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Co-benefits of and trade-offs between natural climate solutions and Sustainable Development Goals

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Combating climate change and achieving the UN Sustainable Development Goals (SDGs) are two important challenges facing humanity. Natural climate solutions (NCSs) can contribute to the achievement of these two commitments but can also generate conflicting trade-offs. Here, we reviewed the literature and drew on expert knowledge to assess the co-benefits of and trade-offs between 150 SDG targets and NCSs within 12 selected ecosystems. We demonstrate that terrestrial, coastal, and marine NCSs enable the attainment of different sets of SDG targets, with low redundancy. Implementing NCSs in various ecosystems would therefore maximize achievement of SDG targets but would also induce trade-offs, particularly if best practices are not followed. Reliance on NCSs at large scales will require that these trade-offs be taken into consideration to ensure the simultaneous realization of positive climate outcomes and multiple SDG targets for diverse stakeholders.

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In 2015, the world's leaders pledged to address two of the greatest challenges facing humanity: (i) ensure the sustainable development of human societies and (ii) limit climate change. To address the first challenge, member states of the UN adopted the 2030 Agenda for Sustainable Development, a comprehensive plan of actions for "people, planet, and prosperity", featuring 17 Sustainable Development Goals (SDG) and 169 associated targets (UN 2015). To address the second challenge, a legally binding international treaty on climate change was adopted by 196 parties under the UN Framework Convention on Climate Change to limit global warming to 1.5°C or well below 2°C relative to preindustrial levels (UNFCCC 2015). These two commitments are closely linked given that actions to mitigate climate change can have positive (co-benefits) or negative (trade-offs) impacts on human capacity to meet the SDG targets (Fuso Nerini *et al*. 2019; Soergel *et al*. 2021). However, developing effective strategies that simultaneously promote sustainable development and mitigate climate change may be difficult.

In a nutshell:

- Conservation, restoration, and ecosystem management actions that mitigate climate change are commonly referred to as natural climate solutions (NCSs)
- In addition to climate mitigation, NCSs should be sustainable and aim to improve people's livelihoods and well-being—all of which can be embedded within the UN Sustainable Development Goals (SDGs)
- Complementarity among terrestrial, coastal, and marine NCSs may aid in achieving multiple SDG targets
- However, because certain NCSs may hinder the achievement of certain SDG targets, trade-offs must be identified and considered during decision-making processes

Improved stewardship of global ecosystems to both reduce atmospheric greenhouse-gas (GHG) emissions and enhance carbon sinks is collectively referred to as a natural climate solution (NCS). Alongside drastic reductions in emissions (Dooley *et al*. 2022; Seddon 2022), NCSs are now recognized as cost-effective contributions (ie ≤US$100 per metric ton of carbon dioxide equivalent) to meet the goals specified in the 2015 UN Paris Agreement. NCSs may contribute 37% of the cost-effective mitigation needed between now and 2030 (Griscom *et al*. 2017; Girardin *et al*. 2021). If properly deployed, NCSs can also generate multiple benefits such as enhancing biodiversity, adapting to climate change, and promoting an acceptable and equitable quality of life for most people (Pörtner *et al*. 2021). For example, coastal blue carbon ecosystems, which act as carbon sinks (Duarte *et al*. 2013), can also improve coastal defenses against extreme natural disasters (eg tsunamis; Menéndez *et al*. 2020) and substantially support marine biodiversity and fisheries

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(Nordlund *et al.* 2018). In some circumstances, however, NCSs can inhibit the achievement of certain SDG targets, through trade-offs involving factors on which local people depend (eg avoiding mangrove conversion into aquaculture ponds can conflict with food production; Richards and Friess 2016). Thus, maximizing the number of SDG targets that can be achieved while minimizing undesirable trade-offs linked to NCS implementation is a major challenge, particularly in impoverished parts of the world, as "leave no-one behind" is a core principle of the SDGs. Yet the extent to which NCSs are linked to SDG targets and whether NCSs can be complementary in their coverage of SDG targets remain unassessed. Identifying such relationships is a much-needed step toward effective policy formulation as the world prepares to deploy NCSs at large scales (Pörtner *et al.* 2021).

Here, we reviewed the links between NCSs in 12 ecosystems and the SDG targets. We divided the 12 ecosystems into three groups: terrestrial (forest, peatland, urban forest, and grassland), coastal (mangrove, tidal marsh, seagrass meadow, and macroalgae), and marine (seabed, pelagic, mesopelagic, and Antarctic) systems (Figure 1; Appendix S1: Table S1), as the five latter ecosystems contain potential emerging NCSs. Although it has yet to be confirmed whether those potential NCSs will (i) have substantial and measurable climate mitigation potential and (ii) implement best practices to avoid or minimize impacts on native biodiversity, we nevertheless include them in our review to assess their impact on achieving the SDGs and their complementarity with well-established NCSs. This global analysis of the available evidence may not only inform strategies across fields of study, potentially requiring coordination in international policy, but also guide local decision-making processes.

Assessment of links and their complementarity

We assessed co-benefits of and trade-offs between the 20 NCSs identified by Griscom *et al.* (2017) as related to each of the 12 ecosystems and the 150 targets of SDGs 1–16 using evidence from the scientific literature (using Google Scholar queries) and expert knowledge (see Appendix S1: Table S2 and the GitHub link provided in the Data Availability Statement below, hereafter referred to as the GHLink). Scores

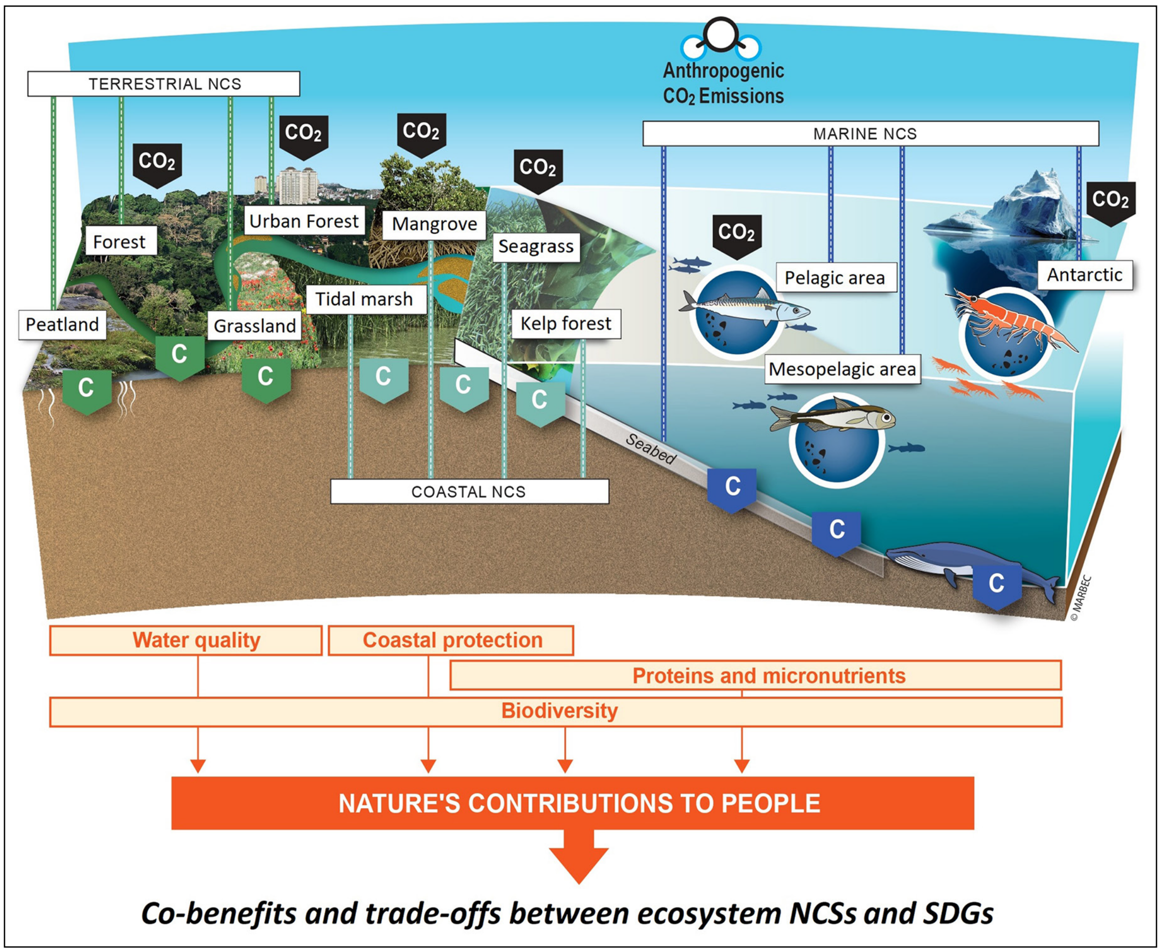

Figure 1. Links between natural climate solutions (NCSs) in 12 ecosystems and Sustainable Development Goals (SDGs). Measures that promote the protection, restoration, or sustainable management of ecosystems (NCSs) represent opportunities to meet both climate objectives and sustainable development objectives through nature's contributions to people. The list of nature's contributions to people is not exhaustive. Pentagons marked with a "C" represent carbon stocks.

between each ecosystem NCS and a given SDG target varied from –2 (trade-off) to +2 (co-benefit) based on the strength of each link and its scale of evidence. All links and resulting analyses were performed at the ecosystem level by merging co-benefits and trade-offs of the NCSs within a given ecosystem (the pool of NCSs in an ecosystem is hereafter called "ecosystem NCSs"). Because each ecosystem contains a different number of NCSs, this approach allowed us to assign the same weight to each ecosystem when analyzing the degree of complementarity between terrestrial, coastal, and marine NCSs. Given the number of potential links between each ecosystem NCS and each SDG target, we chose not to perform a systematic review of all possibilities. Instead, to ensure that we consulted a large enough portion of the relevant literature obtained through Google Scholar queries, we estimated how many search pages of references for each search result were needed to screen in order to capture a sufficient percentage (>70%) of relevant articles (Appendix S1: Panel S1; Singh *et al*. 2019).

We then used indicators of bipartite networks (modularity and nestedness) to assess the complementarity of ecosystem NCSs in achieving SDG targets. We also adapted ecological diversity indices to estimate the level of "insurance" (redundancy and vulnerability; Mouillot *et al*. 2014) for each SDG target through implementation of multiple ecosystem NCSs (Panel 1; Figure 2). SDG target redundancy reflected a relatively high level of repetition in identified linkages between NCS implementations across the 12 ecosystems and a given SDG target. By contrast, SDG target vulnerability corresponded to a low level of repetition in identified linkages after NCS implementations, in

Panel 1. Network vocabulary and indices

Bipartite network

A bipartite network (Figure 2a) is composed of two groups of nodes (large circles), with interactions between groups represented by edges (lines) (Dormann and Strauss 2014). Here, the two groups of nodes are the 12 ecosystem natural climate solutions (NCSs) (Group 1, top row) and the 150 Sustainable Development Goal (SDG) targets (Group 2, bottom row). In the top row, small circles within a large circle represent NCSs within an ecosystem.

Modularity

Modularity (Figure 2b) is defined as the extent to which a network is organized into distinct modules (clusters). Here, a module (M) can be interpreted as a group of ecosystem NCSs interacting with the same SDG targets. Values of modularity vary from 0 to 1 (Newman 2006). A high modularity of the network (value of 1) means that ecosystem NCSs enable the achievement of a different set of SDG targets and highlights the complementarity of ecosystem NCSs in SDG target achievement.

Nestedness (NODF)

Nestedness (Figure 2c) describes the extent to which ecosystem NCSs with fewer links are a subset of ecosystem NCSs with more links. Values of nestedness vary from 0 to 100, where values of 0 and 100 indicate non-nestedness and complete nestedness, respectively (Almeida-Neto *et al*. 2008). A low value means that ecosystem NCSs with fewer links achieve SDG targets that are not linked to other ecosystem NCSs.

Target insurance

The level of insurance (Figure 2d) of each SDG target depends on the number of ecosystem NCSs enabling its achievement. Here, a target linked to fewer ecosystem NCSs than expected by chance is vulnerable. A target linked to only one ecosystem NCS is highly vulnerable (HV), whereas a target linked to more ecosystem NCSs than expected by chance is redundant. For trade-offs, we use target insurance to assess the likelihood that various NCS implementations would reinforce trade-offs.

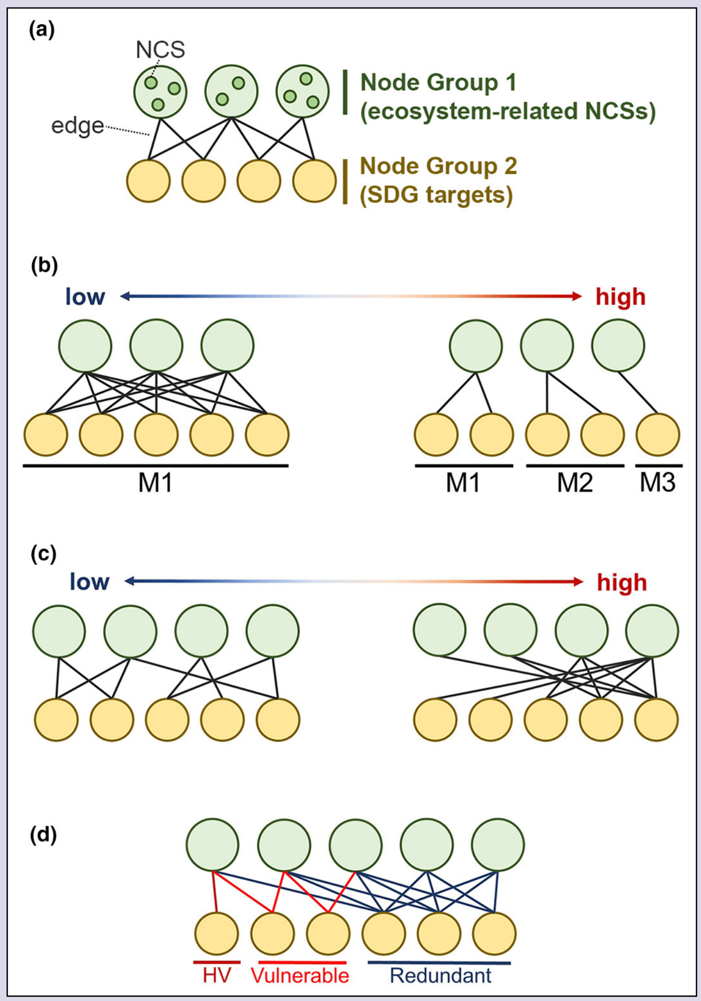

Figure 2. Schematic representation of indices. From top to bottom: (a) a bipartite network, (b) the modularity index (where M stands for module), (c) the nestedness index, and (d) the insurance index.

the sense that SDG targets linked to only one ecosystem NCS were considered highly vulnerable. In other words, if the NCS involved in this unique link is not implemented, then there is no other NCS that can promote this SDG target in any other ecosystem (Appendix S1: Panel S1).

Uncertainty analyses and null models were performed to assess the robustness of—and to ensure that the missing percentage of relevant articles would not influence—our results. We therefore randomly converted 10% of the +1 (and –1) scores into 0 and converted 10% of the +1 (and –1) scores into +2 (and –2), which served to mimic disagreement among experts and the failure to find existing quantitative evidence at the global scale (Appendix S1: Panel S1).

Relationships between ecosystem NCSs and SDG targets

The 17 experts we consulted identified 634 positive and 228 negative links between ecosystem NCSs and SDG targets (see GHLink). On average, 8.5 search pages of references (maximum of 14 search pages) had to be screened for each search result before no additional relevant articles were found. Thus, screening the first ten search pages of references for each search ensured the capture of at least 71% of the relevant literature.

Our analysis detected negative links for up to 93% of the SDGs and 35.3% (53/150) of their targets with at least one ecosystem NCS (Figure 3, a and b). On average, 34.8 ± 20.8% of targets within each SDG were negatively linked to at least one ecosystem NCS (Figure 3b). All SDGs and 72% of their targets (108/150) were positively related to at least one NCS in a given ecosystem (Figure 3, b and c). For each SDG, the mean proportion of targets that were positively linked to at least one NCS in one ecosystem was 72.6 ± 15.6%, ranging from 54% (SDG 3: Good health and well-being) to 100% ([SDG 6: Clean water and sanitation] and [SDG 14: Life below water]). Overall, with respect to NCSs and SDG targets, we observed almost three times as many potential co-benefits than potential trade-offs. Despite this observed disparity, the magnitude of many important trade-offs may

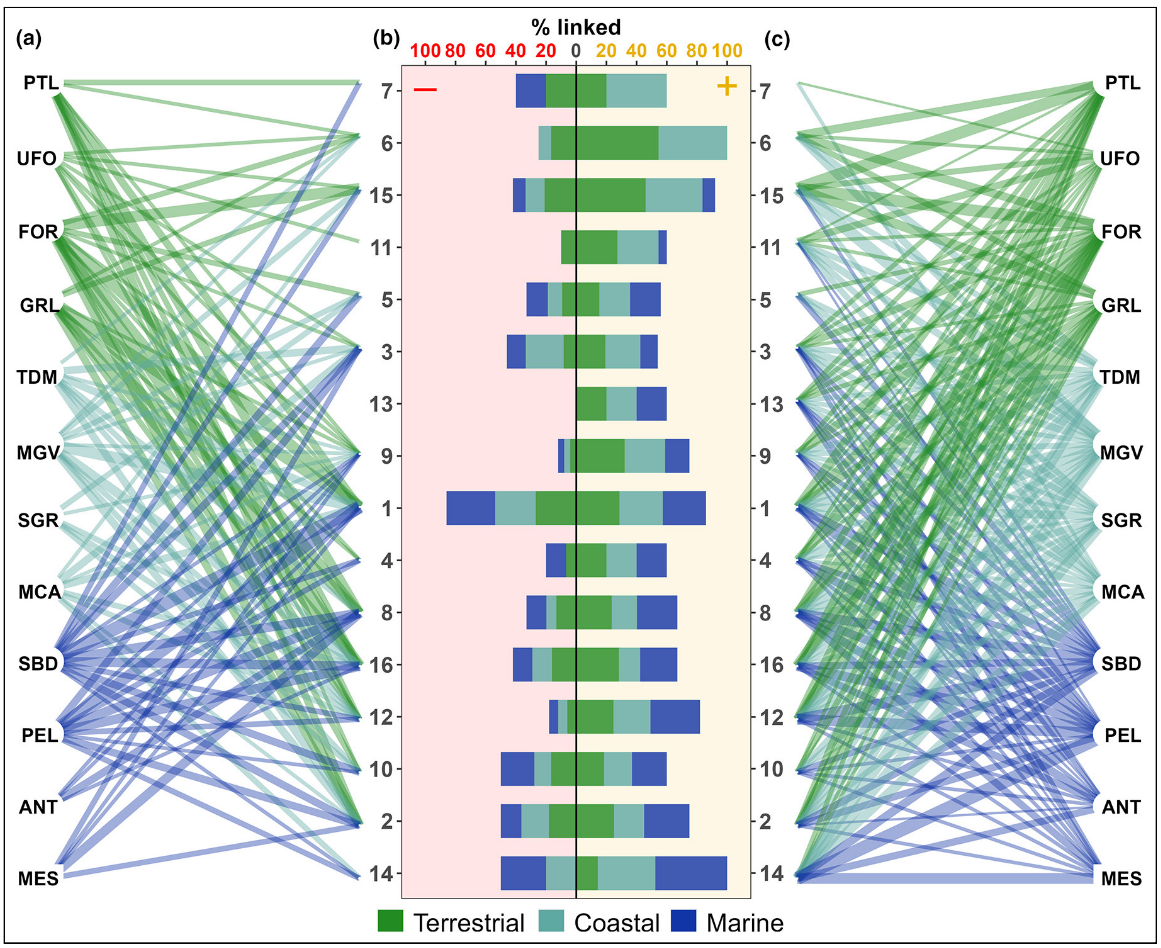

Figure 3. Relationships between ecosystem NCSs and SDGs. Bipartite network of the (a) negative links (trade-offs) and (c) positive links (co-benefits) between ecosystem NCS implementation and SDG target achievement. Edge (line) thickness is proportional to the number of targets. (b) Percentage of targets within each SDG that are positively (+) and negatively (–) linked to ecosystem NCS implementation, and the contribution of each ecosystem type. For (a) and (c): peatland (PTL), urban forest (UFO), forest (FOR), grassland (GRL), tidal marsh (TDM), mangrove (MGV), seagrass (SGR), macroalgae (MCA), seabed (SBD), pelagic (PEL), Antarctic (ANT), and mesopelagic (MES). Values along the vertical axis correspond to the SDG number (SDGs 1–16).

outweigh the greater frequency of co-benefits, and the difference between trade-off magnitude and co-benefit frequency may vary from local to global scales. While determining the magnitude of effects is beyond the scope of this study, it remains an important research gap.

In particular, SDG targets linked to poverty reduction (SDG 1: No poverty) and economic growth (SDG 8: Decent work and economic growth) may be difficult to achieve simultaneously because of potential conflicts with biodiversity conservation (Marques *et al*. 2019; Otero *et al*. 2020). Furthermore, certain NCSs may also inhibit the achievement of SDG targets related to societal aspects (ie SDG 2: Zero hunger), because of potential competing demands for land between food production and NCS implementation (Mehrabi *et al*. 2018; Schleicher *et al*. 2019). Nonetheless, as progress is urgently needed if the goals of the Paris Agreement are to be met (Griscom *et al*. 2017; Girardin *et al*. 2021), climate action would bring far fewer trade-offs than climate inaction. For example, the negative impacts of terrestrial NCSs on food security (SDG 2) must be viewed relative to the projected severe negative impacts of climate change on agricultural productivity, food security, and malnutrition (Ortiz-Bobea *et al*. 2021). In any case, even if NCS-related benefits outweigh NCS-related costs in the long term, trade-offs must be carefully assessed to maximize uptake and avoid friction between NCSs and SDGs. These social and economic trade-offs are also critical for the realistic implementation and feasibility of NCSs (Roe *et al*. 2021; Schulte *et al*. 2021) and may be important considerations for policy makers in the use of NCSs to address multiple goals.

Complementarity among ecosystem NCSs in reaching SDG targets

We used bipartite network indicators to assess the complementarity among ecosystem NCSs in achieving SDG targets (Panel 1).

For positive links, the overall modularity of the network between ecosystem NCSs and SDG targets (0.20) was significantly higher than would be expected to occur by chance (range of null model expectations [RNME]: 0.16–0.18; Appendix S1: Figure S2 and Table S3), indicating that the network was more divided into clusters (ecosystem NCSs linked to the same SDG targets) than expected by chance (ie if the links were made randomly). However, modularity remained low as compared to that of a highly clustered network (ie with a value of 1), suggesting that ecosystem NCSs may contribute to achieving a broad pool of SDG targets, such as those in SDG 2. However, some SDG targets can only be achieved by NCSs in one particular ecosystem (eg targets in SDG 7 [Affordable and clean energy] and SDG 11 [Sustainable cities and communities]), suggesting a certain level of complementarity. The relatively low level of nestedness (35.4), which was significantly below levels expected by chance (RNME: 36.1–37.2; Appendix S1: Figure S2 and Table S3), confirmed this observation. This level of complementarity was underscored by the results of the correspondence analysis (CA) between SDG targets and NCSs in the 12 ecosystems. Complementarity was mainly due to differences in SDG target achievement between terrestrial, coastal, and marine ecosystems, because NCSs in terrestrial (urban forests and peatlands) and marine (seabed, pelagic, and Antarctic areas) ecosystems were found to significantly contribute to the variance along the first axis of the CA (Appendix S1: Figure S2). Despite enabling only a few SDG targets (Appendix S1: Figure S7), urban-related NCSs contributed greatly to this complementarity because they promote distinct SDG targets, including SDG 7.3 (Improve energy efficiency) and SDG 11.7 (Access to green and public spaces).

For negative links, the network was significantly more modular than expected by chance but was not significantly less nested (Appendix S1: Table S3 and Figure S4), meaning that clusters of ecosystem NCSs tend to inhibit the same SDG targets. The higher level of modularity than expected by chance was mainly due to NCSs linked to macroalgae and urban forests, both of which have inhibitory effects on SDG target 3.9 (Reduce death and illness from chemical air and water pollution) (Appendix S1: Figure S3), as macroalgae can accumulate high levels of toxic metals (Kumar and Sharma 2021) and urban trees can increase air pollution by releasing biogenic volatile organic carbons (Viippola *et al*. 2018).

Uncertainty analyses revealed no significant differences between the randomly modified datasets and the original dataset (2.5th percentile < observed values < 97.5th percentile; Appendix S1: Table S4, Figure S5, and Figure S6), indicating that our results were robust to expert disagreements or to omission of parts of the scientific evidence.

Despite the effort to assess links at the SDG target level, we likely underestimated the complementarity of ecosystem NCSs in target achievement for both positive and negative links because complementarity between ecosystem NCSs is sometimes conflated when assessed globally across terrestrial, coastal, or marine ecosystems. For example, the majority of ecosystem NCSs have an influence—positive or negative—on achieving SDG target 2.1 (End hunger and ensure access for all to safe, nutritious, and sufficient food). However, NCSs in pelagic areas may primarily impact this target in certain countries and islands with dense coastal populations (Teh *et al*. 2016). Similarly, forest NCSs could support the achievement of target 2.1 for local terrestrial communities, as forests provide foodstuffs (Hall *et al*. 2022) and offset reductions in food productivity due to lower precipitation (Smith *et al*. 2020). Thus, the implementation of NCSs across all ecosystems would also have complementary effects within SDG targets.

Redundancy and vulnerability of linkages

For positive links, 54.6% of SDG targets were more vulnerable than expected by chance (Figure 4). The level of target

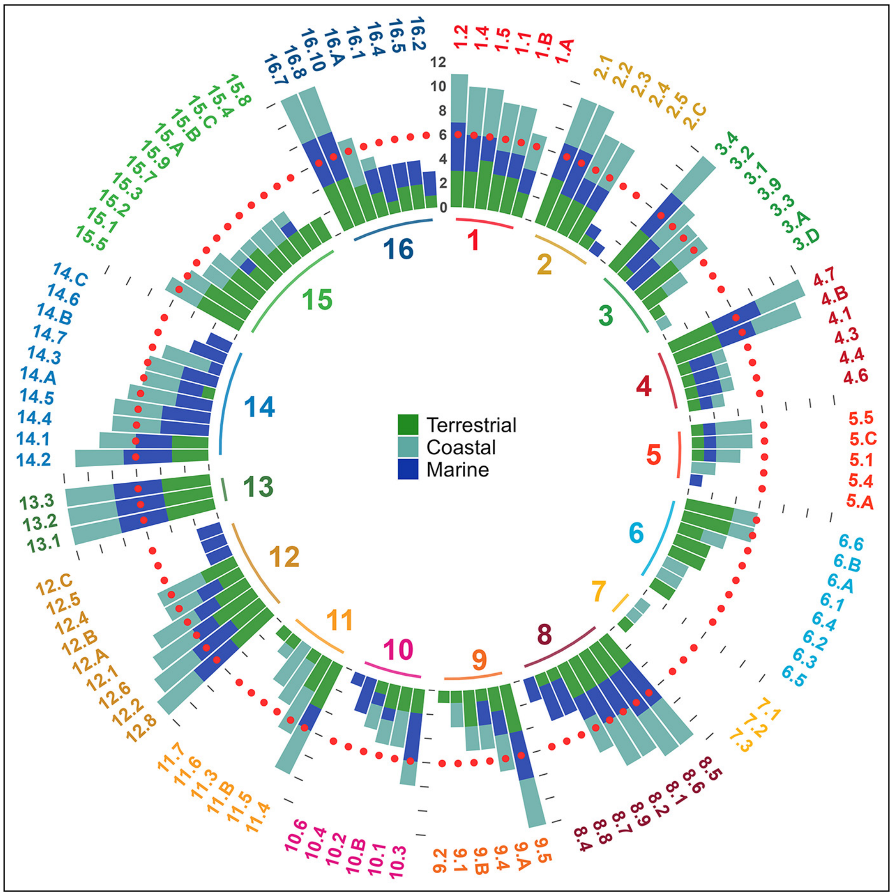

Figure 4. "Insurance" of SDG targets for positive links. The bars represent the number of ecosystems (*y* axis from 0 to 12) that contribute to achieving each target after ecosystem NCS implementation. Bar colors represent the type of ecosystem that promotes SDG target achievement. Red circles represent the number of times a given target is (as expected by chance) positively linked to an ecosystem (n = 6). Targets impacted less than randomly expected are vulnerable. Colored values at the end of each bar (along the outer circumference) indicate the target numbers of the 16 individual SDGs (depicted by the inner values within the circular plot).

vulnerability (0.093) was significantly higher than expected by chance (RNME: 0–0.019; Appendix S1: Figure S2 and Table S3). Moreover, 9.3% of SDG targets were found to be highly vulnerable because they were supported by NCS implementation in only one of the 12 ecosystems (Figure 4). At the same time, 45.4% of SDG targets were equally or more redundant than expected by chance, with achievement ensured by 25.6% more ecosystem NCSs than expected by chance (RNME: 0.10–0.13; Appendix S1: Figure S2 and Table S3).

For negative links, we used the same metric to assess the likelihood that various ecosystem NCS implementations would reinforce trade-offs: 69.8% of SDG targets were vulnerable because they were linked to ecosystem NCSs at levels several times lower than expected by chance (Figure 5). The level of target vulnerability (0.26) was significantly higher than expected by chance (RNME: 0–0.11; Appendix S1: Figure S4 and Table S3), meaning that 26% of SDG targets were inhibited after NCS implementation in only one ecosystem (Figure 5).

Thus, diversifying NCSs in various ecosystems would increase both potential co-benefits and trade-offs.

For both positive and negative links, uncertainty analysis revealed no significant differences between values obtained on randomly modified matrices and the observed ones (2.5th percentile < observed values < 97.5th percentile; Appendix S1: Table S4, Figure S5, and Figure S6), suggesting that our results were robust to some degree of uncertainty.

Research gaps and insights

Our results, which are based on expert knowledge and literature review, provide a qualitative assessment of possible interactions and can be used as a basis to pursue efforts in areas lacking more solid scientific evidence. Indeed, despite their level of expertise and the degree of complementarity detected, experts may have overlooked some links. Given the local context-dependence of co-benefits and trade-offs in areas where NCSs can be implemented, the inclusion of other literature sources, such as non-English gray literature (Angulo *et al.* 2021), may complement our assessment and improve its granularity for local or regional applications (Amano *et al.* 2023). However, our uncertainty analyses highlight the robustness of our results to literature omission and expert disagreement at the global scale. As environmental decisions and management rarely occur on a global scale, this suggests that future work should focus on determining vulnerability and complementarity of linkages at local and regional scales. In addition, our assessment can be limited by how ecosystems' contributions to people's quality of life are studied, more so than a real effect. Indeed, publication bias toward positive results may partly explain why we identified more co-benefits than trade-offs (Koricheva and Kulinskaya 2019). Also, part of the complementarity can be explained by the observational bias created by only looking where it is relatively easy to do so and where data are available (streetlight effect; Hendrix 2017). For example, NCSs in mesopelagic areas promote the achievement of fewer SDG targets as compared to NCSs in other ecosystems like forests (32 versus 78 targets, respectively; Appendix S1: Figure S3) at least in part because mesopelagic ecosystems remain comparatively poorly studied. Thus, mesopelagic NCS-related co-benefits and trade-offs have not been fully assessed but they may be large (Martin *et al.* 2020).

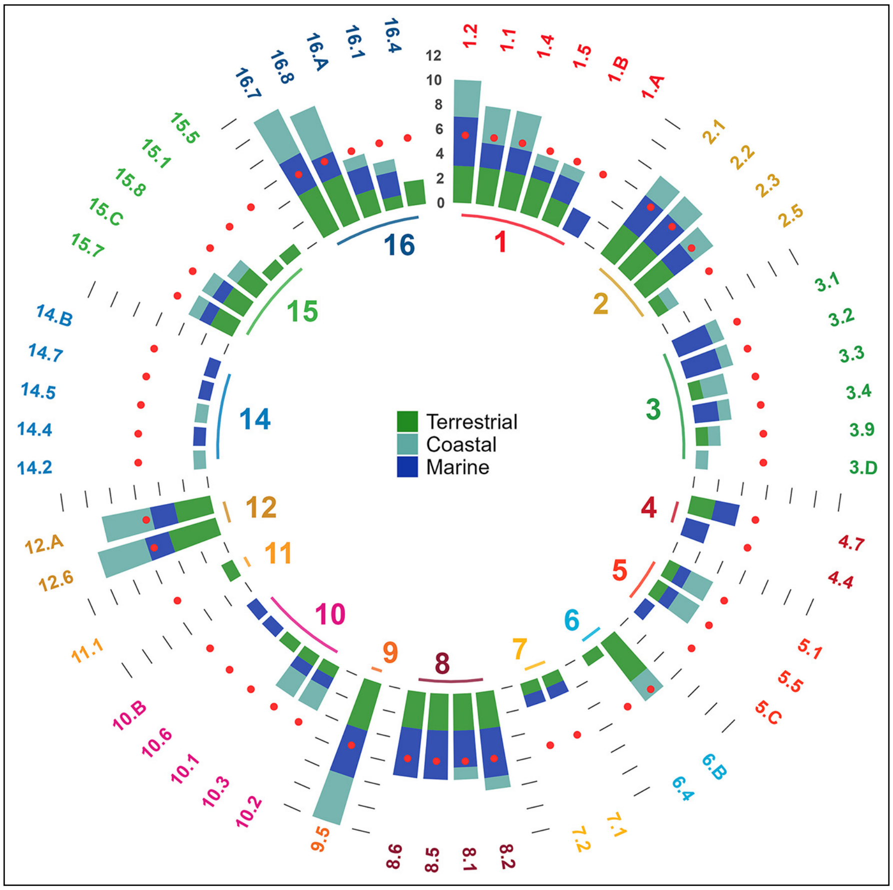

Figure 5. "Insurance" of SDG targets for negative links. The bars represent the number of ecosystems (*y* axis from 0 to 12) that impede achievement of each target after ecosystem NCS implementation. Bar colors represent the type of ecosystem that inhibits SDG target achievement. Red circles represent the number of times a given target is (as expected by chance) negatively linked to an ecosystem (n = 6). Targets negatively impacted less than randomly expected are vulnerable. Targets impacted less than randomly expected are vulnerable. Colored values at the end of each bar (along the outer circumference) indicate the target numbers of the 16 individual SDGs (depicted by the inner values within the circular plot). SDG 13 (Climate action) is not represented as NCSs are supposed to only promote climate-change mitigation.

Our results emphasize the importance of jointly implementing NCSs in a diversity of ecosystems to enable the achievement of multiple SDG targets, especially the most vulnerable. There is additional nuance, however: for methodological purposes, our analyses were performed at the ecosystem level by merging all respective NCSs in an ecosystem into one. Consequently, further studies are needed to assess the complementarity of NCSs within each ecosystem and estimate whether our results can be explained by one or two specific NCSs having particularly influential links with SDG targets. Moreover, our study ignored interactions between ecosystem NCSs. Indeed, positive influences of ecosystem NCSs are not always additive because some ecosystem NCSs may be in direct competition with one another. For example, at a local scale, choices might have to be made between two or more NCSs (eg reforestation versus improved grassland management) as both compete for the same land but with different outcomes. Therefore, to recognize and manage trade-offs, we argue that integrative and coordinated policy making between actors and across sectors is essential, and intensive monitoring programs must be developed to provide an early warning if unexpected trade-offs occur.

Trade-offs are often a matter of scale, whether temporal or spatial. The potential discrepancy between the temporal scales of benefits and costs can be counterproductive when unanticipated or managed inappropriately because several years may be required before benefits are realized while trade-offs could appear soon after implementation (Blicharska *et al*. 2019). It also means that co-benefits and trade-offs after NCS actions would differ across generations, as co-benefits will be passed on to future generations experiencing more pronounced effects of climate change while trade-offs will be faced by current generations. Likewise, discrepancies in spatial scales can trigger conflicts because co-benefits and trade-offs are not homogeneous across space and may impact people differently (Fisher *et al*. 2009) due to specific local or regional socioeconomic contexts and because of the disconnect between local impacts and global benefits. For example, although large-scale monoculture plantations can be beneficial for climate mitigation, they can also lead to local socioeconomic conflicts because these NCSs may compete for land with other sectors (Pörtner *et al*. 2021), deprive local communities from access to land (Holl and Brancalion 2020), promote local conflicts over water sources (Zheng *et al*. 2016), and jeopardize local biodiversity (Brundu and Richardson 2016). NCS implementation in all ecosystems would therefore require locally adapted modes of governance to ensure the equitable sharing of co-benefits and management of trade-offs. In this study, we found that many trade-offs occur when NCSs are implemented with little to no inclusion of or engagement with local communities, or when best practices are not followed. An inclusive and pluralist mode of governance that, when associated with robust social and environmental safeguards, facilitates engagement with local people and incorporates local knowledge into decision-making processes (Visseren-Hamakers *et al*. 2021) would therefore be a cornerstone of fair and sustainable NCS implementation (Seddon *et al*. 2021). Other effective conservation measures can serve as complementary tools to protected areas, in that they may enhance equity and prove useful in overcoming trade-offs when part of an inclusive process (Gurney *et al*. 2021; Obura *et al*. 2021). Finally, increasing NCS implementation while minimizing trade-offs would require cooperation among multiple countries; not only would such cross-border initiatives help countries to manage trade-offs among multiple ecosystem services, they would also improve biodiversity protection and strengthen regional climate-change mitigation or adaptation measures (Shin *et al.* 2022).

Management options and decision-making processes

To better address co-benefits of and trade-offs between NCSs and SDG targets in decision-making processes, we propose several pathways. The first pathway would be to avoid trade-offs altogether by proposing that only NCSs for which there are no known adverse effects (or at least preventable ones) be employed. However, such win–win or win–neutral solutions between NCSs and SDG targets appear unrealistic given that certain trade-offs are difficult to avoid due to inherent conflicts between certain objectives (eg agricultural land either maintained for production or designated for reforestation; Mehrabi *et al.* 2018), or because of antagonisms between environmental SDGs and SDGs linked to economic growth (Hickel 2019; Zeng *et al.* 2020) or human well-being (Scherer *et al.* 2018).

A second pathway would aim to maximize co-benefits without any consideration of trade-offs, leading to the implementation of all NCSs with positive links to a given SDG target regardless of the negative links. This strategy may be unrealistic but also inappropriate, particularly in countries where feasibility is low due to economic, institutional, or social barriers (Roe *et al.* 2021), potentially leading to local conflicts (Kriegl *et al.* 2021) and failing to adhere to the core SDG principle of "leaving no-one behind".

Thus, a well-balanced prioritization of economic, social, and environmental SDG targets that integrates both potential co-benefits and trade-offs would promote an optimized set of NCSs while facilitating adaptation to local contexts. Such an inclusive process could follow a course similar to that illustrated in Appendix S1: Figure S8, but other decision criteria to navigate likely unavoidable trade-offs exist. According to SDG principles, local participatory workshops should focus on the priorities of and benefits for the most marginalized groups in the decision context. After the presentation of all NCS options, unachieved SDG targets can be compiled using tools like SDG Tracker (Our World in Data Team 2023) and ranked by stakeholder categories according to their priorities, followed by inclusive assessments of co-benefits and trade-offs between each NCS option and SDG targets at the local scale. The outcome of this process would be a single multicriteria decision analysis (MDA) per stakeholder, where NCS options can be evaluated simultaneously based on their respective priorities. Each MDA can be iteratively presented to all participants and discussed to move toward an inclusive final decision process that focuses on the views of marginalized groups. Other dimensions, such as the degree of interaction between SDG targets (Weitz *et al.* 2018; Tremblay *et al.* 2021), the socioeconomic cost of an NCS, or a quantified degree of interaction between NCSs and SDG target achievement (Fujimori *et al.* 2020), could also be integrated into such an optimization framework to aid in selection of the best combination of NCSs for the local context. Such an approach would foster the downscaling of international goals by providing local guidance on how to achieve both SDG and climate objectives with simple, fair, and efficient policy decisions.

Conclusion

Our analysis highlights the potential co-benefits for humanity from NCS implementation in terms of achieving the SDG targets. Yet the full benefits and widespread acceptance of NCSs can only be achieved if potential trade-offs are minimized. We argue that implementing a variety of NCSs in different ecosystems is key because NCSs in terrestrial, coastal, and marine ecosystems show complementarity and low redundancy in achieving SDG targets. Moreover, when comparing NCSs, the mitigation potential of NCSs should not be the only metric to consider; equally important is their respective capacity to achieve SDG targets. However, implementing various NCSs in different ecosystems also increases trade-offs, which may inhibit the achievement of some SDG targets. Diversifying the pool of NCSs therefore necessitates a full understanding and accounting of trade-offs linked to NCS implementation to not penalize anyone, particularly the global poor, in the achievement of climate and sustainable development objectives. Doing so will require an integrated modeling optimization approach to prioritize achievement of SDG targets based on local socioeconomic and environmental context, or, alternatively, a more fundamental analytical approach to identify and rank NCSs with substantial SDG co-benefits but few trade-offs.

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Data Availability Statement

Data and code are provided as public-for-peer review at https://github.com/GaelMariani/NCSSDGproj.

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