SCIENCE ADVANCES | RESEARCH ARTICLE

SCIENCE POLICY

A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate

E. Dinerstein[1]*, A. R. Joshi[2], C. Vynne[1], A. T. L. Lee[1], F. Pharand-Deschênes[3,4], M. França[4], S. Fernando[1], T. Birch[5], K. Burkart[6], G. P. Asner[7], D. Olson[8]

Global strategies to halt the dual crises of biodiversity loss and climate change are often formulated separately, even though they are interdependent and risk failure if pursued in isolation. The Global Safety Net maps how expanded nature conservation addresses both overarching threats. We identify 50% of the terrestrial realm that, if conserved, would reverse further biodiversity loss, prevent CO_2 emissions from land conversion, and enhance natural carbon removal. This framework shows that, beyond the 15.1% land area currently protected, 35.3% of land area is needed to conserve additional sites of particular importance for biodiversity and stabilize the climate. Fifty ecoregions and 20 countries contribute disproportionately to proposed targets. Indigenous lands overlap extensively with the Global Safety Net. Conserving the Global Safety Net could support public health by reducing the potential for zoonotic diseases like COVID-19 from emerging in the future.

INTRODUCTION

Approximately half of Earth's terrestrial surface is considered to be in a natural or seminatural condition (*1*, *2*). How does this remaining habitat overlap with global conservation priorities and carbon storage requirements? This paper highlights sites of particular importance for biodiversity where additional conservation attention is needed, and other intact lands of high value for carbon storage and other ecosystem services. It also depicts the coincidence and disparities between terrestrial biodiversity and carbon storage priorities. This spatially explicit output, entitled the Global Safety Net for saving life on Earth, is intended to be a dynamic tool to support multilateral, national, and subnational land use planning efforts.

While the parallel crises of biodiversity loss and climate change have generally been approached separately, a key solution for two of the most pressing challenges of our time is the same: conserve enough nature and in the right places. Analyses designed to protect biological diversity have converged on the need to conserve and connect approximately half the Earth (*1*, *3*, *4*). In addition, several studies indicate that above 1.5°C in global average temperature rise, many ecosystems would be unable to adapt and, with increased biodiversity loss, could collapse (*5*). Nature-based solutions offer essential means to achieving the global climate objective of staying below 1.5°C (*6*–*8*). Achieving a future in which people and nature thrive is possible, but more ambitious conservation targets will be required (*9*, *10*).

To this end, a Global Deal for Nature has been proposed as a time-bound, science-based plan to be paired with the Paris Climate Agreement to save the diversity and abundance of life on Earth (*11*). This framework describes a set of science-based targets—organized by country and ecoregion—that would be required to conserve the vast majority of terrestrial plant and animal species. The Global Deal for Nature framework is mutually supportive of policies to address climate change. Scaling nature conservation offers fast and cost-effective measures to help stabilize the climate while providing cobenefits from ecosystem services such as the provisioning of clean air and water and the reduction in edge effects that could lead to future disease outbreaks.

The need for an ambitious global conservation agenda has taken on a new urgency in 2020 after the rapid spread of the COVID-19 virus. Global shifts in mammalian population trends reveal key predictors of virus spillover risk (*12*). Extensive deforestation in the tropics has led to humans coming into greater direct contact with vector-borne pathogens (e.g., Zika virus, which emerged from mosquito carriers in the Lake Victoria Basin forest-savanna) or via mammalian carriers that serve as viral hosts (e.g., HIV virus, which emerged from primates in the Northeast Congolian lowland forests). As important, achieving the area-based targets to protect all remaining intact and semi-intact terrestrial habitats would be an effective solution to reduce contact zones, helping to limit the chance of zoonotic diseases from affecting human populations in the future.

Here, using the Global Deal for Nature as a guiding framework, we examine where conservation of the terrestrial realm could be scaled to support biodiversity by securing additional lands to improve the resilience of ecosystems and secure terrestrial carbon stocks, both of which are essential if we are to have a chance of achieving the 1.5°C goal. The Global Safety Net explicitly avoids areas of concentrated human settlement, but it does not exclude resident human populations at relatively low densities in remote areas. We view this as a positive because, in particular, the sustained presence of indigenous communities within intact areas can have long-term benefits for both biodiversity and carbon storage (*13*).

This initial version of the Global Safety Net includes 11 spatial layers that, when combined, address expanded biodiversity protection and climate stabilization for the terrestrial realm. We also scope out a preliminary system of wildlife and climate corridors to identify the approximate amount of land that would be required to connect protected areas and intact landscapes. Besides mapping and assessing remaining natural habitat, we present tables of optimized contributions by ecoregion and by country required to maximize both biodiversity outcomes and land-based carbon storage. We also show how these targets may overlap with indigenous lands.

---

[1]RESOLVE, Washington, DC, USA. [2]University of Minnesota, Minneapolis, MN, USA. [3]Globaïa, Wellington, New Zealand. [4]EarthX, London, UK. [5]Google, Mountain View, CA, USA. [6]One Earth, Rockefeller Philanthropy, Los Angeles, CA, USA. [7]Arizona State University, Tempe, AZ, USA. [8]World Wildlife Fund, Hong Kong SAR.
*Corresponding author. Email: edinerstein@resolve.ngo

One potential application of the Global Safety Net is to inform the development of "common but differentiated" targets under the new post-2020 framework of the Convention on Biological Diversity (CBD). It could also help guide land-based mitigation in Nationally Determined Contributions made under the United Nations (UN) Framework Convention on Climate Change. The digital map of the Global Safety Net can be disaggregated by country, ecoregion, and indigenous territory, to shed light on overarching questions: How much does an ecoregion or country contribute to meeting global biodiversity targets? Do ecoregions identified as priorities for biodiversity protection also contribute disproportionately to carbon storage? What is the potential role of indigenous peoples' lands in supporting biodiversity protection and climate stabilization? Which ecoregions and countries will require the greatest investment in connectivity? At a local scale, the Global Safety Net can serve as a framework to align subnational land use planning efforts with global conservation and climate targets. The reverse is also imperative, as regional conservation planning efforts can replace various parts of the global layers where they are available.

Elements of the terrestrial Global Safety Net

We anchored the Global Safety Net with the current network of global protected areas (*14*). This network performs fairly well in representing sites important to narrow-range endemic vertebrates, yet gaps remain (*15*). The Global Safety Net fills in those gaps and targets other elements of biodiversity that need additional conservation attention. We built the Global Safety Net by mapping a comprehensive set of biodiversity elements to determine how much unprotected land needs increased conservation attention. To the extent possible, we included only remaining habitat and avoided agricultural lands. We then assessed where additional conservation measures are needed to achieve climate targets. Third, we created a preliminary network of wildlife and climate corridors to connect remaining natural habitat.

Target 1: Conserving the diversity and abundance of life on Earth

This target is designed to achieve, by 2030, conservation of unprotected biodiversity. For ease of conceptualization and presentation of results, these data layers can be logically placed into four clusters based on ecological factors, areal extent, or both. These include species rarity, distinct species assemblages, rare phenomena, and intactness. The first cluster, species rarity, is intended to capture species that are naturally rare—that is, they have narrow ranges, occur at low densities, or exhibit both conditions (*16*). The following are the six layers comprising the species rarity cluster: single populations of endangered species [Alliance for Zero Extinction sites (AZE); zeroextinction.org], an estimate of range rarity in vertebrates (*17*), ranges of threatened vertebrate species (iucnredlist.org), key biodiversity areas (KBAs) (*18*), vertebrate species distributions (*15*), and a new study of the spatial distribution of species rarity in plants (*19*). The distinct species assemblages cluster, intended to capture β-diversity—the turnover of plant and animal species communities with distance and along elevational or environmental gradients—includes remaining unprotected habitat of the biodiversity hot spots (*20*) and ecoregions of high β-diversity (*11*). Rare phenomena addresses unprotected landscapes containing rare global phenomena; here, we include areas containing the last intact large mammal assemblages of the terrestrial realm (including species such as large mammalian carnivores that are rare locally but range widely) (*21*). The fourth cluster, intactness, is composed of unprotected parts of the Last of the Wild in each ecoregion (*22*) and other wilderness areas (*23*) that provide potential macrorefugia for wildlife and representation of fauna.

Target 2: Enhancing carbon storage and drawdown

To identify important carbon stores, we used a map of total carbon biomass—a composite of above ground, below ground, and soil carbon (*24*). We first identified ecoregions above 215 metric tons (MT) of total carbon biomass per hectare, which is the median level across the 846 terrestrial ecoregions. We then overlaid the high carbon storage areas with areas selected under target 1 to determine overlap with important carbon reservoirs. Where coverage from target 1 was insufficient to meet climate objectives, we mapped additional areas containing high carbon stocks, designated as tier 1 climate stabilization areas (CSAs). We also mapped tier 2 CSAs, places that contribute to carbon storage and drawdown ranging between 50 and 215 MT of total carbon biomass per hectare. Ecoregions with median total carbon density per hectare of <50 MT were not included in this analysis.

Target 3: Wildlife and climate corridors: A scoping exercise

Connectivity is a time-bound issue of global consequence, yet most conservation plans fail to address potential climate corridors or interecoregional connectivity (*1*). Pressures on remaining natural habitats from land clearing and infrastructure development are so intense that options to maintain connectivity that exist today may disappear within a decade. Currently, only half of the 15.1% of the current roster of terrestrial protected areas are connected (*25*). If managed or restored to allow species movement, a system of comprehensive wildlife and climate corridors could connect the world's remaining intact habitats and enable adaptation in a rapidly changing world. To this end, we conducted the first global scoping exercise on connectivity and then checked against mapping studies of corridors delineated at national, ecoregional, and regional scales and published in the peer-reviewed literature or adopted by national agencies in various countries.

RESULTS

Target 1: Conserving the diversity and abundance of life on Earth

The 11 biodiversity layers underpinning the Global Safety Net add 30.6% (41,049,630 km^2) of unprotected land surface to the 15.1% currently protected (Table 1 and Fig. 1). This addition includes 14.6% for species-based approaches (clusters 1 to 3) and 16.0% for habitat intactness (cluster 4). Together with protected areas, these areas encompass 45.7% of the terrestrial realm where nature conservation should be a primary objective in the near term (Fig. 1). Areas identified for increased conservation attention under target 1 are concentrated in 45 ecoregions that contribute 10.9% to the 30.6% increase (Table 2) and 20 countries (Table 3 and table S3). The inclusion of some large, unprotected KBAs in a few nontropical forest ecoregions and countries, for instance, Sahelian Acacia Savanna and Russia, respectively, contributed their higher ranks in cluster 1 by size. Overall, conserving target 1 would increase representation by ecoregion across all major biogeographic realms and ensure continued storage of 1.36 million megatons of carbon (see target 2 below).

Widely used optimization approaches for global priority setting to map species rarity add only 3,047,787 km^2 or 2.3% of new area to the 15.1% already protected (Table 1 and Fig. 1). Overlaying the first global data layer of rare plant species distributions with rare and threatened vertebrates adds but 0.2% (198,231 km^2) to the 2.3%

Table 1. Elements of the Global Safety Net to expand protection of terrestrial biodiversity and stabilize climate beyond the current extent of protected areas and a scoping exercise to enhance connectivity.

Dataset name	Area	Total land surface	Est. total carbon (*24*)	Overlap with mapped indigenous lands (*26*)	
	(km^2)	(%)	(megaton)	(km^2)	(%)
Total land surface*	134,126,000	100.00	2,923,028	37,900,308	28
Global terrestrial protected areas	20,210,878	15.07	484,929	8,032,078	40
Unique contribution of currently unprotected lands[†]					
Target 1. Conserving the diversity and abundance of life on Earth (terrestrial)					
Cluster 1: Species rarity[‡]	3,047,787	2.27	75,638	526,739	17
Cluster 2: Distinct species assemblages	8,072,308	6.02	239,978	3,235,858	40
Cluster 3: Rare phenomena	8,414,171	6.27	442,625	4,092,873	49
Cluster 4: Intactness	21,515,364	16.04	602,157	7,157,106	33
Subtotal	41,049,630	30.61	1,360,399	15,042,327	37
Target 2. Enhancing carbon drawdown and storage					
Tier 1 climate stabilization areas[§]	2,337,236	1.74	82,878	309,899	13
Tier 2 climate stabilization areas[‖]	3,946,581	2.94	48,122	549,335	14
Subtotal	6,283,826	4.69	131,000	859,234	14
Total area to achieve targets 1 and 2	47,333,457	35.29	1,420,499	15,871,809	34
Total area for greater conservation attention within the Global Safety Net (including current protected areas (*14*))	67,544,335	50.36	1,905,428	23,903,887	35
Target 3. Wildlife and climate corridors: A scoping exercise[¶]					
Area required if targets 1 and 2 achieved	3,584,614				
Area required if targets 1 and 2 are not achieved (existing protected areas only)	5,705,206				

*On the basis of Earth's total terrestrial area excluding Antarctica. †Subtracts overlap with previous datasets. ‡All layers in cluster 1, except rare plant species, include a 1-km buffer around each site. §Includes ecoregions with median total carbon density above 215 MT/ha. ‖Includes ecoregions with median total carbon density between 50 to 215 MT/ha. ¶On the basis of corridor width of 2.5 km.

total for species rarity. While the amount of land is small, these areas are highly concentrated and irreplaceable for species conservation. Unprotected areas containing distinct species assemblages draw from 279 ecoregions that add 8,072,308 km^2 or 6.0% to the total of 30.6% for enhanced protection (Table 1 and Fig. 1). Rare phenomena (intact large mammal assemblages) contributed 6.3% (8,414,171 km^2) to the 30.6% increase.

The greatest extension by area to increasing global biodiversity protection comes from the inclusion of intactness (Fig. 1). These areas comprise over 21.5 million km^2 of unprotected habitat or 16.0% of the total land surface (Table 1). Grouped together, rare phenomena and intactness are primarily found in the taiga and tundra ecoregions in Siberia and Northern Canada. Russia and Canada and species-rich habitats in Brazil, the United States, Australia, and China contain almost 75% of the total area that could be added by targeting intactness while also conserving the most carbon (Tables 2 and 3).

Target 2: Enhancing carbon drawdown and storage through additional CSAs

We identified currently unprotected high-carbon areas that must be conserved to meet global climate targets. A by-product of conserving areas high in biodiversity value is that most, but not all such areas, also store the most carbon (Fig. 2). In ecoregions where the median total carbon density is above 215 MT/ha, a total of 29,247,979 km^2 of terrestrial area storing 1,331,834 megatons of carbon require increased conservation attention for carbon storage. Ninety-two percent of this area is already captured in target 1 (Fig. 2 and table S2), underlining the interdependence of carbon and biodiversity and the importance of these lands to achieve the dual goals

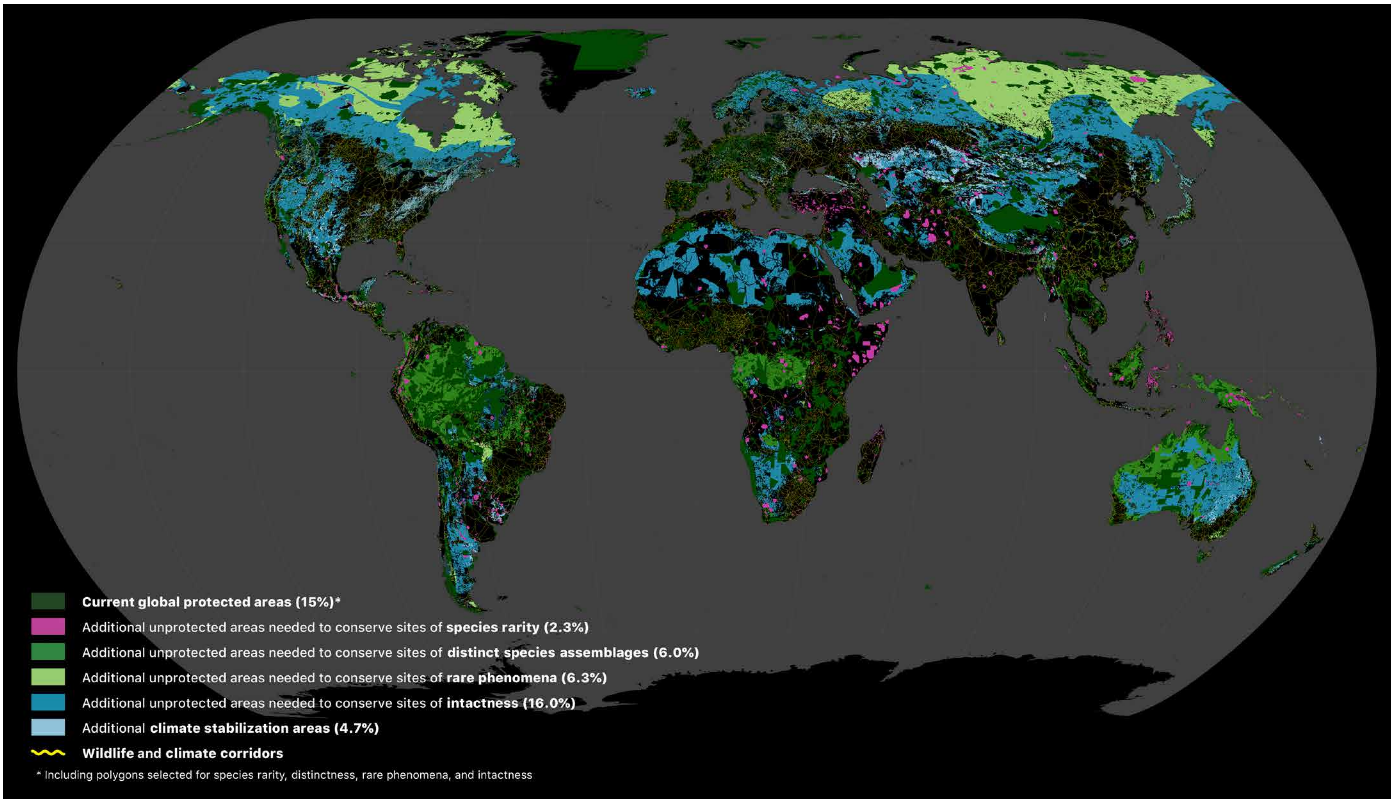

Fig. 1. Areas of the terrestrial realm where increased conservation action is needed to protect biodiversity and store carbon. Numbers in parentheses show the percentage of total land area of Earth contributed by each set of layers. Unprotected habitats drawn from the 11 biodiversity data layers underpinning the Global Safety Net augment the current 15.1% protected with an additional 30.6% required to safeguard biodiversity. Additional CSAs add a further 4.7% of the terrestrial realm. Also shown are the wildlife and climate corridors to connect intact habitats (yellow lines). Data are available for interactive viewing at www.globalsafetynet.app.

of biodiversity conservation and climate stabilization. To bridge the gap for adequate carbon storage beyond areas identified in target 1, the remaining 2,337,246 km^2 or 1.7% of Earth's land surface was selected as tier 1 CSAs in target 2 (Fig. 2).

In addition, we identified 3,946,581 km^2 of unprotected land, or 2.9% of Earth's surface, as tier 2 CSAs. Together, tiers 1 and 2 CSAs add 6,283,826 km^2 of currently unprotected lands, or 4.7% of global land area, to the Global Safety Net. These land areas store an estimated 131,000 megatons of carbon (Table 1). Indigenous lands (*26*) contribute extensively to carbon storage. Greater than 74% of all mapped indigenous lands (28,123,013 km^2) are tier 1 or tier 2 CSAs, and together, these areas store >931,000 megatons of carbon biomass.

Combined targets

Together, the two targets described above and currently protected areas that form the Global Safety Net cover 50.4% of the terrestrial realm as regions to enhance biodiversity protection and carbon storage (Table 1 and Fig. 1). Approximately 34% of the area in targets 1 and 2 is indigenous land (*26*). The overlap is particularly pronounced in high β-diversity ecoregions (41%; cluster 2), cluster 3 rare phenomena (49%), and cluster 4 intactness (33%). This includes many ecoregions in the tundra, boreal, tropical forests, and xeric biomes (table S1). We map results on a finer scale across five biogeographic realms—Neotropic, Nearctic, Afrotropic, Palearctic, and Indo-Malayan (Fig. 3, A to D). All mapped layers are available for online viewing at www.globalsafetynet.app.

Target 3: Wildlife and climate corridors: A scoping exercise

The scoping exercise on connectivity revealed the relatively small percentage of land that would be required to connect all intact areas. The percentage drops by almost half if the areas set aside for conservation under targets 1 and 2 are achieved. Connecting all current terrestrial protected areas via potential wildlife and climate corridors (using 2.5 km as an average corridor width) adds 5,705,206 km^2 or 4.3% of the terrestrial realm. Connecting proposed Global Safety Net areas (targets 1 and 2) would require substantially less total area for corridors to connect all intact terrestrial habitats if all targets are met. Connectivity varies greatly by biome, biogeographic realm, and within each realm. In general, Tundra and Taiga still retain excellent connectivity, less so in tropical forests outside the Congo Basin, Amazonia, and New Guinea, and xeric formations. The most fragmented biomes requiring extensive corridors to achieve connectivity are temperate grasslands, tropical dry forests, and tropical grasslands.

DISCUSSION

Interdependence of climate and biodiversity strategies and targets

Recent reports of tipping points and accelerating feedback loops related to climate change have profound implications for the need to scale nature-based solutions (*27*, *28*). Furthermore, new climate models highlight the important role of halting land use–driven

Table 2. Fifty ecoregions that contribute most to enhancing biodiversity protection and carbon storage through the addition of currently unprotected lands.

Ecoregion name	ID	Realm	Potential contribution of unprotected lands		Median total carbon density (MT/ha)	Est. total carbon (megatons)	Overlap with mapped indigenous lands	
			(km^2)	(% of land surface)			(km^2)	(% overlap)
Target 1: Conserving the diversity and abundance of life on Earth (terrestrial)								
Cluster 1: Species rarity			3,047,787	2.27		75,638	526,739	17
Sahelian Acacia Savanna	53	Afrotropic	64,794	0.05	32	207	12,873	20
Central Range Papuan Montane Rain Forests	139	Australasia	49,794	0.04	661	3,291	1,007	2
Sulawesi Montane Rain Forests	157	Australasia	45,021	0.03	520	2,341	31,674	70
Madagascar Humid Forests	17	Afrotropic	41,708	0.03	306	1,276	–	0
Mindanao-Eastern Visayas Rain Forests	247	Indomalayan	41,492	0.03	315	1,307	6,890	17
Registan-North Pakistan Sandy Desert	838	Palearctic	41,450	0.03	22	91	132	0
Southern Anatolian Montane Conifer and Deciduous Forests	804	Palearctic	40,482	0.03	151	611	–	0
Sulawesi Lowland Rain Forests	156	Australasia	38,542	0.03	389	1,499	17,016	44
Uruguayan Savanna	574	Neotropic	36,728	0.03	162	595	1	0
Northwest Andean Montane Forests	486	Neotropic	36,137	0.03	506	1,829	4,727	13
Taimyr-Central Siberian Tundra	781	Palearctic	35,932	0.03	549	1,973	29,660	83
Eastern Mediterranean Conifer-Broadleaf Forests	791	Palearctic	33,990	0.03	103	350	220	1
Northeast Siberian Taiga	714	Palearctic	32,581	0.02	504	1,642	502	2
Humid Chaco	571	Neotropic	31,479	0.02	196	617	4,572	15
Cerrado	567	Neotropic	30,602	0.02	128	392	250	1
Eastern Cordillera Real Montane Forests	460	Neotropic	30,133	0.02	470	1,416	7,509	25
Luzon Rain Forests	241	Indomalayan	29,630	0.02	257	761	3,099	10
Dry Chaco	569	Neotropic	29,224	0.02	151	441	2,896	10
Somali Acacia-Commiphora Bushlands and Thickets	55	Afrotropic	29,107	0.02	104	303	12,055	41
Napo Moist Forests	483	Neotropic	28,275	0.02	498	1,408	16,295	58
Albertine Rift Montane Forests	1	Afrotropic	27,559	0.02	286	788	1,697	6
Central Asian Northern Desert	817	Palearctic	27,436	0.02	71	195	–	0
Kazakh Steppe	732	Palearctic	27,040	0.02	246	665	–	0
Central Bushveld	38	Afrotropic	25,579	0.02	69	176	–	0
Taklimakan Desert	843	Palearctic	25,165	0.02	63	159	11,549	46
Subtotal of top 25 ecoregions			879,881	0.66		24,335	164,623	19
Cluster 2: Distinct species assemblages			8,072,308	6.02		239,978	3,235,858	40
Great Sandy-Tanami Desert	210	Australasia	485,000	0.36	44	2,134	404,287	83

continued on next page

Ecoregion name	ID	Realm	Potential contribution of unprotected lands		Median total carbon density (MT/ha)	Est. total carbon (megatons)	Overlap with mapped indigenous lands	
			(km^2)	(% of land surface)			(km^2)	(% overlap)
Southwest Amazon Moist Forests	505	Neotropic	390,591	0.29	299	11,679	100,613	26
Northeast Congolian Lowland Forests	24	Afrotropic	335,644	0.25	270	9,062	46,102	14
Carpentaria Tropical Savanna	184	Australasia	302,470	0.23	72	2,178	154,446	51
Central Congolian Lowland Forests	3	Afrotropic	290,187	0.22	286	8,299	112,087	39
Northwest Congolian Lowland Forests	26	Afrotropic	280,551	0.21	304	8,529	81,550	29
Guianan Lowland Moist Forests	465	Neotropic	270,402	0.20	311	8,410	65,002	24
Borneo Lowland Rain Forests	219	Indomalayan	246,876	0.18	588	14,516	179,866	73
Madeira-Tapajós Moist Forests	476	Neotropic	237,641	0.18	273	6,488	21,861	9
Kimberly Tropical Savanna	186	Australasia	219,780	0.16	77	1,692	156,686	71
Subtotal of top 10 ecoregions			3,059,146	2.28		72,987	1,322,501	43
Clusters 3 and 4: Rare phenomena and intactness			29,929,535	22.31		1,044,782	11,249,979	38
East Siberian Taiga	710	Palearctic	3,191,009	2.38	432	137,851	2,296,934	72
West Siberian Taiga	720	Palearctic	1,101,626	0.82	955	105,205	852,961	77
Scandinavian and Russian Taiga	717	Palearctic	907,079	0.68	464	42,088	188,611	21
Northeast Siberian Taiga	714	Palearctic	893,387	0.67	504	45,027	635,724	71
North Saharan Xeric Steppe and Woodland	833	Palearctic	876,310	0.65	17	1,490	140,665	16
Canadian Middle Arctic Tundra	414	Nearctic	811,954	0.61	559	45,388	176,023	22
South Sahara Desert	842	Palearctic	772,701	0.58	11	850	396,380	51
Taimyr-Central Siberian Tundra	781	Palearctic	742,422	0.55	549	40,759	557,934	75
Eastern Canadian Shield Taiga	374	Nearctic	712,100	0.53	386	27,487	1,007	0
Canadian Low Arctic Tundra	413	Nearctic	683,279	0.51	563	38,469	162,758	24
Subtotal of top 10 ecoregions			10,691,867	7.97		484,615		51
Target 2: Enhancing carbon drawdown and storage								
Tier 1 climate stabilization areas			2,342,989	1.78		83,087	311,330	13
Sarmatic Mixed forests	679	Palearctic	252,482	0.19	422	10,655	–	0
Kazakh Steppe	732	Palearctic	178,348	0.13	246	4,387	–	0
West Siberian Taiga	720	Palearctic	105,467	0.08	955	10,072	56,333	53
Tian Shan Montane Steppe and Meadows	767	Palearctic	103,509	0.08	229	2,370	30,866	30
New England-Acadian Forests	338	Nearctic	99,898	0.08	345	3,446	445	0
Subtotal of top 5 ecoregions			739,704	0.55		31,227	87,643	12

emissions to meet global climate targets. Staying below the 1.5°C limit will require much of the world's remaining habitat—and a substantial amount of restored habitat in forest biomes—be put under some form of conservation by 2030 (*29*). Advances being championed under the two conventions responsible for biodiversity and climate—the Convention on Biological Diversity and the UN Framework Convention on Climate Change—must be accelerated if we are to protect the abundance and diversity of life on Earth and stabilize the climate. A holistic solution is emerging that will accelerate both efforts: conserve at least half and in the right places (*9*, *11*). The Global Safety Net provides a pathway for using nature-based solutions to unite the two work streams.

The spatial coincidence of areas important for biodiversity conservation and carbon storage has long been suspected but is strongly confirmed here. The ecoregions and countries that score high for rare phenomena and intactness (clusters 3 and 4) conserve 1,044,783 megatons of carbon, equivalent to 35.7% of the total carbon present in natural habitats (Table 1). The gains in carbon storage achieved by adding protection of rare phenomena, a single layer, is comparable to carbon storage levels in the 15.1% of land that is currently in protected areas. By focusing conservation effort intensely on high β-diversity ecoregions, large mammal assemblages, intact areas, and wilderness, the payoff for climate stability is enormous.

The Global Safety Net framework presented here contrasts with the classic questions posed by conservation biologists: "How much is enough to save the biodiversity of each biome or ecoregion?" and "How do we protect all species globally in optimization approaches that conserve the greatest number of endemic or threatened species in the smallest area?" These concerns become less relevant under the extensive land conservation requirements of a 1.5°C climate pathway. The various global priority-setting approaches should be viewed as noncompeting: All are necessary to reverse biodiversity loss and stabilize the global climate system. A hopeful outcome of this framework and its implications for conservation is that every stakeholder and group can unite under the goal of staying below the dangerous threshold of 1.5°C in global average temperature rise, beyond which it would likely be too late to achieve most of the biodiversity goals set forth in the Convention on Biological Diversity.

Restoration

One overlooked area of research that should inform future iterations of the Global Safety Net is the restoration opportunities on degraded lands (*30*). These degraded landscapes could be restored to address both climate and biodiversity concerns. Further, reconnecting forest corridors in degraded lands could offset emissions that will occur before a moratorium on land-based emissions is reached. Focusing restoration efforts on degraded lands that can serve as wildlife corridors could help achieve other objectives, such as the Bonn Challenge (*31*). Similarly, massive tree-planting programs, if designed using native species and planted to restore corridors, riparian and coastal vegetation, and upper watersheds, could contribute to stabilizing climate and restoring connectivity.

Major opportunities exist for restoration of forests using native plants. Ecoregions such as the Atlantic Forest of Brazil, several forest ecoregions in Madagascar, and the Western Ghats of India are currently underrepresented in this version of the Global Safety Net, which is focused on protection of remaining habitat. Restoration opportunities should drive future iterations and allow for monitoring of recovery efforts. A prime example is the mid-elevation forests of Nepal, previously one of the more deforested and degraded ecoregions, where intensive community forestry programs have led to nearly doubling forest cover in 24 years (*32*), increasing carbon stocks from 213.42 to 502.03 megatons.

Indigenous lands

The overlay of mapped indigenous territories with spatial targets 1 to 3 reveals an extensive overlap of 37% and underscores the central role that indigenous peoples and their lands play to preserve biodiversity and regulate Earth's atmosphere (*26*, *33*, *34*). Another observation is echoed by other conservation biologists who have examined maps of indigenous lands and global biodiversity priorities: A 30% area–based target for protection by 2030, as advocated by many groups to the Convention on Biological Diversity, effectively already exists when accounting for indigenous lands, should effectively conserved lands be formally acknowledged by governments as other area-based effective conservation measures (OECMs) (*35*). In short, the "30 × 30" target is far less ambitious when viewed through this perspective. Many conservation organizations, indigenous peoples, and local communities have called for an area-based target of "at least 50%" under the Convention on Biological Diversity. Explicit in these calls is to allow for the protection of the land rights and traditional management practices of communities most at risk to food insecurity, the negative impacts of land degradation, and climate change.

Can a Global Safety Net be created in time?

There are reasons to support the notion that a Global Safety Net encompassing approximately 50% of land area is achievable. Addressing indigenous land claims, upholding existing land tenure rights, and resourcing programs on indigenous-managed lands could help achieve biodiversity objectives on as much as one-third of the area required by the Global Safety Net. Simultaneously, this focus would positively address social justice and human rights concerns. In addition, economists are examining pathways for scaling conservation and restoration across all land jurisdictions (*36*). New research from the World Economic Forum ties half the world's gross domestic product—$44 trillion dollars—directly to nature and its services (*37*). The recent COVID-19 crisis has demonstrated the ability of the world's governments to mobilize trillions of dollars, and there are a number of proposals emerging to tie environmental restoration and climate response to economic recovery. CSAs offer one framework to move beyond the incrementalism of protected area designation over the past couple of decades. Last, a key finding of this study is that species closest to the brink of extinction or where rare species concentrate could be protected by an addition of only 2.3% more land area if allocated to the right places and well managed. That target should be achievable within 5 years.

The connectivity analysis offers a template to build from and engage local and regional entities in designing programs centered on restoring connectivity. This effort could merge with global habitat restoration and native tree-planting initiatives now under way. Investments needed for the establishment and management of additional protected areas and restoration of degraded lands, while substantial, are small compared with enormous fossil fuel subsidies. The estimated $4.7 trillion per year in fossil fuel subsidies are expected to decline as the Paris Climate Agreement is implemented, making government resources available for restoring, rather than destroying, our global climate system.

Today, the emergence of a strong advocacy for science-based targets offers hope of an accelerated timeline for delivery far faster than we might expect. National-level leadership to champion the Global Safety Net and, by extension, the Global Deal for Nature, could ideally come from the list of 20 countries where increased conservation attention is most needed (Table 3). Russia, Brazil, Indonesia, and the United States have an outsized role to play and abundant internal resources to do so. Leadership could also come from

Table 3. Top countries that contribute most to enhancing biodiversity protection through the addition of currently unprotected lands (target 1).

Country name	Potential contribution of unprotected lands		Overlap with mapped indigenous lands	
	(km^2)	**(% of land surface)**	**(km^2)**	**(% overlap)**
Cluster 1: Species rarity	3,047,787	2.27	526,739	17
Russia	209,303	0.16	85,912	41
Indonesia	167,755	0.13	81,534	49
Turkey	154,675	0.12	–	0
China	128,963	0.10	36,686	28
Argentina	119,732	0.09	32,961	28
Brazil	114,098	0.09	911	1
Philippines	107,095	0.08	19,008	18
Kazakhstan	104,034	0.08	–	0
Australia	99,955	0.07	41,080	41
Papua New Guinea	99,468	0.07	–	0
Subtotal of top 10 countries	1,305,078	0.97	298,093	23
Cluster 2: Distinct species assemblages	8,072,308	6.02	3,235,858	40
Australia	1,580,457	1.18	1,033,319	65
Brazil	1,025,312	0.76	42,350	4
Indonesia	810,872	0.60	524,929	65
Democratic Republic of the Congo	726,843	0.54	188,665	26
Colombia	542,762	0.40	257,344	47
Peru	449,408	0.34	169,896	38
Papua New Guinea	266,264	0.20	91,577	34
China	264,675	0.20	10	0
Bolivia	229,561	0.17	63,642	28
Guyana	154,616	0.12	21,539	14
Subtotal of top 10 countries	6,050,770	4.51	2,393,273	40
Clusters 3 and 4: Rare phenomena and intactness	29,929,535	22.31	11,249,979	38
Russia	9,715,587	7.24	6,703,659	69
Canada	6,711,800	5.00	557,055	8
Australia	2,143,745	1.60	1,149,499	54
United States of America	2,116,096	1.58	240,141	11
China	1,191,623	0.89	707,847	59
Saudi Arabia	858,089	0.64	281	0
Algeria	715,269	0.53	260,128	36
Libya	660,683	0.49	87,753	13
Argentina	568,778	0.42	128,449	23
Brazil	512,384	0.38	10,957	2
Subtotal of top 10 countries	25,194,055	18.78	9,845,767	39

countries such as Costa Rica, Peru, Namibia, and others, creating their own national safety nets that incorporate the landmark conservation plans of each nation's constituent ecoregions, including adjacent marine ecoregions. In the United States, one could envision a California Safety Net or Maine Safety Net built from enhanced terrestrial and marine ecoregion plans. The Global Safety Net could also inform country-scale conservation and development plans, supporting UN conventions through an overlap analysis with outputs of the Country Emissions Gap Reports (*38*).

Similar to the Paris Climate Agreement, and in alignment with the Sustainable Development Goal 15 (SDG15), a Global Deal for Nature calls for common but differentiated contributions by every

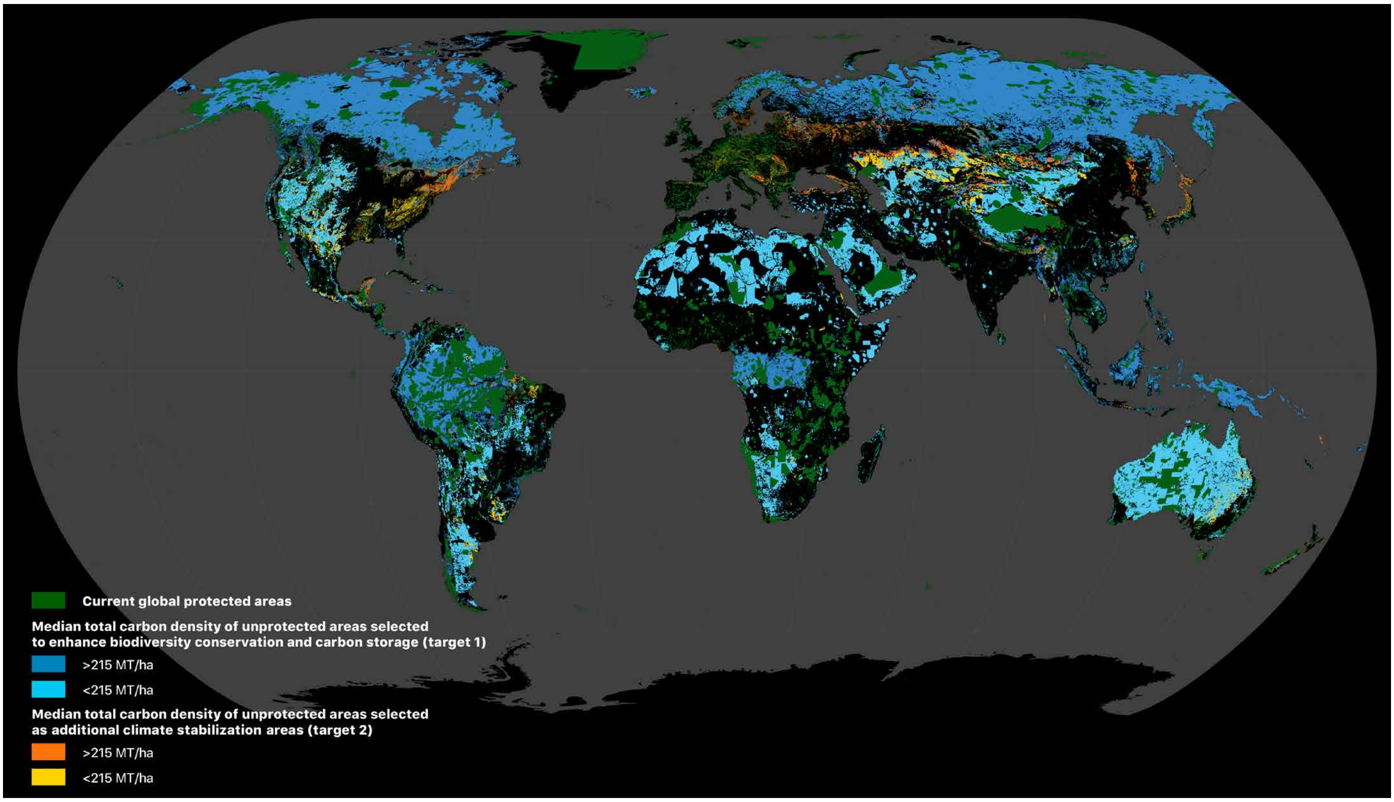

Fig. 2. Interdependence of carbon and biodiversity. Currently unprotected high-carbon areas with median total carbon >215 MT/ha overlap extensively (92.0%) with areas selected under target 1, highlighting the importance of these lands for biodiversity conservation and climate stabilization. Other areas important for biodiversity but of lower carbon value, i.e., <215 MT/ha, are also shown. Additional CSAs, including tier 1 and tier 2 CSAs, are also selected to bridge the gap for adequate carbon storage beyond areas identified in target 1.

nation on Earth toward the collective goal of protecting ecosystems, halting land degradation, and stopping biodiversity loss. Most conservation efforts and land use decisions are local or regional in nature, and implementation of the Global Safety Net will occur from the ground up, by district, state, province, and nation. Saving biological diversity and stabilizing the climate will require increased conservation action, but the tools and designations will vary by place and must be locally appropriate. Countries and indigenous communities will use a variety of designations from International Union for Conservation of Nature (IUCN) category 1 protection levels, to OECMs, to CSAs managed for retaining vegetative cover and preventing emissions.

While our analysis makes a distinction between areas managed for biodiversity and those additional areas managed for climate stabilization, a target could still be reached if land were designated as a CSA and managed for priority species. In the current environment, we could also envision intact areas set aside under a pandemic prevention program. These natural habitats would be managed and protected to avoid conversion and reduce human contact with pathogens that lead to zoonotic diseases in areas of high risk. Protecting wildlife in these pandemic prevention areas from overhunting, restricting access to bat caves and roosts, could also reduce the potential for more catastrophic outbreaks.

Future iterations of the Global Safety Net should incorporate additional biodiversity metrics (including marine and freshwater species) and layers that could help inform food and water security. Current and future energy and transportation infrastructure should also be included. Connectivity analyses should be refined by ecoregion to account for the habitats and species populations requiring connectivity and to account for likely climate impacts. To this end, we have designed this version of the Global Safety Net to be updated by adding new data layers and allowing for dynamic analyses via Google Earth Engine (*39*), so that targets may be adjusted in real time as changes in land use occur. Future iterations can also incorporate higher-resolution ecoregional plans, recent spatial data on arable land, agricultural productivity, yield gaps, energy needs and resources, water balance, and the most recent climate models and various carbon maps. Ultimately, these evolving maps can refine pathways for conserving Earth's land surface to save the diversity and abundance of life, to produce enough food for humanity, and to stay within the bounds of a safe operating space to ensure the well-being of future generations.

For the Global Safety Net to be politically achievable requires broad engagement from civil society, public agencies, communities, and indigenous peoples. Yet, it is also essential to state clearly that the formulation of the Global Safety Net in no way is intended, is not based on, and does not advocate taking current agricultural land out of production, removing indigenous or other people from lands, or implying that 50% of all 846 terrestrial ecoregions be conserved. In particular, with regard to indigenous peoples, the Global Safety Net reaffirms their role as essential guardians of nature.

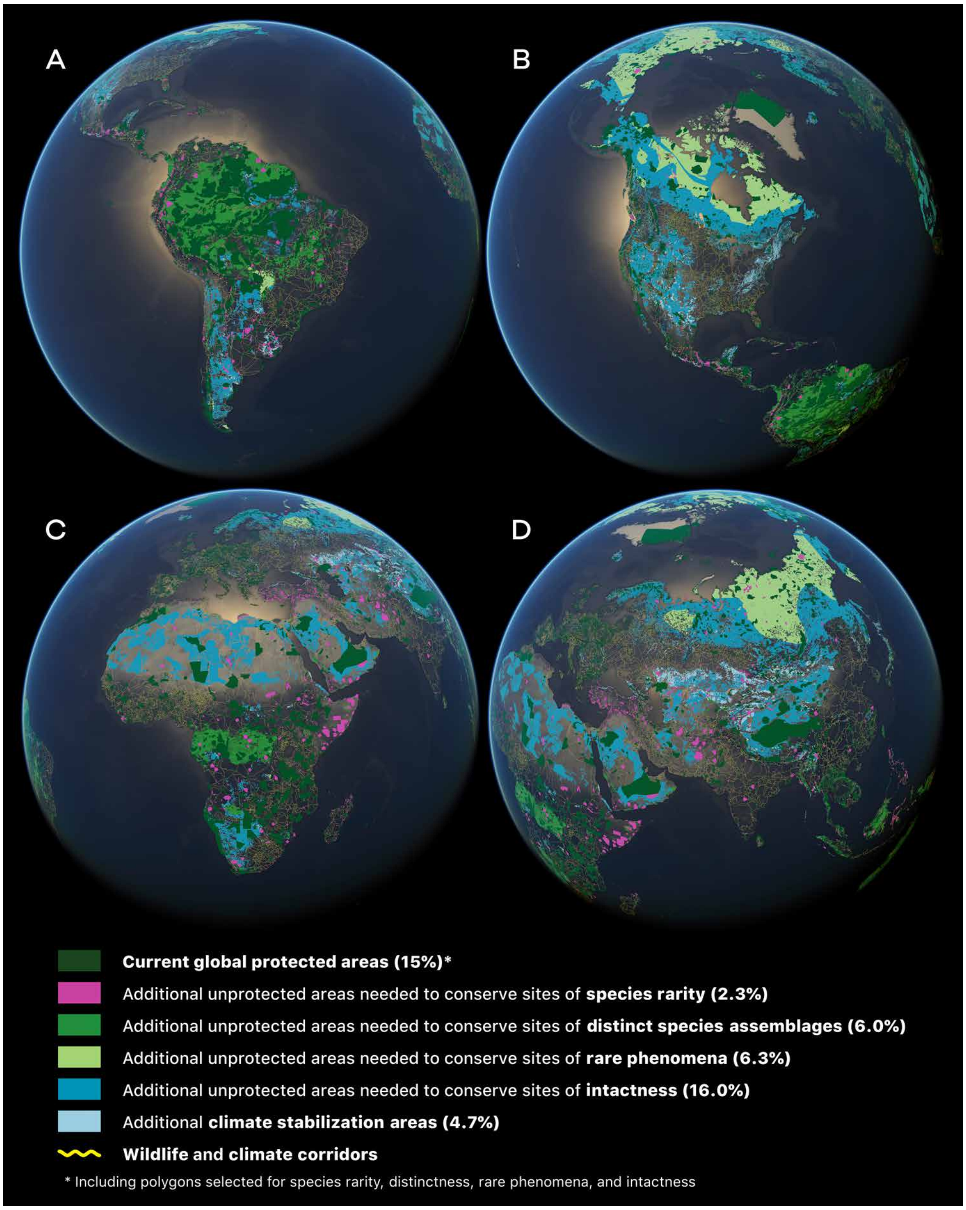

Fig. 3. The Global Safety Net made more visible in a close-up of five biogeographic realms. Shown here are Neotropic (A), Nearctic (B), Afrotropic (C), and Palearctic and Indo-Malayan (D) (adjacent realms partly included). Existing protected areas are expanded to account for additional lands requiring increased conservation attention (target 1), augmented by additional CSAs (target 2), and connected by potential wildlife and climate corridors (target 3). Numbers in parentheses show the percentage of total land area of Earth contributed by each set of layers. To explore the component terrestrial layers of the Global Safety Net, please visit www.globalsafetynet.app. Indigenous lands are not shown but overlap extensively with proposed areas for increased conservation attention (see table S2 for ecoregions depicted in Fig. 3).

The level of planning and foresight that is needed to properly scale nature conservation requires the emergence of a worldview that embraces the notion of stewardship at a planetary scale. Decades after the famous motto “think globally, act locally” was coined, the Global Safety Net offers a possible solution to today’s converging socioecological crises, from local to global. Human societies are late in the game to rectify impending climate breakdown, massive biodiversity loss, and, now, prevent pandemics. The Global Safety Net, if erected promptly, offers a way for humanity to catch up and rebound.

MATERIALS AND METHODS

Rationale for data layers and sources

Species rarity (layers 1 to 6)

Many species are naturally rare, that is, they have narrow ranges, occur at low densities, or exhibit both conditions (*16*). Other species may once have been widespread and common, but as a result of human activities such as habitat conversion, overhunting, or invasive species, now have limited ranges or few remaining individuals. Conservation biologists have devoted considerable effort to mapping narrow range endemic and threatened species. Most of these data layers are generated using optimization approaches to conserve the maximum number of species in the smallest area possible.

Distinct species assemblages (layers 7 to 8)

Almost all conservation priority mapping to date is informed by α-diversity—the number of species present in a given area. Much neglected is β-diversity—the turnover of plant and animal species communities with distance and along elevational or environmental gradients. The turnover effect creates distinct species assemblages, a conservation priority in its own right. High levels of β-diversity are characteristic across tropical moist forest, tropical dry forest, tropical grassland and savanna, tropical montane grasslands, Mediterranean climate shrublands, and some of the tropical xeric biome. Many of the high–β-diversity ecoregions have undergone extensive conversion and are recognized as biodiversity hot spots (*20*).

Rare ecological and evolutionary phenomena (hereafter rare phenomena; layer 9)

This cluster addresses unprotected landscapes containing rare global phenomena. Here, we include areas containing the last intact large mammal assemblages of the terrestrial realm (including species such as large mammalian carnivores that are rare locally but range widely) (*21*). Some of these large polygons also overlap with terrestrial large-mammal migrations of the most wide-ranging large-mammal species, perhaps the most endangered ecological phenomenon on Earth (*40*).

The latter element is not comprehensively mapped on a global scale but could be added to this category. Other rare ecological and evolutionary phenomena, not included in this formulation, are aggregations of breeding species, sites of adaptive radiations across multiple taxa, and migratory stopover sites. Some of the polygons selected in layers 1 to 8 and 10 and 11 encompass these incompletely mapped elements of biodiversity. KBAs, for example, include many migratory stopover sites and breeding aggregations of birds.

Intactness (layers 10 and 11)

Maps of wilderness and intact forest landscapes show that structurally intact habitats are increasingly rare (*23*, *41*). Large intact habitats contain ecological features that cannot be conserved in the small polygons characteristic of ecological elements in the first two clusters. To this end, we included the Last of the Wild in each ecoregion (*22*) and wilderness areas (*23*).

Mapping the elements

The current version of the Global Safety Net is formulated from 11 biodiversity layers (fig. S1, A to K, and table S1). We partitioned two of the above datasets to calculate a median pixel values: IUCN range-size rarity raster (median = 0.006) (*17*) and small-range vertebrates raster (median = 24) (*15*). For both datasets, only pixels greater than or equal to the median values were used. In the case of rare plant species, to be conservative, we excluded pixels containing only one to two rare plant species. The rationale here is that some of these are known from one to a few specimens. All raster data were converted to vector data (polygon) for further analysis.

We overlaid each of these biodiversity data layers with all terrestrial protected areas (*14*) to remove areas already set aside for conservation. To remove double counting, we subtracted any overlapping areas with previous datasets. For example, all AZEs are included as KBAs. We ingested resulting layers into the Google Earth Engine to derive remaining habitat in each layer using percent tree-cover maps (*42*) in forested ecoregions (except boreal forests) and excluded globally significant patterns of human land use and populations (“anthromes”) in nonforested ecoregions (*43*) [see (*1*) for detailed methods]. We selected all nonoverlapping unprotected areas within each of layers 1 to 4 and only the remaining habitat for layers 5 and 6 as contributions toward target 1. For layers 1 to 5 within “species rarity,” we added a 1-km buffer around all unprotected sites except layer 6, rare plant species, as the size of a “rare plant pixel” was ~10,000 km^2.

To estimate carbon storage potential by biodiversity layer to construct (Fig. 2, Table 1, and table S1), we first overlaid a map of total carbon biomass (*24*)—which includes above ground, below ground, and soil carbon—with terrestrial ecoregion boundaries (*1*) to derive the median carbon density for each ecoregion. To determine CSAs, we selected ecoregions with a median total carbon density >215 MT/ha as candidates for tier 1 CSAs. Ecoregions with a median total carbon density between 50 and 215 MT/ha were designated as tier 2 CSA candidates. Ecoregions with low levels of carbon density (<50 MT of total carbon per hectare) were not selected as potential sites for additional CSAs. We then selected all remaining habitat outside protected areas after removing any overlap with the 11 biodiversity layers to derive the polygons for tier 1 and tier 2 CSAs.

On the basis of the best available literature, we designed wildlife corridors to meet the ecological requirements of the most wide-ranging species that must disperse as part of their life histories and climate corridors that would allow species movement up and down mountainsides, along riparian corridors, or across human-dominated landscapes (*44*). The connectivity analysis was a computationally intensive analysis that included producing a cost-distance matrix, weighing land cover classifications, buffering, and processing. The cost-distance matrix surface was developed as a surface intended to represent varying levels of resistance for wildlife to move along a landscape with regard to vegetation cover, slope, roads, and other land uses. While future iterations should be more specific to ecoregions and local fauna, for this first global scoping phase, we used continents as the unit of analysis and corridors were modeled considering variables that are potentially important for the gene flow of terrestrial species generally. We weighted both variables and classes, depending on the type of data, so that higher weights were given for factors that have higher costs. Land cover data were obtained from the European Spatial Agency with a spatial resolution of 300 m and was reclassified considering the degree of anthropized areas. Urban areas and water bodies were excluded from the modeling. Roads, railways, and mining areas were buffered. The design of the corridor network and the links between core areas was done with the Linkage Mapper Toolkit of the Circuitscape project (www.circuitscape.org). A full description of the methods is available from the authors.

Sources of variation

Here, we identify five potential sources of variation in our results that could be improved in future iterations of the Global Safety Net. We also point to how variants in methods or data sources differ from other, recent efforts to map global biodiversity (*3*, *15*).

1) Total areal extent of the terrestrial realm

The total land surface we used to produce the Global Safety Net is based on Earth’s entire terrestrial area excluding Antarctica, which amounts to 134,126,000 km^2. Much of Antarctica includes rock and ice, and the 18 tundra ecoregions on the continent do not contribute to the key targets of the Global Safety Net. The total land area calculated by this method is closely comparable to that adapted by the World Database on Protected Areas from which they derive the 15.1% terrestrial coverage that is the standard used in other biodiversity analyses in preparation for the Convention on Biological Diversity. As a result, the Global Safety Net does differ from other studies—Allan *et al.* (*3*)—that use a larger total terrestrial area estimate of about 146,000,000 km^2. The 44% of Earth's terrestrial area that Allan *et al.* (*3*) call for increased conservation attention amounts to 64 million km^2. In contrast, the 45.7% of Earth's terrestrial area included under Global Safety Net for currently protected areas and target 1 totals 61.3 million km^2.

2) Potential but limited error of inclusion of nonhabitat from cluster 1 datasets

When applying layers 1 to 4 of cluster 1, we used the original polygons provided by the authors of each dataset. As a result, these four data layers include varying amounts of nonhabitat within each selected polygon. We did not apply habitat suitability modeling to refine these datasets as it would further fragment these critical areas for narrow-range and rare species, which could have detrimental effects for biodiversity conservation, especially where some of these adjacent nonhabitat areas are prime candidate for restoration or reconnecting via wildlife corridors. For those reasons, we used the original polygons, including nonhabitat areas, in our analysis for cluster 1. The inclusion of nonhabitat areas is essentially moot because of its limited spatial extent: Summing the entire area of nonhabitat from layers 1 to 4 adds only 388,089 km^2 (or 0.3% of the total land surface of Earth to the 2.3% selected for cluster 1). We suggest removal of nonhabitat is best performed at the ecoregion scale by local experts and done on a case-by-case basis.

3) Remaining habitats in layers 5 to 11

A goal for the Global Safety Net is to identify near-term opportunities to achieve the global nature conservation target, i.e., areas where additional protection can have the most effective conservation outcome. Thus, we focused on suitable natural habitat remaining without the need for major restoration. We therefore selected only intact or semi-intact habitat remaining outside currently protected areas to derive potential contributions to the Global Safety Net from layers 5 to 11 (clusters 1 to 4) and from additional areas for carbon storage (CSAs).

4) Indigenous lands

We overlaid the Global Safety Net with the most recent global map of lands managed or controlled by indigenous peoples (*26*) to determine the extent to which such lands overlap with the existing network of protected areas. The intent was to illustrate the role such lands could have in enhancing biodiversity protection and carbon storage if this were the intention of peoples managing such areas. Two sources of variation are noted: (i) Many indigenous peoples' lands remain unmapped. Blank areas merely indicate that no publicly available datasets currently indicate the presence of indigenous peoples from those areas; the map, however, should not imply absence of indigenous peoples. (ii) The scale at which indigenous lands are mapped in is based on multiple public datasets varying greatly in spatial resolution (*26*). For example, polygons in the Sahara and in the tundra ecoregions are much larger and more coarse grained than those mapped within the United States and the Brazilian Amazon.

5) Using median carbon density per hectare across the ecoregion as a proxy for carbon value for individual pixels in each ecoregion

Total carbon was mapped as metric tons per hectare for each pixel (pixel size ~0.09 km^2 at the equator) (*24*). We used the zonal statistic tool in ArcMap 10.6.1 to calculate median total carbon value for each of Earth's 846 terrestrial ecoregions (*1*). As a result, the values for median total carbon density per ecoregion include pixels that are classified as protected areas, remaining habitat outside protected areas, and nonhabitat (e.g., cities and agricultural lands). To estimate the total carbon that could be safeguarded via additional protection of lands under targets 1 and 2, we multiplied the carbon density of the ecoregion by the area of remaining habitat for each data layer in that ecoregion that could contribute to the Global Safety Net. However, our approach implies that the total carbon added in certain ecoregions may be overestimated or underestimated. For example, in an ecoregion where the majority of the habitat is protected, the median total carbon density per hectare for the ecoregion could be higher than the carbon density per hectare of the habitat remaining outside protected areas. Alternatively, in an ecoregion containing a large expanse of nonhabitat (urban areas or converted lands for agriculture), the median total carbon density for the ecoregion might be lower than the carbon density of the habitat remaining outside protected areas.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/6/36/eabb2824/DC1

REFERENCES AND NOTES

1. E. Dinerstein, D. Olson, A. Joshi, C. Vynne, N. D. Burgess, E. Wikramanayake, N. Hahn, S. Palminteri, P. Hedao, R. Noss, M. Hansen, H. Locke, E. C. Ellis, B. Jones, C. V. Barber, R. Hayes, C. Kormos, V. Martin, E. Crist, W. Sechrest, L. Price, J. E. M. Baillie, D. Weeden, K. Suckling, C. Davis, N. Sizer, R. Moore, D. Thau, T. Birch, P. Potapov, S. Turubanova, A. Tyukavina, N. de Souza, L. Pintea, J. C. Brito, O. A. Llewellyn, A. G. Miller, A. Patzelt, S. A. Ghazanfar, J. Timberlake, H. Klöser, Y. Shennan-Farpon, R. Kindt, J.-P. B. Lillesø, P. van Breugel, L. Graudal, M. Voge, K. F. Al-Shammari, M. Saleem, An ecoregion-based approach to protecting half the terrestrial realm. *Bioscience* **67**, 534–545 (2017).
2. C. M. Kennedy, J. R. Oakleaf, D. M. Theobald, S. Baruch-Mordo, J. Kiesecker, Managing the middle: A shift in conservation priorities based on the global human modification gradient. *Glob. Chang. Biol.* **25**, 811–826 (2019).
3. J. R. Allan, H. P. Possingham, S. C. Atkinson, A. Waldron, M. Di Marco, V. M. Adams, S. H. M. Butchart, O. Venter, M. Maron, B. A. Williams, K. R. Jones, P. Visconti, B. A. Wintle, A. E. Reside, J. E. M. Watson, Conservation attention necessary across at least 44% of Earth's terrestrial area to safeguard biodiversity. *bioRxiv*, 839977 (2019).
4. R. F. Noss, A. P. Dobson, R. Baldwin, P. Beier, C. R. Davis, D. A. Dellasala, J. Francis, H. Locke, K. Nowak, R. Lopez, C. Reining, S. C. Trombulak, G. Tabor, Bolder thinking for conservation. *Conserv. Biol.* **26**, 1–4 (2012).
5. T. E. Lovejoy, L. Hannah, Eds. *Biodiversity and Climate Change: Transforming the Biosphere* (Yale Univ. Press, 2019).
6. B. W. Griscom, J. Adams, P. W. Ellis, R. A. Houghton, G. Lomax, D. A. Miteva, W. H. Schlesinger, D. Schoch, J. V. Siikamäki, P. Smith, P. Woodbury, C. Zganjar, A. Blackman, J. Campari, R. T. Conant, C. Delgado, P. Elias, T. Gopalakrishna, M. R. Hamsik, M. Herrero, J. Kiesecker, E. Landis, L. Laestadius, S. M. Leavitt, S. Minnemeyer, S. Polasky, P. Potapov, F. E. Putz, S. Sanderman, M. Silvius, E. Wollenberg, J. Fargione, Natural climate solutions. *Proc. Natl. Acad. Sci. U.S.A.* **114**, 11645–11650 (2017).
7. S. Roe, C. Streck, M. Obersteiner, S. Frank, B. Griscom, L. Drouet, O. Fricko, M. Gusti, N. Harris, T. Hasegawa, Z. Hausfather, P. Havlík, J. House, G.-J. Nabuurs, A. Popp, M. J. S. Sánchez, J. Sanderman, P. Smith, E. Stehfest, D. Lawrence, Contribution of the land sector to a 1.5°C world. *Nat. Clim. Chang.* **9**, 817–828 (2019).
8. S. L. Maxwell, T. Evans, J. E. M. Watson, A. Morel, H. Grantham, A. Duncan, N. Harris, P. Potapov, R. K. Runting, O. Venter, S. Wang, Y. Mahi, Degradation and forgone removals increase the carbon impact of intact forest loss by 626%. *Sci. Adv.* **5**, eaax2546 (2019).

9. L. Hannah, P. R. Roehrdanz, P. A. Marquet, B. J. Enquist, G. Midgley, W. Foden, J. C. Lovett, R. T. Corlett, D. Corcoran, S. H. M. Butchart, B. Boyle, X. Feng, B. Maitner, J. Fajardo, B. J. McGill, C. Merow, N. Morueta-Holme, E. A. Newman, D. S. Park, N. Raes, J.-C. Svenning, 30% land conservation and climate action reduces tropical extinction risk by more than 50%. *Ecography* **43**, 943–953 (2020).
10. H. M. Tallis, P. L. Hawthorne, S. Polasky, J. Reid, M. W. Beck, K. Brauman, J. M. Bielicki, S. Binder, M. G. Burgess, E. Cassidy, A. Clark, J. Fargione, E. T. Game, J. Gerber, F. Isbell, J. Kiesecker, R. McDonald, M. Metian, J. L. Molnar, J. L. Mueller, C. O'Connell, D. Ovando, M. Troell, T. M. Boucher, B. McPeek, An attainable global vision for conservation and human well-being. *Front. Ecol. Environ.* **16**, 563–570 (2018).
11. E. Dinerstein, C. Vynne, E. Sala, A. R. Joshi, S. Fernando, T. E. Lovejoy, J. Mayorga, D. Olson, G. P. Asner, J. E. M. Baillie, N. D. Burgess, K. Burkart, R. F. Noss, Y. P. Zhang, A. Baccini, T. Birch, N. Hahn, L. N. Joppa, E. Wikramanayke, A Global Deal for Nature: Guiding principles, milestones, and targets. *Sci. Adv.* **5**, eaaw2869 (2019).
12. C. K. Johnson, P. L. Hitchens, P. S. Pandit, J. Rushmore, T. S. Evans, C. C. W. Young, M. M. Doyle, Global shifts in mammalian population trends reveal key predictors of virus spillover risk. *Proc. R. Soc. B Biol. Sci.* **287**, 20192736 (2020).
13. R. Schuster, R. R. Germain, J. R. Bennett, N. J. Reo, P. Arcese, Vertebrate biodiversity on indigenous-managed lands in Australia, Brazil, and Canada equals that in protected areas. *Envir. Sci. Pol.* **101**, 1–6 (2019).
14. IUCN, UNEP-WCMC, The World Database on Protected Areas (WDPA, 2018); www.protectedplanet.net.
15. S. L. Pimm, C. N. Jenkins, B. V. Li, How to protect half of Earth to ensure it protects sufficient biodiversity. *Sci. Adv.* **4**, eaat2616 (2018).
16. W. E. Kunin, K. J. Gaston, The biology of rarity: Patterns, causes and consequences. *Trends Ecol. Evol.* **8**, 298–301 (1993).
17. S. L. L. Hill, A. Arnell, C. Maney, S. H. M. Butchart, C. Hilton-Taylor, C. Ciciarelli, C. Davis, E. Dinerstein, A. Purvis, N. D. Burgess, Measuring forest biodiversity status and changes globally. *Front. For. Glob. Chang.* **2**, 70 (2019).
18. Birdlife International, Digital boundaries of Key Biodiversity Areas from the World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Global Wildlife Conservation, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and World Wildlife Fund (2018); keybiodiversityareas.org/site/requestgis.
19. B. J. Enquist, X. Feng, B. Boyle, B. Maitner, E. A. Newman, P. M. Jørgensen, P. R. Roehrdanz, B. M. Thiers, J. R. Burger, R. T. Corlett, T. L. P. Couvreur, G. Dauby, J. C. Donoghue, W. Foden, J. C. Lovett, P. A. Marquet, C. Merow, G. Midgley, N. Morueta-Holme, D. M. Neves, A. T. Oliveira-Filho, N. J. B. Kraft, D. S. Park, R. K. Peet, M. Pillet, J. M. Serra-Diaz, B. Sandel, M. Schildhauer, I. Šímová, C. Violle, J. J. Wieringa, S. K. Wiser, L. Hannah, J.-C. Svenning, B. J. McGill, The commonness of rarity: Global and future distribution of rarity across land plants. *Sci. Adv.* **5**, eaaz0414 (2019).
20. M. Norman, Biodiversity hotspots revisited. *Bioscience* **53**, 916–917 (2003).
21. J. C. Morrison, W. Sechrest, E. Dinerstein, D. S. Wilcove, J. F. Lamoreux, Persistence of large mammal faunas as indicators of global human impacts. *J. Mammal.* **88**, 1363–1380 (2007).
22. A. J. Plumptre, D. Baisero, W. Jędrzejewski, H. Kühl, F. Maisels, J. C. Ray, E. W. Sanderson, S. Strindberg, M. Voigt, S. Wich, Are we capturing faunal intactness? A comparison of intact forest landscapes and the "last of the wild in each ecoregion". *Front. Forests Glob. Chang.* **2**, 24 (2019).
23. O. Venter, E. W. Sanderson, A. Magrach, J. R. Allan, J. Beher, K. R. Jones, H. P. Possingham, W. F. Laurance, P. Wood, B. M. Fekete, M. A. Levy, J. E. M. Watson, Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nat. Commun.* **7**, 12558 (2016).
24. C. Soto-Navarro, C. Ravilious, A. Arnell, X. de Lamo, M. Harfoot, S. L. L. Hill, O. R. Wearn, M. Santoro, A. Bouvet, S. Mermoz, T. Le Toan, J. Xia, S. Liu, W. Yuan, S. A. Spawn, H. K. Gibbs, S. Ferrier, T. Harwood, R. Alkemade, A. M. Schipper, G. Schmidt-Traub, B. Strassburg, L. Miles, N. D. Burgess, V. Kapos, Mapping co-benefits for carbon storage and biodiversity to inform conservation policy and action. *Philos. Trans. R. Soc. B Biol. Sci.* **375**, 20190128 (2020).
25. S. Saura, B. Bertzky, L. Bastin, L. Battistella, A. Mandrici, G. Dubois, Protected area connectivity: Shortfalls in global targets and country-level priorities. *Biol. Conserv.* **219**, 53–67 (2018).
26. S. T. Garnett, N. D. Burgess, J. E. Fa, A. Fernández-Llamazares, Z. Molnár, C. J. Robinson, J. E. M. Watson, K. K. Zander, B. Austin, E. S. Bondizio, N. F. Collier, T. Duncan, E. Ellis, H. Geyle, M. V. Jackson, H. Jonas, P. Malmer, B. McGowan, A. Sivongxay, I. Leiper, A spatial overview of the global importance of Indigenous lands for conservation. *Nat. Sustain.* **1**, 369–374 (2018).
27. C. H. Trisos, C. Merow, A. L. Pigot, The projected timing of abrupt ecological disruption from climate change. *Nature* **580**, 496–501 (2020).
28. T. E. Lovejoy, C. Nobre, Amazon tipping point: Last chance for action. *Sci. Adv.* **5**, eaba2949 (2019).
29. S. Teske, Ed., Achieving The Paris Climate Agreement Goals, *Global and Regional 100% Renewable Energy Scenarios with Non-Energy GHG Pathways for +1.5°C and +2°C* (Springer, 2019).
30. P. H. S. Brancalion, A. Niamir, E. Broadbent, R. Crouzeilles, F. S. M. Barros, A. M. Almeyda Zambrano, A. Baccini, J. Aronson, S. Goetz, J. L. Reid, B. B. N. Strassburg, S. Wilson, R. L. Chazdon, Global restoration opportunities in tropical rainforest landscapes. *Sci. Adv.* **5**, eaav3223 (2019).
31. IUCN, Bonn Challenge (2011); bonnchallenge.org.
32. J. Fox, S. Saksena, K. Hurni, J. Van Den Hoek, A. C. Smith, R. Chhetri, P. Sharma, Mapping and understanding changes in tree cover in Nepal: 1992 to 2016. *J. Forest Livelihood* **18**, 1 (2019).
33. J. E. Fa, J. E. M. Watson, I. Leiper, P. Potapov, T. D. Evans, N. D. Burgess, Z. Molnár, A. Fernández-llamazares, T. Duncan, S. Wang, B. J. Austin, H. Jonas, C. J. Robinson, P. Malmer, K. K. Zander, M. V. Jackson, E. Ellis, E. S. Bondizio, S. T. Garnett, Importance of indigenous peoples' lands for the conservation of intact forest landscapes. *Front. Ecol. Environ.* **18**, 135–140 (2020).
34. G. P. Asner, R. E. Martin, D. E. Knapp, R. Tupayachi, C. B. Anderson, F. Sinca, N. R. Vaughn, W. Llactayo, Airborne laser-guided imaging spectroscopy to map forest trait diversity and guide conservation. *Science* **355**, 385–389 (2017).
35. Precision, not slogans. Submission from Civil Society on the discussions of the Thematic Workshop on Area-based Conservation Measures. Montreal, Canada, 3 December 2019 (Montreal, 2019).
36. E. B. Barbier, J. C. Burgess, T. J. Dean, How to pay for saving biodiversity. *Science* **360**, 486–488 (2018).
37. World Economic Forum, Rising, Nature risk rising: Why the crisis engulfing nature matters for business and the economy (New Nature Economy Series, 2020).
38. UNEP, The Emissions Gap Report 2018, United Nations Environment Programme, Nairobi (2018).
39. N. Gorelick, M. Hancher, M. Dixon, S. Ilyushchenko, D. Thau, R. Moore, Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sens. Environ.* **202**, 18–27 (2017).
40. G. Harris, S. Thirgood, J. G. C. Hopcraft, J. P. G. M. Cromsigt, J. Berger, Global decline in aggregated migrations of large terrestrial mammals. *Endang. Species Res.* **7**, 55–76 (2009).
41. P. Potapov, M. C. Hansen, L. Laestadius, S. Turubanova, A. Yaroshenko, C. Thies, W. Smith, I. Zhuravleva, A. Komarova, S. Minnemeyer, E. Esipova, The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. *Sci. Adv.* **3**, e1600821 (2017).
42. M. C. Hansen, P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, J. R. G. Townshend, High-resolution global maps of 21st-century forest cover change. *Science* **342**, 850–853 (2013).
43. E. C. Ellis, K. K. Goldewijk, S. Siebert, D. Lightman, N. Ramankutty, Anthropogenic transformation of the biomes, 1700 to 2000. *Glob. Ecol. Biogeogr.* **19**, 589–606 (2010).
44. P. Beier, Conceptualizing and designing corridors for climate change. *Ecol. Restor.* **30**, 312–319 (2012).

Acknowledgments: We would like to thank D. Basiero, N. Burgess, S. Butchart, S. Garnett, C. Jenkins, R. Noss, S. Pimm, A. Plumptre, and two anonymous reviewers for comments on the manuscript. We thank the KBA Secretariat and UNEP-WCMC for sharing several data layers used in the analysis. **Funding:** This work was supported by a grant from One Earth. **Author contributions:** E.D., A.R.J., M.F., K.B., D.O., and C.V. designed the study. E.D. and C.V. drafted the manuscript. C.V. helped obtain data layers and permissions from authors. A.J. and M.F. performed the spatial analysis. A.T.L.L. and S.F. processed analysis output, generated the tables, and contributed to the Materials and Methods section. F.P.-D. generated the figures. G.P.A. and T.B. contributed to β-diversity and carbon sections and methods and editing. T.B., C.V., K.B., and A.R.J. helped create the website to serve as repository for data and also to rerun analyses on Google Earth Engine. All authors participated in manuscript and figure editing. **Competing interests:** The authors declare that they have no competing interests. **Data and materials availability:** All data needed to evaluate the conclusions in the paper are present in the paper and/or the Supplementary Materials. Additional data related to this paper are available at www.globalsafetynet.app concurrent with publication and may be requested from the authors.

Submitted 14 February 2020
Accepted 22 July 2020
Published 4 September 2020
10.1126/sciadv.abb2824

Citation: E. Dinerstein, A. R. Joshi, C. Vynne, A. T. L. Lee, F. Pharand-Deschênes, M. França, S. Fernando, T. Birch, K. Burkart, G. P. Asner, D. Olson, A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate. *Sci. Adv.* **6**, eabb2824 (2020).