached 30% coverage in some capacity, and yet still carried substantial responsibility under the scenarios we assessed: Brazil was allocated \$1.16 billion per year and Germany \$0.78 billion. For recipients, large Sahelian and Saharan states were required to pay only a small proportion of what their own shortfall would cost: Mali 1.6%, Mauritania 1.8%, Libya 2.6%, and Niger 2.8%. Under any scenario which gave a large weighting to capacity or responsibility, these countries received substantial international support to reach 30% coverage.

Across the core scenarios (**Figure 3a**), all scenarios allocated between 54% and 61% of the pool as cross-border funding support. By contrast, when we used an equal weighting scenario including the domestic PA gap + capacity + cumulative impact, cross-border support fell to 36%. Although the overall share of cross-border support was similar across core scenarios, the distribution varied. Under the cumulative-impact only scenario, 66 countries were net recipients, compared with 82 under the pure capacity scenario.

An equivalent comparison for the consumption theme is presented in **Appendix S5**.

4. Discussion

This study examined how considering various fairness principles alters the distribution of national effort towards fulfilling commitments made under three key targets of the Kunming-Montreal Global Biodiversity Framework. Reaching CBD goals and targets requires countries to address their impacts both at home and overseas. However, effort towards all three targets examined here carries economic and opportunity costs, meaning that no allocation can avoid the question of what countries are able to bear (Armstrong, 2019). Rather than try to determine the most “fair” way of allocating effort, which depends on the values of different stakeholders, we aimed to make the consequences of different fairness decisions visible. We show that these choices matter substantially and should be made explicit in the implementation of the KMGBF, and more broadly in CBD processes.

4.1 Fairness principles reshape national burden

A large amount of effort was reallocated between countries depending on which single fairness principle was used (47–49% of the overall effort). These large-magnitude shifts were particularly visible among the largest contributors. Using the finance pool as an example, the United States moved from USD 52.5 billion under capacity to USD 13.5 billion under cumulative impact, while Brazil moved the other way, from USD 4.0 to 12.5 billion. Yet, country rankings remained comparatively consistent despite these shifts (Spearman's $\rho = 0.74\text{--}0.79$). Therefore, similar countries appeared near the top in terms of their share of global effort for most of the fairness principles, while the size of the obligation placed on them changed considerably.

The extent to which the choice of fairness principle materially changes national allocations has also been debated in climate effort-sharing. Ringius et al. (2002) argued that responsibility, capacity, and development need “to a large extent point in the same general direction” in the climate context, and typically produce similar implications. Our findings qualify this expectation, as while rank agreement remains high across allocations, the changes in the absolute level of contribution experienced by different countries could have varying impacts on their ability to pay for their share. This divergence would likely widen under a broader set of bases than the four we consider here. For example, Stark et al. (2022) suggest that cost-sharing should also account for technical capacity, and the potential of different actors to benefit.

The implications of allocations become more notable when a share is expressed as a proportion of a country's national economy. Using the finance theme as the example, we found that when switching from purely capacity (which allocates a standard 0.18% of each country's GDP) to include other fairness principles, low-income countries often carried an uneven relative burden. This concern is well established in the biodiversity cost-sharing literature (Armstrong, 2019; Stark et al., 2022), and Lehmann et al. (2025) note that lower-income countries face relatively higher opportunity and establishment costs in meeting Target 3 than high-income countries do. Beyond fairness, when countries perceive their allocated burden as disproportionate, cooperation to achieve KMGBF goals is less likely (Stark et al., 2022).

Our development floor bounds these disparities by halving the relative burden on low-income countries while moving under 1% of the pool, making it progressive without being substantially

redistributive. This aligns with the Greenhouse Development Rights framework in climate effort-sharing (Baer et al., 2009) and with the HDI weighting parameter Sun et al. (2022) use to assign responsibility for biodiversity loss. Any approach for allocating effort should therefore report relative burden alongside absolute shares, so that deliberations using the outputs can address them.

4.2 How responsibility is attributed changes effort distributions

How we attributed responsibility for a country's impact on biodiversity loss proved almost as consequential as which principle we applied. Two questions governed how responsibility was assigned: whether we excluded domestic impact when calculating a country's effort allocation, and whether we considered current or cumulative impact. The first had a larger impact on allocations than the second.

Domestic vs. overseas impact

Our expert elicitation raised concerns that allocation models could attribute disproportionate impact responsibility to biodiverse countries. Excluding domestic flows from responsibility weightings removed locally sourced consumption from the account, and acknowledged that metrics such as LIFE scale with species richness and endemism (Ball et al., 2025; Eyres et al., 2025), so consumption met from domestic production registers as high impact in the most biodiverse countries.

Comparing allocations in our analysis which excluded domestic consumption with those which considered total impact separated two largely distinct groups of countries: the most biodiverse countries, whose footprint falls almost entirely within their borders, and import-reliant economies, whose footprint falls largely overseas. Additionally, whether a country gained or lost share between these two allocations was strongly associated with its income, with high-income countries more than doubling their share when we excluded domestic consumption from the current impact basis. Significant numbers of species are threatened as a result of international trade, and wealthy countries often drive habitat loss in the countries which supply their

consumption (Lenzen et al., 2012; Sun et al., 2022). Others have highlighted that actions to address biodiversity impact must tackle these impacts which are often overlooked (Ball et al., 2025). The decision to exclude domestic consumption impacts from responsibility therefore acts as one of the more progressive dials in our approach. It also restates a question established in carbon accounting debates, on whether responsibility is assigned either to carbon producers, to consumers, or on the basis of income (Marques et al., 2012).

Cumulative vs Current Impact

There is a fundamental question about whether responsibility for biodiversity loss should be based on impacts occurring now or accumulated over time, and whether historical beneficiaries should bear a greater share of the effort burden. In our allocations, the temporal window shifted burden from fast-growing consumers to long-industrialized economies, halving India's share while Japan's nearly doubled. How to account fairly for historical impact is among the more contested questions in climate effort-sharing (Ringius et al., 2002), and Roe et al. (2023) argue that the loss and damage principle under the UNFCCC should extend to biodiversity loss with the same justice rationale, that wealthy countries are responsible for and have benefited disproportionately from impacts now borne across the Global South.

However, climate policy can draw on emissions records extending into the nineteenth century (van den Berg et al., 2020), for which biodiversity has no equivalent (Purvis, 2025). Much of Europe had severely degraded its natural habitats by 1800 (Kaplan et al., 2009), so metrics with modern baselines, such as the Living Planet Index and its 1970 reference year, do not register that loss (Freeman, 2020). The SCP-HAT metric we use to attribute cumulative impact only extends to 1990 (UNEP, 2024). Cumulative impact as a proxy for historical impact remains a fairness basis in the approach, though it systematically under-represents the countries that degraded their own landscapes and impacted other countries through their consumption throughout the past centuries.

4.3 Protected-area effort allocations require cross-border support

Protected Area is the theme in which the need for effort is most clearly fixed geographically. Each country's shortfall depends on its land area and current coverage, so the global gap is concentrated in large countries which lack designated protected areas such as Russia. Capacity and impact as weightings are distributed on much different grounds, so allocating responsibility for closing the gap separates where the protection must occur from who is asked to help pay for it.

Transfer is therefore an essential function of any capacity- or responsibility-based allocation of spatial biodiversity effort. Over half the cost of closing the global shortfall in these scenarios fell on countries other than those where the protection is needed, and 113 of 187 countries were allocated more than their own shortfall would cost. While our focus was on where responsibility should be assigned, where costs actually arise is also important. Waldron et al. (2020) estimate that between 69% and 91% of the costs of implementing the 30% target fall on low- and middle-income countries, and argue that this is far more than what their domestic public spending budget could support. Additionally, nearly half the world's population lives within 10 km of areas included in a biodiversity-maximizing 30x30 scenario, making Target 3 a social as well as an ecological target requiring commitment to development funding and support for local residents (Fajardo et al., 2026). Our management-cost estimate prices the area, but excludes the burden falling on the people who live there, which a fuller account would need to assess. Stark et al. (2022) call for the integration of responsibility-based cost sharing approach for Target 3, with a recognition of where funds are needed the most, arguing that the CBD should involve an explicit cost-sharing mechanism recognizing common but differentiated responsibilities in its area-based agenda. Our approach can help supply the first half of this by making explicit who would be asked to contribute given a set of fairness assumptions.

4.4 Extending the Approach

Four extensions would widen what the approach can measure and refine the allocation process.

First, because the protection shortfall basis is derived from self-reported PA coverage, it inherits any biases in reporting; in particular whether PA management is actually effective and whether

the PA estate is actually additional. Protected areas are systematically biased towards economically marginal, high elevation land that is unlikely to face conversion pressure in the absence of protection (Joppa & Pfaff, 2009). Whether existing coverage is effective is largely unknown, with only 7% of Asian protected areas carrying any assessment of management effectiveness (Farhadinia et al., 2022). Farhadinia et al. (2022) estimate that when including potential other effective area-based conservation measures (OECMs), Russia's coverage could climb by 41%; currently it has the largest single share of our global gap at 16.6%. Emerging methodologies for evaluating whether protection is genuinely effective (Pedersen et al., 2026), alongside improved reporting of OECMs, would improve the accuracy of our protection shortfall metric and PA theme pool.

Additionally, as metrics improve, there will be an opportunity to expand the scope of the impact indicators used to represent responsibility for biodiversity loss in our approach. Currently, LIFE and SCP-HAT capture only land-use driven biodiversity loss. Marine impacts, overexploitation, and invasive alien species remain absent from multi-regional input-output analysis and are seldom addressed in life cycle assessment (Marques et al., 2017). Incorporating metrics which address further drivers and attempt to make historical estimates with earlier baselines would improve our ability to attribute responsibility for loss.

Further, bounding the allocation rule would remove results which allocate beyond what is possible for a given country to contribute. For example, under the capacity + overseas current impact scenario, France is allocated an unfeasibly high consumption reduction; 1,178 Mt against its own current raw material use of 1,189 Mt. Integrating rules from the claims literature that constrain allocations, such as constrained equal awards, could prevent this while maintaining our distribution methodology (Booth et al., 2024; Kampas, 2015).

Finally, this approach allocates costs, and does not consider how benefits should be shared fairly among countries. Because a country's position also depends on what it receives, cost allocations should be read alongside benefit-sharing processes (Nunez-Vega et al., 2025), either through official CBD channels or external evaluations. Additionally, national allocation approaches such as this one are removed from the distribution of effort within a country. In the case of protected areas, land set for protection is often home to Indigenous Peoples and local communities

(Fajardo et al., 2026), and who carries the local costs of protection depends heavily on the way 30 by 30 is implemented (Sandbrook et al., 2023). Making those sub-national distributions fair and explicit is an essential next step, as a full account of a country's fair share will require transparency at all levels.

4.5 Potential implementation within the KMGBF framework and civil society

The KMGBF's implementation architecture requires Parties regularly to revise their national biodiversity strategies and action plans (NBSAPs) in line with the framework and to report progress against headline indicators. These reports feed a global review of collective progress, but review at the level of an individual Party remains voluntary (CBD, 2022). Through this process the KMGBF implicitly acknowledges its Parties' common but differentiated responsibilities for its implementation (Lehmann et al., 2025), but it lacks a process for determining whether national contributions are fair and proportional (Milner-Gulland et al., 2026).

An approach such as the one presented in this paper could provide the methodological infrastructure for assigning effort shares amongst Parties towards quantifiable targets. Within the global review process, the distribution of global effort could be evaluated against allocations produced by such an approach, each explicitly attached to principles of fairness. When applied in a country-level review, stated contributions could be compared to a range of defensible allocations. Rather than requiring agreement on a specific weighting, our approach establishes the range of contributions that defensible fairness principles suggest and shows where a stated contribution or global effort distribution may fall short.

While including this framework within the CBD processes would require agreement among Parties, its functions can provide meaningful contributions externally. Milner-Gulland et al. (2026) call for an approach for prioritizing impactful actions that are rooted in principles of fairness and propose that initiatives such as NATURE Impacts can help achieve this goal. The NATURE Impacts project aims to support nations and their decision makers in identifying

priority actions, and considering how their contributions could align with principles of fairness (Leverhulme Centre for Nature Recovery, 2026). The approach developed in this paper could be employed in an expert elicitation to show stakeholders how the principles they consider fair translate into potential national contributions, to inform identification of national-level priorities.

Given the substantial costs of reducing biodiversity loss, a fair way of sharing effort is vital for achieving the goals of the KMGBF. We present an approach and usable tool that can make implicit fairness decisions in CBD processes explicit by showing the impact of different fairness principles on the effort required by individual nations to help reach global biodiversity goals. By understanding how different perceptions of fairness influence national-level contributions, we hope users can assess the adequacy of their current national level actions and identify priorities for future actions.

References

- Armstrong, C. (2019). Sharing conservation burdens fairly. *Conservation Biology*, 33(3), 554–560. <https://doi.org/10.1111/cobi.13260>
- Athanasίου, T., Kartha, S., & Baer, P. (2014). *National fair shares: The mitigation gap — domestic action and international support*. Climate Equity Reference Project.
- Baer, P., Kartha, S., Athanasίου, T., & Kemp-Benedict, E. (2009). The Greenhouse Development Rights framework: Drawing attention to inequality within nations in the global climate policy debate. *Development and Change*, 40(6), 1121–1138.
- Bai, X., Hasan, S., Andersen, L. S., Bjørn, A., Kilkış, Ş., Ospina, D., Liu, J., Cornell, S. E., Sabag Muñoz, O., de Bremond, A., Crona, B., DeClerck, F., Gupta, J., Hoff, H., Nakicenovic, N., Obura, D., Whiteman, G., Broadgate, W., Lade, S. J., ... Zimm, C. (2024). Translating Earth system boundaries for cities and businesses. *Nature Sustainability*, 7, 108–119. <https://doi.org/10.1038/s41893-023-01255-w>
- Ball, T. S., Dales, M., Eyres, A., Green, J. M. H., Madhavapeddy, A., Williams, D. R., & Balmford, A. (2025). Food impacts on species extinction risks can vary by three orders of magnitude. *Nature Food*, 6(9), 848–856. <https://doi.org/10.1038/s43016-025-01224-w>
- Bell-James, J., & Watson, J. E. M. (2025). Ambitions in national plans do not yet match bold international protection and restoration commitments. *Nature Ecology & Evolution*, 9, 417–424. <https://doi.org/10.1038/s41559-025-02636-4>
- Booth, H., Milner-Gulland, E. J., Bang, A., Bull, J., Moreno-Ternero, J. D., & Squires, D. (2024). Fair division for avoidance of biodiversity impacts. *Trends in Ecology & Evolution*, 39(12), 1102–1110. <https://doi.org/10.1016/j.tree.2024.09.002>
- Convention on Biological Diversity. (2022). *Kunming-Montreal Global Biodiversity Framework* (CBD/COP/DEC/15/4). United Nations Environment Programme.
- Croft, S., West, C., Harris, M., Green, J., Molotoks, A., Wood, E., Ball, T., & Way, L. (2025). *Technical documentation for an official statistic estimating the global environmental impacts of consumption: 2025 version* (JNCC Report 808). JNCC. <https://jncc.gov.uk/resources/7a4063c9-a221-4ca1-ab6a-3b2fae544b32>
- Deutz, A., Heal, G. M., Niu, R., Swanson, E., Townshend, T., Li, Z., Delmar, A., Meghji, A., Sethi, S. A., & Tobin de la Puente, J. (2020). *Financing nature: Closing the global*

- biodiversity financing gap*. Paulson Institute; The Nature Conservancy; Cornell Atkinson Center for Sustainability. <https://doi.org/10.13140/RG.2.2.26226.32968>
- Eyres, A., Ball, T. S., Dales, M., Swinfield, T., Arnell, A., Baisero, D., Durán, A. P., Green, J. M. H., Green, R. E., Madhavapeddy, A., & Balmford, A. (2025). LIFE: A metric for mapping the impact of land-cover change on global extinctions. *Philosophical Transactions of the Royal Society B*, 380, 20230327. <https://doi.org/10.1098/rstb.2023.0327>
- Fajardo, J., Bingham, H. C., Brockington, D., Chaplin-Kramer, R., Fitzsimons, J. A., Fleischman, F., Frechette, A., Garrett, R. D., Hazin, C., Kuemmerle, T., Lessmann, J., Nuvunga, M. O. F., O'Donnell, B., Onyai, F., Pinto, R., Pfeifer, M., Pritchard, R., Ryan, C. M., Shyamsundar, P., ... Sandbrook, C. (2026). Social implications of the 30×30 global conservation target. *Nature Communications*, 17, Article 4067. <https://doi.org/10.1038/s41467-026-71860-8>
- Farhadinia, M. S., Waldron, A., Kaszta, Ż., Eid, E., Hughes, A., Ambarlı, H., Al-Hikmani, H., Buuveibaatar, B., Gritsina, M. A., Haidir, I., Johnson, P. J., & Macdonald, D. W. (2022). Current trends suggest most Asian countries are unlikely to meet future biodiversity targets on protected areas. *Communications Biology*, 5, 1221. <https://doi.org/10.1038/s42003-022-04061-w>
- Freeman, R. (2020, November 18). *How is the Living Planet report made?* Zoological Society of London. <https://www.zsl.org/news-and-events/feature/how-living-planet-report-made>
- Herrero, C., Moreno-Ternero, J. D., & Ponti, G. (2010). On the adjudication of conflicting claims: An experimental study. *Social Choice and Welfare*, 34(1), 145–179. <https://doi.org/10.1007/s00355-009-0393-5>
- Höhne, N., den Elzen, M., & Escalante, D. (2014). Regional GHG reduction targets based on effort sharing: A comparison of studies. *Climate Policy*, 14(1), 122–147. <https://doi.org/10.1080/14693062.2014.849452>
- Holz, C., Kartha, S., & Athanasiou, T. (2018). Fairly sharing 1.5: National fair shares of a 1.5 °C-compliant global mitigation effort. *International Environmental Agreements*, 18, 117–134. <https://doi.org/10.1007/s10784-017-9371-z>
- IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (E. S. Brondízio, J. Settele, S. Díaz, & H. T. Ngo, Eds.). IPBES Secretariat. <https://doi.org/10.5281/zenodo.3831673>

- Jagu Schippers, E., & Lowing, D. (2026). Fair effort-sharing for climate change mitigation: A normative approach. *Ecological Economics*, 245, 108995.
- Joppa, L. N., & Pfaff, A. (2009). High and far: Biases in the location of protected areas. *PLoS ONE*, 4(12), e8273. <https://doi.org/10.1371/journal.pone.0008273>
- Ju, B.-G., Miyagawa, E., & Sakai, T. (2007). Non-manipulable division rules in claim problems and generalizations. *Journal of Economic Theory*, 132, 1–26.
- Kampas, A. (2015). Combining fairness and stability concerns for global commons: The case of East Atlantic and Mediterranean tuna. *Ocean & Coastal Management*, 116, 414–422.
- Kaplan, J. O., Krumhardt, K. M., & Zimmermann, N. (2009). The prehistoric and preindustrial deforestation of Europe. *Quaternary Science Reviews*, 28, 3016–3034. <https://doi.org/10.1016/j.quascirev.2009.09.028>
- Lehmann, I., Kok, M., Immerzeel, R., & Marques, A. (2025). Implications of global distributive justice principles for implementation of the Kunming-Montreal Global Biodiversity Framework. *Conservation Biology*. <https://doi.org/10.1111/cobi.70167>
- Lenzen, M., Moran, D., Kanemoto, K., Foran, B., Lobefaro, L., & Geschke, A. (2012). International trade drives biodiversity threats in developing nations. *Nature*, 486, 109–112. <https://doi.org/10.1038/nature11145>
- Leverhulme Centre for Nature Recovery. (2026). *NATURE Impacts: National Assessment Tool for Understanding Relative Environmental Impacts*. University of Oxford. <https://naturerecovery.ox.ac.uk/projects/nature-impacts-national-assessment-tool-for-understanding-relative-environmental-impacts/>
- Marques, A., Rodrigues, J., Lenzen, M., & Domingos, T. (2012). Income-based environmental responsibility. *Ecological Economics*, 84, 57–65. <https://doi.org/10.1016/j.ecolecon.2012.09.010>
- Marques, A., Verones, F., Kok, M. T., Huijbregts, M. A., & Pereira, H. M. (2017). How to quantify biodiversity footprints of consumption? A review of multi-regional input–output analysis and life cycle assessment. *Current Opinion in Environmental Sustainability*, 29, 75–81. <https://doi.org/10.1016/j.cosust.2018.01.005>
- Milner-Gulland, E. J., Farrelly, É., Bromwich, T., Haverkamp, C., Karlsdóttir, S. A., Kumpel, N. F., Pardo, L. E., Shaw, R., White, T. B., Broekhoven, G., Jones, S. K., Obersteiner, M., Visconti, P., Yamamoto, K., & Barrett, M. (2026). *A critical year for nature: Now is the*

- time to accelerate action on the Global Biodiversity Framework* [Preprint]. Conservation Letters.
- Nunez-Vega, G., Reimer, L. C., Overmann, J., & Hartman Scholz, A. (2025). A new indicator for the Kunming–Montreal Global Biodiversity Framework: Capturing non-monetary benefit data from access and benefit-sharing agreements. *BioScience*, 75(4), 298–306. <https://doi.org/10.1093/biosci/biae132>
- O'Neill, B. (1982). A problem of rights arbitration from the Talmud. *Mathematical Social Sciences*, 2(4), 345–371.
- Pedersen, P. B. M., Petersen, A. H., Corcoran, D., Madsen, N., Svenning, J.-C., Timmermann, K., Kaae, B. C., Kragh, T., Olsen, B. E., Strange, N., Normand, S., & Rahbek, C. (2026). Identifying conservation gaps: A framework for evaluating national contributions to the 30×30 target. *One Earth*, 9, 101620. <https://doi.org/10.1016/j.oneear.2026.101620>
- Purvis, A. (2025). Bending the curve of biodiversity loss requires a 'satnav' for nature. *Philosophical Transactions of the Royal Society B*, 380, 20230210. <https://doi.org/10.1098/rstb.2023.0210>
- Ringius, L., Torvanger, A., & Underdal, A. (2002). Burden sharing and fairness principles in international climate policy. *International Environmental Agreements: Politics, Law and Economics*, 2, 1–22.
- Roe, D., Holland, E., Nisi, N., Mitchell, T., & Tasnim, T. (2023). Loss and damage finance should apply to biodiversity loss. *Nature Ecology & Evolution*, 7, 1336–1338. <https://doi.org/10.1038/s41559-023-02088-8>
- Sandbrook, C., Albury-Smith, S., Allan, J. R., Bhola, N., Bingham, H. C., Brockington, D., Byaruhanga, A. B., Fajardo, J., Fitzsimons, J., Franks, P., Fleischman, F., Frechette, A., Kakuyo, K., Kaptoyo, E., Kuemmerle, T., Kalunda, P. N., Nuvunga, M., O'Donnell, B., Onyai, F., ... Zaehring, J. G. (2023). Social considerations are crucial to success in implementing the 30×30 global conservation target. *Nature Ecology & Evolution*, 7(6), 784–785. <https://doi.org/10.1038/s41559-023-02048-2>
- SEI/JNCC. (2025). *Commodity Footprints Dashboard*. <https://www.commodityfootprints.earth>
- Stark, K., Adams, V. M., Brown, C. J., Chauvenet, A., Davis, K., Game, E. T., Halpern, B. S., Lynham, J., Mappin, B., Selkoe, K., Watson, J. E. M., Possingham, H. P., & Klein, C. J. (2022). Importance of equitable cost sharing in the Convention on Biological Diversity's protected area agenda. *Conservation Biology*, 36(2), e13812. <https://doi.org/10.1111/cobi.13812>

- Sun, Z., Behrens, P., Tukker, A., Bruckner, M., & Scherer, L. (2022). Shared and environmentally just responsibility for global biodiversity loss. *Ecological Economics*, 194, 107339.
- Tomoi, H., Ohsawa, T., Quevedo, J. M. D., & Kohsaka, R. (2022). Is "Common But Differentiated Responsibilities" principle applicable in biodiversity? Towards approaches for shared responsibilities based on updated capabilities and data. *Ecological Indicators*, 145, 109628.
- UNEP-WCMC, & IUCN. (2026). *Protected Planet: The World Database on Protected Areas*. Retrieved June 2026, from <https://www.protectedplanet.net>
- United Nations Development Programme. (2024). *Human Development Report 2023/24*. UNDP.
- United Nations Environment Programme. (2024). *SCP-HAT database v3.0*. UN Life Cycle Initiative, UN One Planet Network, UN International Resource Panel. <https://scp-hat.org/methods>
- United Nations Framework Convention on Climate Change. (1992). *United Nations Framework Convention on Climate Change*. United Nations.
- van den Berg, N. J., van Soest, H. L., Hof, A. F., den Elzen, M. G. J., van Vuuren, D. P., Chen, W., Drouet, L., Fujimori, S., & Blok, K. (2020). Implications of various effort-sharing approaches for national carbon budgets and emission pathways. *Climatic Change*, 162(4), 1805–1822. <https://doi.org/10.1007/s10584-019-02368-y>
- Waldron, A., Adams, V., Allan, J., Arnell, A., Asner, G., Atkinson, S., Baccini, A., Baillie, J., Balmford, A., Beau, J. A., Brander, L., Brondizio, E., Bruner, A., Burgess, N., Burkart, K., Butchart, S., Button, R., Carrasco, R., Cheung, W., ... Zhang, Y. (2020). *Protecting 30% of the planet for nature: Costs, benefits and economic implications*. Campaign for Nature.
- World Bank. (2024). *World Development Indicators*. <https://databank.worldbank.org/source/world-development-indicators>
- WWF. (2024). *Living Planet Report 2024: A system in peril*. World Wide Fund for Nature. <https://livingplanet.panda.org/>
- Yang, L., Xu, Z.-H., Chen, T., Fan, Y.-X., Chapman, C. A., Liu, Y., Lee, T.-M., & Fan, P.-F. (2026). Cost-effective expansion of protected areas reduces global zoonotic risk and biodiversity loss. *One Earth*, 9(3), 101611. <https://doi.org/10.1016/j.oneear.2026.101611>

Young, H. P. (1994). *Equity: In theory and practice*. Princeton University Press.
<https://doi.org/10.2307/j.ctv10crfx7>

Zurell, D., Bocedi, G., Velazco, S. J. E., Gonzalez, A., Purvis, A., Wintle, B., Merow, C.,
Lundquist, C., Guillera-Aroita, G., Settele, J., Serra-Diaz, J. M., Sarmiento Cabral, J.,
Travis, J. M. J., Schifferle, K., Buckley, L., Briscoe, N. J., Isaac, N. J. B., Peres-Neto, P.
R., Keuth, R., ... Urban, M. C. (2025). Predicting the way forward for the Global
Biodiversity Framework. *Proceedings of the National Academy of Sciences*, 122(41),
e2501695122. <https://doi.org/10.1073/pnas.2501695122>

Appendices

Appendix S1. The protected area pool: costing and scope

Shares for protected-area allocation scenarios are reported in dollars, which requires an estimate of what protection and management of additional area will cost (**Table S1**). We used the median annual management cost per square kilometer compiled by Yang et al. (2026) from 305 records across 29 sources. The estimates vary by region: \$2,321 per km² per year in North America, \$1,993 in Oceania, \$1,384 in Asia, \$1,208 in Africa and \$538 in South America in 2023 US dollars. Each country's shortfall was converted from km² to US dollars using their regional rate, with the pool being the sum of these costs at USD 28.0 billion per year. Allocated shares are converted at a single mean rate of \$1,478 per km² per year because the unit distributed is global effort.

Table S1. Protected-area responsibility in dollars including the twelve largest contributors by allocation (capacity + cumulative impact 50/50). Each country's own domestic gap is converted to annual costs in dollars using its estimated regional management rate (Yang et al., 2026); the allocation is its share of the combined USD 28.0 billion annual pool. A positive net figure means a country is allocated a larger share than the costs of closing its own gap.

Country	Own gap	Rate	Cost of own gap	Allocated	Net	Position
United States	1,613,759 km ²	\$2,321/km ²	\$3.75 bn	\$4.62 bn	+0.87 bn	Net supporter
China	1,348,118 km ²	\$1,384/km ²	\$1.87 bn	\$3.65 bn	+1.78 bn	Net supporter
India	663,535 km ²	\$1,384/km ²	\$0.92 bn	\$1.19 bn	+0.27 bn	Net supporter
Brazil	0 km ²	\$538/km ²	\$0.00 bn	\$1.16 bn	+1.16 bn	Net supporter
Mexico	301,937 km ²	\$538/km ²	\$0.16 bn	\$0.98 bn	+0.82 bn	Net supporter
Indonesia	338,891 km ²	\$1,384/km ²	\$0.47 bn	\$0.91 bn	+0.44 bn	Net supporter
Japan	1,787 km ²	\$1,384/km ²	\$0.00 bn	\$0.84 bn	+0.84 bn	Net supporter
Germany	0 km ²	\$2,321/km ²	\$0.00 bn	\$0.78 bn	+0.78 bn	Net supporter
Colombia	147,791 km ²	\$538/km ²	\$0.08 bn	\$0.74 bn	+0.66 bn	Net supporter
Madagascar	131,224 km ²	\$1,208/km ²	\$0.16 bn	\$0.69 bn	+0.54 bn	Net supporter
Australia	612,450 km ²	\$1,993/km ²	\$1.22 bn	\$0.64 bn	−0.58 bn	Net recipient
United Kingdom	3,800 km ²	\$2,321/km ²	\$0.01 bn	\$0.59 bn	+0.58 bn	Net supporter

There are a few important notes for the costing process. First, Yang et al. did not identify a rate for Europe, so European countries are assigned the North American rate. The converted shares also only cover costs of annual management, which excludes land acquisition and opportunity costs. Additionally, because the rates are annual, the conversion puts effort in terms of a recurring cost, which keeps temporal unit's standard across the three allocation themes. Comparing our estimate with other literature, Waldron et al. (2020) estimate the cost of adding new protected areas to reach 30% to be between USD 35.5-110 billion per year when including marine area. The 28.0 billion we used includes only terrestrial areas so it is reasonably consistent with the Waldron et al. range.

Excluding marine 30 by 30: We restrict this theme to terrestrial coverage because both impact indicators we use, LIFE and SCP-HAT, measure land-driven biodiversity loss, so a marine shortfall would have no matching measure of responsibility to be measured against. Extending the approach to marine 30 by 30 would be a natural next step.

Appendix S2. Expert consultation

Participants in the two workshops were given an information sheet describing the purpose of the study and how their responses would be used and gave informed consent before taking part. Participation in the survey and discussion was voluntary and responses were anonymized, with no personally identifying information collected.

Table S2. Survey data including the selected factors practitioners said they would weigh the most when using our tool on the left, and the respondent's demographic data on the right. Respondents could choose 3 factors they would weigh the most.

Factor selected	n	Respondents	n
Ability to pay / economic capacity (GDP)	17	Sector	
Current consumption or trade-related footprint	15	Academia/Research	20
Historical biodiversity footprint	12	NGO / civil society	2
Development needs (HDI, poverty)	10	Consultancy	1
Biodiversity held within borders	9	Government	1
Governance and implementation capacity	8	Years of experience	
Population	1	20+ years	6
		11-20 years	6
		6-10 years	6
		3-5 years	4
		0-2 years	2

The survey-informed scenario takes these counts as weights. Four factors correspond directly with bases we included in our approach: capacity, current impact, cumulative impact, and population. Their counts of 17, 15, 12, and 1 respectively sum to 45 (**Table S2**), giving the weightings of 0.38, 0.33, 0.27, and 0.02 respectively. Development need was the fourth most selected factor and is applied as the development floor rather than considered a weighted base (**Section 2.5**). Biodiversity held within borders and governance and implementation capacity were not used as bases as a response to guidance in our workshop discussions following the survey.

Respondents were also asked how realistic it would be for countries to accept an explicit fairness approach for distributing biodiversity effort on a scale from 1 (very unrealistic) to 5 (very realistic). Twenty-one of those surveyed answers, with a median response of 2, and mean of 2.5.

Survey Link: https://qualtricsxmjfy36rt88.qualtrics.com/jfe/form/SV_eRoNYfCrIAVi1Xo

Appendix S3. Data coverage and preprocessing

Our approach covers 195 countries, with exact coverage ranging slightly by fairness base 192 countries have GDP, 191 HDI, 192 have both variants of LIFE, 193 have both SCP-HAT variants, and 187 have a protect-area shortfall. Raw-material consumption, which informs the consumption pool, covers all 195 countries.

Because shares in a scenario can only be calculated for countries that have a value for each of the bases weighted, the country set varies slightly between them: 192 for capacity and the two-basis hybrid scenarios, 191 for the survey-aligned scenario and those that include the development floor, and 187 for protected-area scenarios. The countries excluded are typically microstates holding under 1% of the global GDP. Additional exclusions in some scenarios are the Democratic People’s Republic of Korea which has no GDP, and Somalia and Eritrea which lack protected-area coverage statistics.

Forty-one countries absent from the LIFE and SCP-HAT source datasets were filled using proxies. We used the residual aggregate numbers for each continental region which both metrics provide (labeled “Rest of Americas,” and so on), to apportion amongst the missing countries in that region in proportion to their population. The resulting values were approximate, and assume that impact scales with population within a region. Countries that were assigned proxy values hold 0.60% of global GDP and 1.14% of cumulative impact, so the assumption has little bearing on the allocations reported.

Additionally, neither LIFE or SCP-HAT reports uncertainty at the country level, so allocations are computed from the published values as given.

Appendix S4. Development floor calculations and sensitivity analysis

Development Floor Calculations

For a country i with HDI h_i and threshold τ , the discount is

$$d_i = (h_i / \tau)^p \text{ if } h_i < \tau, \quad d_i = 1 \text{ if } h_i \geq \tau. \quad \text{GDP}'_i = d_i \cdot \text{GDP}_i$$

After the discount is applied, capacity shares are renormalized so the pool still sums to the total being allocated in a given scenario. Relief is therefore redistributed across the set of undiscounted countries. The threshold τ is fixed at 0.70 to reflect the UNDP “high human development” marker (UNDP, 2024), and held constant. The exponent p sets how quickly the discount increases as HDI goes below the threshold, and is adjustable within the approach as a dial between 1 and 3 with the default set to 2. Higher p values apply a more progressive level of development relief.

Because countries below the 0.70 HDI threshold hold a small proportion of global GDP (6.4%), the development floor relocates relatively little of the capacity shares: 0.48% at $p=1$, 0.87% at $p=2$, and 1.19% at $p=3$. It therefore functions more as a normative correction rather than a substantial redistribution of burden. In our analysis, it is applied to the survey-aligned scenario and to capacity on its own as we assessed its effects on allocation.

Development Floor analysis

The development discount as a function of HDI is presented in **Figure S3**. Countries below the HDI threshold of 0.7 receive a reduced capacity score, with the largest reductions applied to the least-developed countries. For example, the United States and China remain unaffected because they are above the threshold, while India, which sits just below the threshold is barely discounted. Kenya’s capacity is reduced to about four-fifths of its original value, and South Sudan is reduced to less than a third. The progressivity parameter alters the steepness of the curve, with $p=3$ creating the strongest reductions for low-HDI countries, and $p=1$ representing the least progressive.

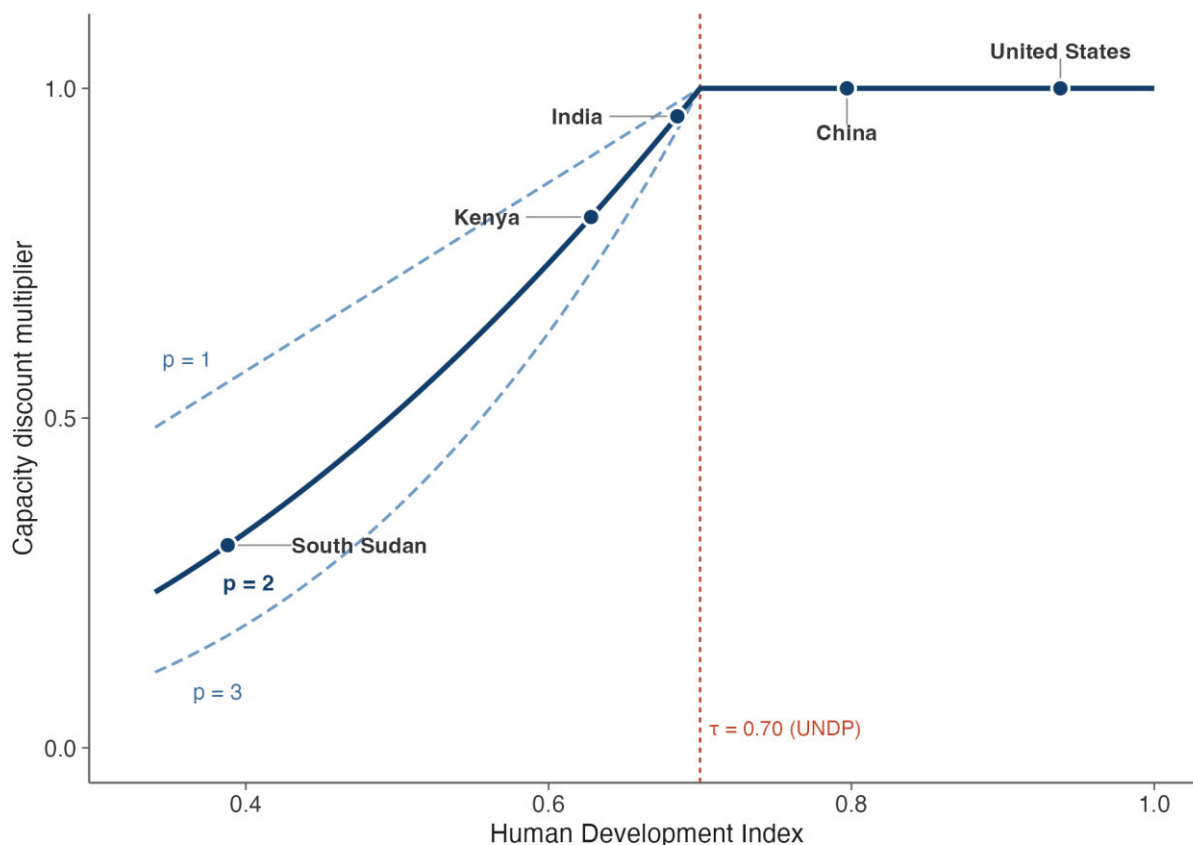


Figure S1. Development floor adjustment applied to the capacity indicator as a function of the Human Development Index (HDI). Countries below the HDI threshold of 0.7 receive a reduced capacity score, with larger reductions for countries with lower HDI values. Countries at or above the threshold retain their full capacity score. The discount parameter (p) is an adjustable parameter of progressivity and is set by default at $p=2$ (solid line).

Functionally, the development floor relieves the countries with the highest development need. 68 countries fall below the threshold and are therefore discounted, and the countries with the most development needs see large discounts to their share. For example, South Sudan has its share reduced by 69% and Somalia by 66%. The average relief across the discounted group is roughly a third. Even so, the development floor only relocates 0.87% of the total, reflecting the relatively low portion of global GDP the countries with the most needs represent. What little is redistributed goes to the largest economies, with the U.S. taking +0.25 percentage points and China +0.16.

Adjusting the progressivity of the discount from 1 to 3 almost doubles the relief given to the countries most in need (South Sudan's discount increases from 45% to 83%). This moves the

amount redistributed from 0.48% to 1.19%. Therefore, the development floor and progressivity dial acts as a way to indicate that capacity should not be counted at face value given the varied need for development within nations, but it does not redistribute the burden substantially.

Appendix S5. Cross-border support for domestic consumption targets.

The consumption theme allows for a similar analysis done for Target 3 in **Section 3.3**. Because target 16 sets no national obligations, the 45° line in **Figure S2** represents a figurative goal of a 30% reduction in national raw-material consumption to display when allocated reduction effort equals a country's 30% target. When this benchmark is applied to the “capacity + current impact overseas” scenario, 138 countries are allocated effort beyond a 30% reduction in consumption. France is allocated 3.3 times its proportional share, and Germany 1.9 times, while China is allocated half its 30% target (5,800Mt).

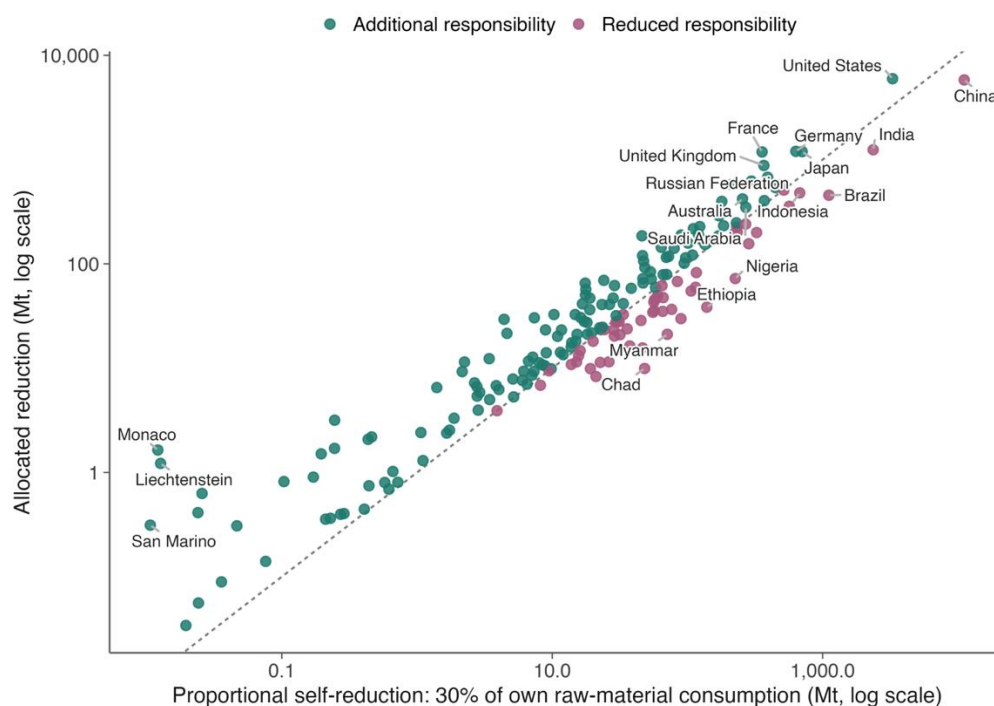


Figure S2. Allocated raw-material consumption reduction (Mt) under the capacity + cumulative impact 50/50 scenario vs. the reduction required to achieve a hypothetical 30% national reduction target, matching the proportion used to define the global pool (**Section 2.3**). Each point represents a country. The dashed 45° line marks where allocated effort equals a country's

30% reduction goal. Countries above the line are allocated additional effort beyond their domestic 30% target, whereas those below the line are allocated reduced effort.

Appendix S6. *Conservation Biology* guide for authors

Link to author guidelines for the journal *Conservation Biology*:

<https://conbio.onlinelibrary.wiley.com/hub/journal/25784854/homepage/author-guidelines>