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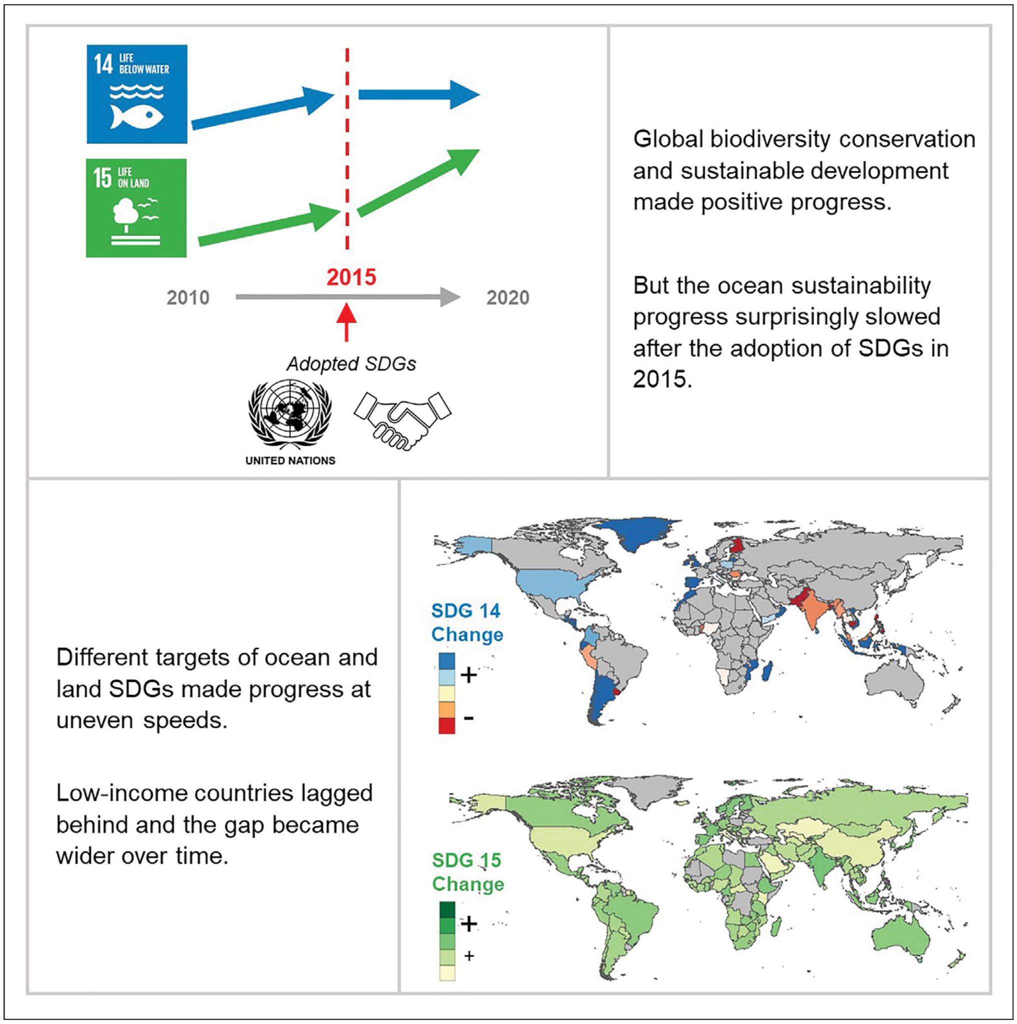
Global decadal assessment of life below water and on land



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Highlights

Global biodiversity conservation and sustainable development made positive progress

The ocean sustainability progress surprisingly slowed after the adoption of SDGs in 2015

Different targets of ocean and land SDGs made progress at uneven speeds

Low-income countries lagged behind and the gap became wider over time

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Global decadal assessment of life below water and on land

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SUMMARY

The United Nations (UN) has adopted the 17 Sustainable Development Goals (SDGs), aiming to provide human welfare and conserve the planet, now and into the future. Two of the SDGs directly address biodiversity conservation and sustainable development – SDG 14 (life below water) and SDG 15 (life on land). Although the UN has issued annual reports on SDGs, the reports did not consistently reveal the progress over time, because of inconsistent methods such as estimation based on different indicators across years. Our research examined the dynamics of the same 10 indicators for SDGs 14 and 15 between 2010 and 2020. Results indicate that the overall SDG 14 scores had a small growth between 2010 and 2020, whereas the substantial increase in SDG 15 scores spotlighted the conservation efforts and sustainable use of terrestrial ecosystem services, especially in countries with biodiversity hotspots. Globally, there was more progress in terms of SDG 15 scores during 2015–2020 than during 2010–2015 (before the UN adopted SDGs in 2015). Surprisingly, SDG 14 score had smaller progress during 2015–2020 than during 2010–2015. Special attention should be given to low-income countries lagging in sustainable development performance when implementing the post-2020 global biodiversity framework.

INTRODUCTION

The diversity of life is the treasure of Earth, and biodiversity shapes the structure and function of the planet's ecosystems.[1] However, biodiversity loss in the Anthropocene has massively accelerated and surpassed its historic natural rates.[2–4] To prevent the further loss of biodiversity, at the 10th meeting of the Conference of the Parties (COP10) to the Convention on Biological Diversity (CBD) in 2010, a strategic plan was adopted for global biodiversity conservation. In 2021 and 2022, the COP15 to the CBD has been reviewing the achievements and implementation of this strategic plan over the past decade[5] to finalize and adopt the post-2020 global biodiversity framework.[6] Better integrated knowledge about biodiversity conservation and sustainable development progress would enhance conservation policymaking to implement the post-2020 global biodiversity framework and global sustainable development.

So far, biodiversity conservation efforts have been largely separated from economic development.[7] In 2015, the United Nations Member States agreed on a shared blueprint for sustainable development now and into the future. The 17 Sustainable Development Goals (SDGs) included multiple aspects such as peace, prosperity for people and the planet, calling for global partnerships among developed and developing countries. Two of the 17 SDGs directly aim to prevent biodiversity loss and facilitate sustainable natural resource management: SDG 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development (life below water), and SDG 15 – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (life on land). Tracking the progress of those two SDGs is essential to assess the biodiversity status and conservation efforts by integrating both socioeconomic and ecological aspects. The CBD and many other (inter)governmental entities (e.g., national government, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) have also recognized the importance of these two SDGs in the international community such as the United Nations High-level Political Forum on Sustainable Development.[8]

Despite the growing domestic and international attention,[9,10] no effort has holistically assessed the two biodiversity-focused SDGs (14 and 15) over space and time. The annual SDG reports by the United Nations

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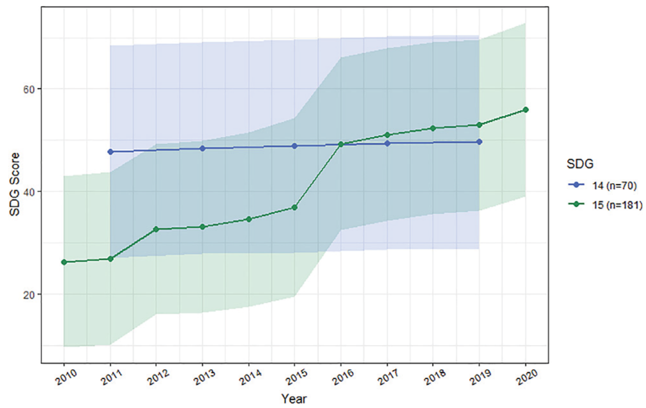

Figure 1. SDGs 14 and 15 score changes between 2010 and 2020

The solid dots represent the average SDG score among countries in a specific year, and the shading represents the standard deviation. The number in the parentheses represents the number of countries analyzed and calculated for SDG scores.

are by far the only assessment, which provides insights into how progress is being made on a global scale. However, the assessments were considered incomparable across years[11,12] because the target and indicator selections were inconsistent from one year to the other.[13] Xu et al. took China as an example and developed a systematic and comparable way to track each province's progress toward each SDG.[13] Still, such an important and urgent assessment at a global scale is lacking. A recent review urges that biodiversity may contribute to the fulfillment of all SDGs.[9] To fill this knowledge gap, we assessed global SDGs 14 and 15 scores between 2010 and 2020 and identified countries/regions with high and low SDG scores. Specifically, we addressed the following questions: (1) How had sustainable development in terms of life below water and on land progressed, as measured in SDGs 14 and 15? (2) How did the SDG scores change before and after the adoption of SDGs in 2015? (3) Which countries had high or low SDG scores? And which countries experienced drastic changes (increase or decrease) in SDG scores?

To answer those questions, we followed the Global indicator framework for the SDGs and targets of the 2030 Agenda for Sustainable Development[14] and selected targets and indicators for SDGs 14 and 15 score calculation. We selected 3 targets and 3 indicators with 3 sub-indicators under SDG 14, and 6 targets and 7 indicators with 13 sub-indicators under SDG 15, for the 10-year analysis and calculation of SDG scores (ranging from 0 to 100). We analyzed 70 countries for SDG 14, and 181 countries for SDG 15 (see detailed explanation about the target, indicator, and sub-indicator in method details). Then we compared the changes in SDG scores before and after 2015 (the year when the SDGs were first adopted by United Nations Member States), identified countries with high and low SDG scores, and mapped global SDG 14 and 15 score changes over time.

RESULTS

Changes in SDGs 14 and 15 scores at the goal level over years

Overall, scores for both SDGs 14 and 15 increased between 2010 and 2020: SDG 14 scores increased by 3.96% from 47.79 to 49.69. SDG 15 score had a large growth (more than 112%) from 26.28 to 55.94, with two major leaps between 2011 (26.92) and 2012 (32.62) increased by 21.19%, as well as 2015 (36.91) and 2016 (49.30) increased by 33.58%. The standard deviation for SDG 14 experienced a slight expansion from 41.37 to 41.90 over time, whereas the standard deviation for SDG 15 fluctuated around 33.7, with a minimum of 33.26 in 2012 and a maximum of 34.89 in 2015 (Figure 1).

Both low-income and high-income countries had a constant increase in SDG 14 scores (Figures 2A and 2B). However, the difference in average scores between high-income and low-income countries became larger, from 4.80 to 5.92. The standard deviation for low-income countries enlarged from 9.26 to 9.92, and for high-income countries also increased from 10.44 to 11.26 over years. Specifically, countries realized a tremendous increase in SDG 14 scores (>10) including Croatia, Gambia, and Lithuania, whereas countries such as Pakistan, Fiji, and Tonga experienced a major decrease (<−2) between 2011 and 2019. The scores for

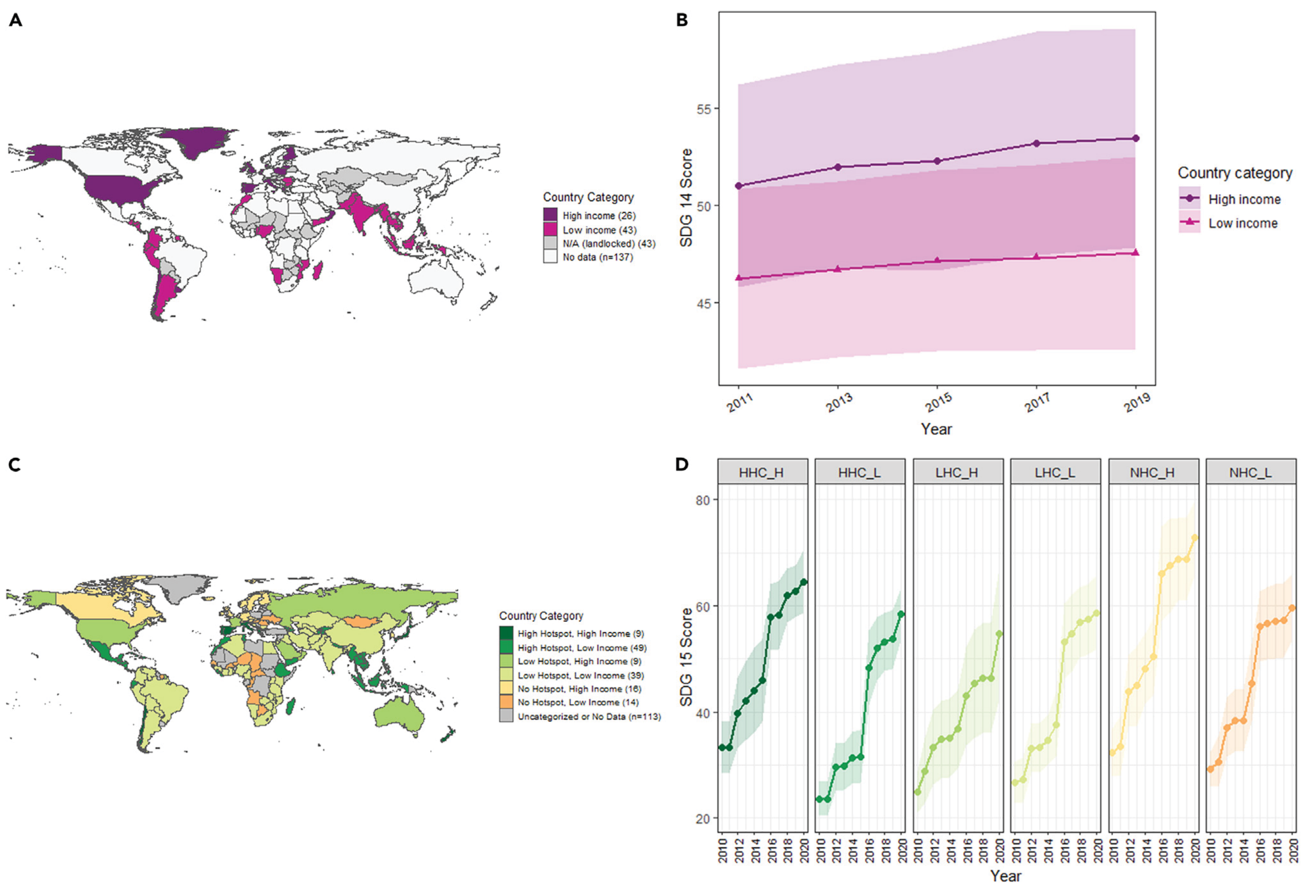

Figure 2. SDG score analysis by income, and biodiversity hotspot groups

(A) The spatial distribution of high- and low-income countries and landlocked countries that have no territory connected to an ocean (numbers in parentheses are the number of countries).

(B) Countries' SDG 14 scores based on income group (the solid dots represent the average SDG 14 score among countries in a specific year, and the shading represents the standard deviation).

(C) The spatial distribution of high hotspot – high income (HHC_H), high hotspot – low income (HHC_L), low hotspot – high income (LHC_H), low hotspot – low income (LHC_L), no hotspot – high income (NHC_H), no hotspot – low income (NHC_L), and uncategorized countries (numbers in parentheses are the number of countries).

(D) Countries' SDG 15 scores based on hotspot-income groups (the solid dots represent the average SDG 15 score among countries in a specific year, and the shading represents the standard deviation).

Barbados, Benin, Nigeria, and Grenada remained relatively low throughout the study period, whereas the scores of Sao Tome and Principe, Greenland, Equatorial Guinea, and the Netherlands stayed at the high end. The SDG 14 scores for all countries can be found in Table S1.

Although the overall SDG 15 score increased between 2010 and 2020, the change rate largely varied across countries. For example, Croatia and the United Arab Emirates achieved the most progress in SDG 15 scores (>55), followed by India and Norway (>50). Israel, Greenland, Kazakhstan, Saudi Arabia, Libya, Italy, Uzbekistan, and Kenya made minimal progress (<10) for SDG 15, whereas several islands even had a decrease (<0) including Guadeloupe, Svalbard and Jan Mayen, American Samoa, Martinique, Gibraltar, Puerto Rico, French Polynesia, Mayotte, and Réunion.

Besides the three high-income countries of Croatia, the United Arab Emirates, and Norway, India is the only low-income country that made exceptional SDG 15 progress (>50). Across the six groups in terms of biodiversity hotspots and income levels (see detailed country classification in method details), the Non-Biodiversity-Hotspot-High-Income (NHC_H) countries performed the best in SDG 15 progress than the other five groups, whereas the High-Biodiversity-Hotspot-Low-Income (HHC_L) countries did the

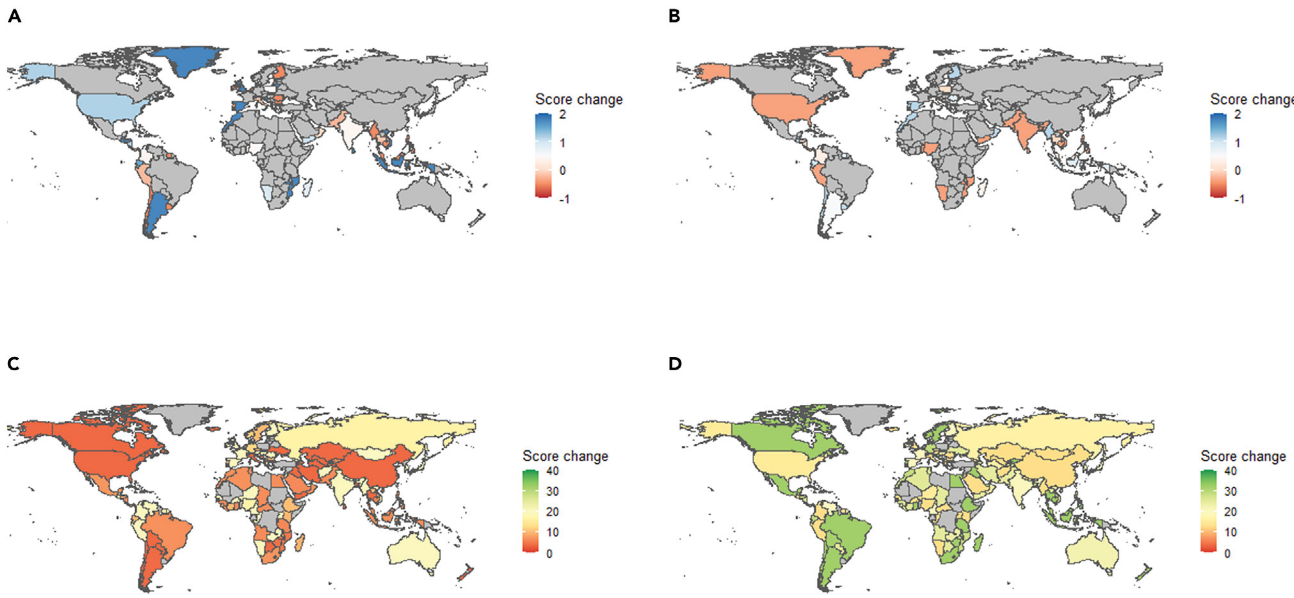

Figure 3. The spatial pattern of SDG score changes over two five-year periods
(A) SDG 14 score change between 2011 and 2015.
(B) SDG 14 score change between 2015 and 2019.
(C) SDG 15 score change between 2010 and 2015.
(D) SDG 15 score change between 2015 and 2020. The gray color refers to countries with no data.

worst: the NHC_H countries had an average score of 54.29 between 2010 and 2020 and end up with 72.9 in 2020, and the HHC_L countries had an average score of 39.56 between 2010 and 2020 ending with 63.33 in 2020, whereas all other countries' average scores were below 50 with ending scores above 65 in 2020 (Figures 2C and 2D). The SDG 15 scores for all countries can be found in Table S2.

Rates of progress in SDGs 14 and 15 across countries before and after 2015

Countries made progress in SDGs 14 and 15 at different rates. To make comparisons before and after the adoption of the SDGs in 2015, we reported the SDG 14 and 15 score changes in two periods: 2010/2011 to 2015, and 2015 to 2019/2020. Overall, the score increase for SDG 14 between 2015 and 2019 (0.84) was less than that between 2011 and 2015 (1.05). The score increase for SDG 15 between 2015 and 2020 (19.03) was more than that between 2010 and 2015 (10.62).

However, countries made discrepant progress in SDG 14 and 15 scores. During 2011 and 2015, Croatia, Lithuania, Morocco, Spain, Mozambique, Guatemala, and other 16 countries did above the average rate in terms of SDG 14 score increase (>1.05) between 2011 and 2015; fifteen countries made small progress for SDG 14 (>0 and $\leq$ 1.05) over this time; thirty-two countries made no progress or retrogress toward SDG 14 ($\leq$ 0) (Figure 3A). Between 2015 and 2019, Gambia, Cook Islands, Belgium, and Comoros in a total of 25 countries made above average progress (>0.84), and 18 countries made small progress for SDG 14 (>0 and $\leq$ 0.84), whereas 27 countries made no progress or retrogress ($\leq$ 0) (Figure 3B).

For SDG 15, between 2010 and 2015, Slovakia, India, Serbia, France, Belgium, Spain, Bhutan, Cameroon, Austria, Peru, and other 51 countries did above average (>10.62), and 101 countries made small progress in SDG 15 (>0 and $\leq$ 10.62) between 2010 and 2015. South Sudan, New Zealand, Thailand, Grenada, Belize, and other 14 countries made no progress or retrogress in SDG 15 ($\leq$ 0), among which New Zealand is the only high-income country (Figure 3C). Between 2015 and 2020, Zimbabwe, Norway, Canada, Sweden, and other 94 countries made above average progress in SDG 15 (>19.03). Sixty-six countries made small progress (>0 and $\leq$ 19.03), whereas 17 countries made no progress or retrogress ($\leq$0) (Figure 3D).

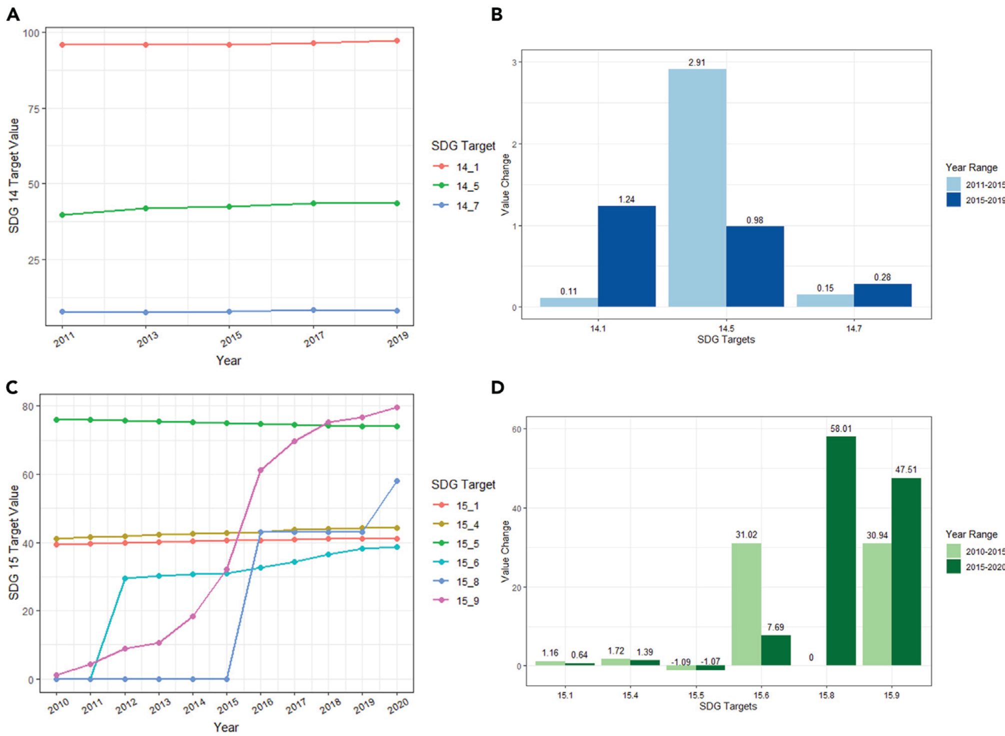

Figure 4. SDG target values between 2010 and 2020

(A) The temporal change in average values of each SDG 14 target among countries.

(B) The SDG 14 target value change between 2011-2015 and 2015–2019.

(C) The temporal change in average values of each SDG 15 target among countries. (D) The SDG 15 target value change between 2010-2015 and 2015–2020.

Changes in scores of SDGs 14 and 15 at the target level

Of interest, although the United Nations Member States adopted the SDGs in 2015, not all SDG 14 targets increased their scores faster after 2015. For example, although Target 14.5 (conserve coastal and marine areas) had the largest increase from 39.68 to 43.58 between 2011 and 2019, the change was mostly owing to the increase between 2011 and 2015 (2.91) rather than between 2015 and 2019 (0.98). Other Targets made small improvements. Targets 14.1 (prevent and reduce marine pollution) slightly increased from 95.75 to 97.10. The increase between 2015 and 2019 (1.24) is larger than that between 2011 and 2015 (0.11). Target 14.7 (increase economic benefits to small island developing states) fluctuated between 7.78 and 8.53 with an ascending trend. No major difference between the increase rate between 2011 and 2015 (0.15) and 2015–2019 (0.28) (Figures 4A and 4B).

Despite the adoption of SDGs in 2015 stimulating countries to make positive progress on the overall SDG 15 scores, the increase was primarily contributed by Targets 15.8 and 15.9, and other targets still grew slowly between 2015 and 2020. Namely, Targets 15.1 (conserve, restore, and sustainably use land and freshwater services) and 15.4 (conserve mountain ecosystem) had a small increase from 39.38 to 41.19 and from 41.09 to 44.20, respectively, whereas Target 15.5 (prevent biodiversity loss - red list index) decreased from 76.10 to 73.94. Notably, Targets 15.6 (promote fair sharing of benefits), 15.8 (prevent and reduce invasive species), and 15.9 (integrate ecosystem and biodiversity values in planning) had a large increase from 0 to 38.71, from 0 to 58.01, and from 1.10 to 79.56 during 2010–2020. Both Targets 15.6 and 15.8 experienced a value jump between years. For example, between 2011 and 2012, the Target 15.6 value jumped from 0 to 29.59 because the binary data of (sub)indicators under Target 15.6 were all 0s before 2012 and then some changed to 1s in 2012. Specifically, the Target 15.6 value was calculated based on five sub-indicators: (1) 15.6.1.1 Countries that are contracting Parties to the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) (1 = YES; 0 = NO); (2) 15.6.1.2 Countries that are parties to the Nagoya Protocol (1 = YES; 0 = NO); (3)

15.6.1.3 Countries that have legislative, administrative and policy framework or measures reported through the Online Reporting System on Compliance of the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) (1 = YES; 0 = NO); (4) 15.6.1.4 Countries that have legislative, administrative and policy framework or measures reported to the Access and Benefit-Sharing Clearing-House (1 = YES; 0 = NO); (5) 15.6.1.5 Total reported number of Standard Material Transfer Agreements (SMTAs) transferring plant genetic resources for food and agriculture to the country (continuous number). Once some sub-indicators were 0s in the previous year but became 1s later, this explained the jumps of values in Targets 15.6 (2011–2012) and 15.8 (2015–2016, and 2019-2020). Although Target 15.9 was also composed of binary data (e.g., countries that have submitted National Biodiversity Strategies and Action Plans (NBSAPs) (1 = YES, 0 = NO)), the increasing trend seemed smoother over years (before 2013 and after 2017) yet with an exponential growth between 2015 and 2016, indicating that many countries submitted their NBSAPs in 2016 (Figures 4C and 4D).

DISCUSSION

Although both SDGs 14 and 15 scores increased between 2010 and 2020, the adoption of the United Nations' SDGs in 2015 did not facilitate all countries' progress toward marine sustainability, because the growth of SDG 14 scores between 2015 and 2019 was slower than those between 2011 and 2015. Only the target of conserving coastal and marine areas (SDG 14.5) made small progress between 2011 and 2017 and plateaued between 2017 and 2019. Other SDG 14 targets were barely improved in terms of preventing and reducing marine pollution or even experienced a loss of economic benefits to small island developing states and least developed countries from the sustainable use of marine resources. A large gap still exists to fulfill marine conservation and sustainable development needs, and more proactive actions should be taken to speed up marine conservation and sustainability.

On a global scale, the growth of SDG 15 scores was faster between 2015 and 2020 than that between 2010 and 2015, mostly owing to the progress of Targets 15.8 (prevent and reduce invasive species), and 15.9 (integrate ecosystem and biodiversity values in planning). The increase of overall SDG 15 scores in biodiversity hotspot countries spotlighted the conservation efforts and sustainable use of terrestrial ecosystem services. Many countries with biodiversity hotspots achieved positive progress in terms of both SDG 15 scores and their global SDG 15 rankings. For example, high-income countries with high biodiversity such as Spain, Japan, New Zealand, and Portugal made a significant improvement in their SDG 15 scores (more than 100% increase) and rankings (more than 10 places forward). Low-income countries with high biodiversity such as Ethiopia, Madagascar, and Indonesia, also achieved significant progress in SDG 15 scores (more than 100% increase) and rankings (more than 10 places forward). However, for other biodiversity hotspot countries, the rankings have dropped although the overall SDG 15 score increased. Namely, the rankings of Cyprus and Italy have dropped more than 70 places, and those of Belize, St Vincent and the Grenadines, and Azerbaijan have dropped more than 40 places, even though their SDG 15 scores have improved by more than 14%. Future research should focus on evaluating the extent of such positive effects in coping with the post-2020 global biodiversity framework and the CBD's blueprint for humans living in harmony with nature.[6]

High-income countries had higher scores than low-income countries in both SDGs 14 and 15, and the gap between those overall SDG scores over years became wider (Figures 2B and 2D), indicating that well-performing countries became better while poor-performing countries became worse. This is likely to fall into the 'success to the successful' pitfall[15] when countries with accumulated wealth, privilege, special access, or inside information are prone to create more wealth, privilege, access, or information.[15] This could explain why high-income countries gained more scores than low-income countries in SDG 14 and especially for the Non-Biodiversity-Hotspot countries (NHC_H and NHC_L) in SDG 15. In addition, the NHC_H countries improved their SDG scores the most, perhaps because they were having less biodiversity 'concern' inside the country and could improve terrestrial sustainability by transferring environmental costs to others as net importers.[16,17] Although the High-Biodiversity-Hotspot-Low-Income (HHC_L) countries benefited from global food trade as net importers[17] to better conserve terrestrial ecosystems, their SDG scores were still behind all other country groups. It would be necessary to examine the international forestry trade and scrutinize domestic natural resource management strategies for those high-hotspot countries. Special attention should be paid to countries with higher biodiversity, lower income, and poorer SDG performances, to prevent them from becoming more lagging behind. The integrated metacoupling framework[18] would be of great use[19] to analyze the barriers for the countries internally (e.g., funding, governance)[20] and externally (e.g., population migration, trade).[17,21–23]

Despite the challenge of missing some countries in our analysis, our study fills the knowledge gap about the progress toward SDGs 14 and 15 at the global and national scales in a consistent manner. This allows national governments to compare their country's SDG scores over time domestically and with other countries. Learning good practices of sustainable development whereas conserving biodiversity from well-performing countries enables poor-performing countries to further tailor domestic conservation policies and enhance international collaborations and communications. However, we must stay vigilant about the decreased scores in some SDG targets and examine the reasons behind them. For example, further research is needed to uncover insufficiency of global monitoring of marine pollution,[24] dysfunction of international treaties to prevent the extinction of threatened species,[25] and inequality in the current global trade environment to benefit small island developing countries in sustainable fishery practicing.[16,17] Although we cannot list all drivers for country-specific SDG performances, this research lays a foundation and provides a database for further investigating such causal inference. Future studies to discover drivers for SDGs 14 and 15 variations can empower policymakers to design better-informed institutions for global biodiversity conservation and sustainable development.

Limitations of the study

Owing to data limitations, our study does not include all targets and indicators for countries' SDG score calculation and analysis. For example, data for SDG 14.3.1 "average marine acidity (pH) measured at agreed suite of representative sampling stations" data did not well fit a country scale. The data insufficiency is two-folded in (1) SDG targets and indicators and (2) the number of countries over the study period. For target and indicator data limitation, although the indicators without data were not included in the SDG score calculation and analysis, the potential impact of omitted indicators and overall result uncertainty analysis were taken into consideration and discussed in the method details. Therefore, we believed that the SDG score analysis with acquired targets and indicators was valid. The second data limitation of country coverage may have an impact on the global overall SDG scores. However, because of the specific indicators selected (e.g., 14.5.1 Coverage of protected areas in relation to marine areas), only a limited number of countries (e.g., countries that have marine territory) were eligible for analysis. We considered this to be the best estimate with available data for applicable countries. We believe additional data for all targets and indicators that were tailored to include all countries would provide more complete information and a holistic picture of global SDG progress.

Our study also demonstrates the need to improve the existing SDG target and indicator design. For instance, future framework design should consider revising some of the current indicators and developing additional targets to better monitor and measure the SDG progress applicable to broader country coverage. Measurable indicators and actionable targets would also enable countries to implement legitimate policies and justify those policies with evidence to achieve greater SDG progress.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

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  - Materials availability
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- METHOD DETAILS
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SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.isci.2023.106420.

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AUTHOR CONTRIBUTIONS

Y.Z. and J.L. designed the research. Y.Z. and Y.L. contributed the data and performed the data analysis. Y.Z. and J.L. interpreted the results and wrote the manuscript. All authors reviewed and commented on the manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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REFERENCES

1. Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D., Wardle, D.A., et al. (2012). Biodiversity loss and its impact on humanity. Nature *486*, 59–67.

2. Mace, G., Masundire, H., and Baillie, J. (2005). In Biodiversity in Ecosystems and Human Well-Being: Current State and Trends, *77*, H. Hassan, R. Scholes, and N. Ash, eds (Island Press), p. 122.

3. Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., 3rd, Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., et al. (2009). A safe operating space for humanity. Nature *461*, 472–475.

4. Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., and Zayas, C.N. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. Science *366*, eaax3100.

5. Convention on Biological Diversity. Cop 10 Decision X/2: Strategic Plan for Biodiversity 2011-2020. https://www.cbd.int/decision/cop/?id=12268.

6. Convention on Biological Diversity (2021). First Draft of the Post-2020 Global Biodiversity Framework. https://www.cbd.int/doc/c/abb5/591f/2e46096d3f0330b08ce87a45/wg2020-03-03-en.pdf.

7. Taylor, B., Chapron, G., Kopnina, H., Orlikowska, E., Gray, J., and Piccolo, J.J. (2020). The need for ecocentrism in biodiversity conservation. Conserv. Biol. *34*, 1089–1096.

8. United Nations (2017). High-level Political Forum on Sustainable Development. United Nations. https://hlpf.un.org/.

9. Blicharska, M., Smithers, R.J., Mikusiński, G., Rönnbäck, P., Harrison, P.A., Nilsson, M., and Sutherland, W.J. (2019). Biodiversity's contributions to sustainable development. Nat. Sustain. *2*, 1083–1093.

10. Zhang, J., Fu, B., Stafford-Smith, M., Wang, S., and Zhao, W. (2021). Improve forest restoration initiatives to meet Sustainable Development Goal 15. Nat. Ecol. Evol. *5*, 10–13.

11. The Sustainable Development Goals Center for Africa (2019). Africa 2030 Sustainable Development Goals Three-Year Reality Check. https://sdgcafrica.org/wp-content/uploads/2019/06/AFRICA-2030-SDGs-THREE-YEAR-REALITY-CHECK-REPORT.pdf.

12. International Institute for Sustainable Development (2020). *Are We Serious about Achieving the Sdgs? A Statistician's Perspective: SDG Knowledge Hub: IISD*. SDG Knowledge Hub. https://sdg.iisd.org/commentary/guest-articles/are-we-serious-about-achieving-the-sdgs-a-statisticians-perspective/.

13. Xu, Z., Chau, S.N., Chen, X., Zhang, J., Li, Y., Dietz, T., Wang, J., Winkler, J.A., Fan, F., Huang, B., and Liu, J. (2020). Assessing progress towards sustainable development over space and time. Nature *577*, 74–78.

14. Indicators - SDG Indicators. United Nations. 2017. https://unstats.un.org/sdgs/indicators/indicators-list/

15. Meadows, D.H. (2008). Thinking in Systems: A Primer (chelsea green publishing).

16. Xu, Z., Li, Y., Chau, S.N., Dietz, T., Li, C., Wan, L., Zhang, J., Zhang, L., Li, Y., Chung, M.G., and Liu, J. (2020). Impacts of international trade on global sustainable development. Nat. Sustain. *3*, 964–971.

17. Chung, M.G., and Liu, J. (2022). International food trade benefits biodiversity and food security in low-income countries. Nat. Food *3*, 349–355.

18. Liu, J. (2017). Integration across a metacoupled world. Ecol. Soc. *22*, art29.

19. Liu, J. (2018). An integrated framework for achieving sustainable development goals around the world. Ecol. Econ. Soc. *1*, 11–17.

20. Jorgenson, A.K., Fiske, S., Hubacek, K., Li, J., McGovern, T., Rick, T., Schor, J.B., Solecki, W., York, R., and Zycherman, A. (2019). Social science perspectives on drivers of and responses to global climate change. Wiley Interdiscip. Rev. Clim. Change *10*, e554.

21. Peeters, A. (2013). Chapter 17—global trade impacts on biodiversity and ecosystem services. In Ecosystem Services, S. Jacobs, N. Dendoncker, and H. Keune, eds. (Elsevier), pp. 191–219.

22. Dietz, T. (2017). Drivers of human stress on the environment in the twenty-first century. Annu. Rev. Environ. Resour. *42*, 189–213.

23. Liu, J., Dou, Y., Batistella, M., Challies, E., Connor, T., Friis, C., Millington, J.D., Parish, E., Romulo, C.L., Silva, R.F.B., and Sun, J. (2018). Spillover systems in a telecoupled Anthropocene: typology, methods, and governance for global

sustainability. Curr. Opin. Environ. Sustain. *33*, 58–69.

24. Bank, M.S., Swarzenski, P.W., Duarte, C.M., Rillig, M.C., Koelmans, A.A., Metian, M., Wright, S., Provencher, J.F., Sanden, M., Jordaan, A., and Ok, Y.S. (2021). Global plastic pollution observation system to aid policy. Environ. Sci. Technol. *55*, 7770–7775.

25. Hoffman, S.J., Baral, P., Rogers Van Katwyk, S., Sritharan, L., Hughsam, M., Randhawa, H., Lin, G., Campbell, S., Campus, B., Dantas, M., and Poirier, M.J. (2022). International treaties have mostly failed to produce their intended effects. Proc. Natl. Acad. Sci. USA *119*, e2122854119.

26. United Nations Statistics (2021). Indicator 15.1.2 (United Nations). https://unstats.un.org/sdgs/dataportal/SDMXMetadataPage?15.1.2-ER_PTD_FRHWTR.

27. International Organization for Standardization [ISO] (2020). ISO 3166 - Country Codes. https://www.iso.org/iso-3166-country-codes.html.

28. Schmidt-Traub, G., Kroll, C., Teksoz, K., Durand-Delacre, D., and Sachs, J.D. (2017). National baselines for the sustainable development goals assessed in the SDG index and Dashboards. Nat. Geosci. *10*, 547–555.

29. Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., and Fuller, G. (2018). SDG Index and Dashboards Report 2018. https://www.sdgindex.org/reports/sdg-index-and-dashboards-2018.

30. World Bank Country and lending groups (2021). World Bank Country and Lending Groups – World Bank Data Help Desk. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

31. RStudio Team (2022). RStudio (Integrated Development for R. RStudio, PBC). https://posit.co/.

STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
SDG 14 scores and targets	This paper	Table S1
SDG 15 scores and targets	This paper	Table S2
SDG data source	This paper	Table S3
Country class/category	This paper	Table S4
Software and algorithms		
R Studio 2022.07.1 + 554	RStudio: Integrated Development for R	https://posit.co/

RESOURCE AVAILABILITY

Lead contact

Further information and requests for resources should be directed to the lead contact, Jianguo Liu (liuji@msu.edu).

Materials availability

All newly created databases from this study can be found in Supplementary Materials.

Data and code availability

All the source data described in the "SDG, target, indicator, and sub-indicator selection" section can be obtained from the United Nations Statistics, United Nations Food and Agriculture Organization, and Convention on Biological Diversity (see details in Table S3). The intermediate data that support the findings of this study are available within the paper and its Supplementary Materials. All code used in conducting the analyses summarized in this paper is available from the corresponding author upon reasonable request.

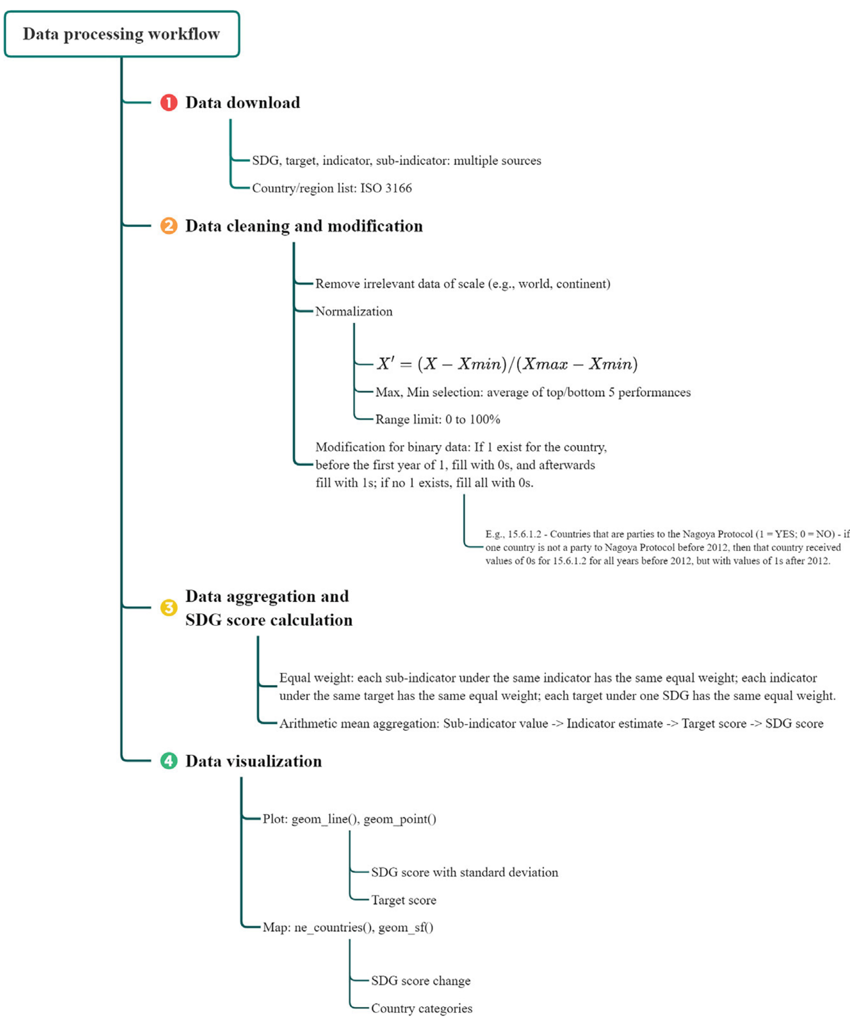
METHOD DETAILS

SDG, target, indicator, and sub-indicator selection

We first followed the Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development[14] from the United Nations Sustainable Development Solutions Network (SDSN) for target and indicator selection for SDGs 14 and 15. Then we used the SDG tracker (https://sdg-tracker.org), an integrated project with Our World in Data (https://ourworldindata.org), to explore and analyze available data for SDGs 14 and 15 at the indicator level. We selected the targets and indicators based on the following criteria: (1) the indicators can be quantifiable in either a binary or a continuous format according to the indicator framework, (2) the data can be publicly accessed at a country scale without a large portion of missing values, (3) each indicator value can be reasonably normalized between the range of 0 and 100%. For example, SDG 14.7.1 was included for analysis because "sustainable fisheries as a proportion of GDP" data are quantifiable as percentages and can be found from the Food and Agriculture Organization of the United Nations (UN FAO); besides, the data can be normalized within the range of 0 and 100% (see data cleaning and modification section for detail). However, we did not select SDG 15.7.1 since the "proportion of traded wildlife that was poached or illicitly trafficked" data was not widely available for countries. We also excluded SDG 14.3.1 while "average marine acidity (pH) measured at agreed suite of representative sampling stations" data did not well fit a country scale.

We selected 3 targets and 3 indicators with 3 sub-indicators under SDG 14, and 6 targets and 7 indicators with 13 sub-indicators under SDG 15. The reason to use sub-indicators was that some indicators cannot be assessed and calculated directly. For example, indicator 15.1.2 (Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type) contains both terrestrial and freshwater ecosystems, so we assessed this indicator by its two sub-indicators 15.1.2.1 (Average proportion of Freshwater Key Biodiversity Areas (KBAs) covered by protected areas (%)) and 15.1.2.2 (Average proportion of Terrestrial Key Biodiversity Areas (KBAs) covered by protected areas (%)).[26] The selections of targets and indicators with sub-indicators are from multiple authoritative and credible data sources based on the best data availability and a detailed description can be found in Table S3. We realized that omitted indicators might lead to a biased result and this bias could not be tested due todata unavailability; however, our previous study[13] with an uncertainty analysis indicated that the median SDG score was almost constant when the number of indicators selected was equal to or greater than two.

The study period was between 2010 and 2020, with a coverage of 70 countries/regions for SDG 14 and 181 for SDG 15. Due to data limitations, we used biannual data (2011, 2013, 2015, 2017, 2019) for SDG 14 analysis and annual data (2010–2020) for SDG 15 analysis. The number of countries/regions included in the analysis was determined by (1) data availability and (2) country suitability. For example, only countries with marine territory were qualified for SDG 14 analysis because the two indicators selected (coastal eutrophication and marine protected area) were only applicable to those countries. The country/region name list (Table S4) was gathered under ISO 3166[27] and the unique three-letter code was used for matching country names (e.g., AFG matches Afghanistan) and aggregating multi-sourced data. The data downloads were listed as step 1 in below figure.



The workflow of data processing and producing analyzed results

Data cleaning and modification

We removed irrelevant values for each indicator if the data was not at a country level (e.g., continent, world) according to the three-letter code. To improve the comparability of values across different SDG indicators, we rescaled and normalized the data ranging from 0 to 1, following the SDSN and Bertelsmann Stiftung's approach.[28,29] We first determined the upper bound (X_{max}, where X is the value of each SDG indicator estimate) and lower bound (X_{min}) for each SDG indicator. If the data was continuous or categorical (more than two categories), we use the average of the top 5 performance values as the upper bound, and the average of the bottom 5 performance values as the lower bound, respectively. If the data was binary, we use 1 as the upper bound, and 0 as the lower bound. We normalized the SDG indicator values with the following formula:

$$X' = (X - X_{min}) / (X_{max} - X_{min})$$

where X′ denotes the normalized indicator estimate for a given SDG indicator. The normalized estimate ranges between 0 and 1, with 0 being the worst performance, and 1 being the best performance. This normalization allows comparison across different indicators among countries.

To modify the original sub-indicator dataset with binary values, we filled either 0 or 1 for the specific sub-indicator for countries over years. The filling rule was that if a country has a 1 in a specific year, then any year beforehand would receive 0s, and years afterward would receive 1s; and that if a country does not have a 1 throughout 2010 to 2020, assign 0s to all years for this country. For instance, Austria submitted its National Biodiversity Strategies and Action Plans (NBSAPs) to the Convention on Biological Diversity (CBD) in 2015, so SDG 15.9.1.1 for Austria has an initial value of 1 in 2015; then the values would be 0 between 2010 and 2014, and 1 between 2015 and 2020. Cyprus, for example, did not submit any NBSAPs, so their SDG 15.9.1.1 would receive 0s for all years from 2010 to 2020. The data cleaning and modification were listed as step 2 in figure in "SDG, target, indicator, and sub-indicator selection" section.

Calculate SDG score and visualization

The SDG score was calculated based on the arithmetic mean of all individual normalized indicator estimates. We followed the SDG Index and Dashboards Reports,[29] and SDG research articles,[13,28] and weighted all individual indicator estimates equally when producing the aggregated SDG score. This was consistent with the spirit of the equal importance of each target.[13,28,29] Firstly, we aggregated normalized indicator estimates to the target level, and produced the mean value as the target value. Then we integrated target values to the SDG level, calculated the mean of all target values under that given SDG, and generated the SDG score.

Each country had its own integrated scores for SDGs 14 and 15, which tracked the progress in achieving SDG targets at a national level. The global SDG score was aggregated as the arithmetic mean of all countries' SDG scores, representing the SDG progress on a global scale.

With the aggregated global SDG scores, we showed the SDGs 14 and 15 progress over the past decade and detected the difference among countries on those SDG scores by observing the standard deviations under different environmental and socioeconomic classifications. For SDG 14, we divided countries into three groups – high income, low income, and no data. The high-income group contains economies with more than $12,696 gross national income per capita, and the low-income group contains economies of upper-middle-income, lower-middle-income, and low-income economies from the World Bank group.[30] We calculated the overall SDG 14 scores with 70 countries, but only had 69 countries (26 high-income and 43 low-income) for the income-based classification analysis because the Cook Islands did not fall within either income category (Table S1). For SDG 15, we categorized countries into the following six hotspot-income groups[17]: (1) high biodiversity hotspot (countries where biodiversity hotspots account for more than 50% of terrestrial lands), high income (HHC_H), (2) high biodiversity hotspot, low income (HHC_L), (3) low biodiversity hotspot (biodiversity hotspots <50%), high income (LHC_H), (4) low biodiversity hotspot, low income (LHC_L), (5) no biodiversity hotspot (countries with no biodiversity hotspots), high income (NHC_H), and (6) no biodiversity hotspot, low income (NHC_L). We calculated the overall SDG 15 scores with 181 countries but included only 136 countries (9 HHC_H, 49 HHC_L, 9 LHC_H, 39 LHC_L, 16 NHC_H, 14 NHC_L) for the income-biodiversity-hotspot-based categorization analysis due to data limitations (Table S2).

We also demonstrated the target value variation over years, delineating which targets or indicators contributed most or least to the overall SDG score variations. In addition, we showed the temporal and spatial change in SDG scores and the change differences between 2010/2011 to 2015 and 2015 to 2019/2020, by providing coloring world maps based on SDGs 14 and 15 scores. This showed the change rate of SDGs 14 and 15 progress before and after the Sustainable Development Goal initiation in 2015 across the decade. The score calculation was listed as step 3, and the result visualization was listed as step 4 in figure in "SDG, target, indicator, and sub-indicator selection" section. All data cleaning, modification, calculation, and visualization were performed with R Studio 2022.07.1 + 554.[31]