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The SDGs Provide Limited Evidence That Environmental Policies Are Delivering Multiple Ecological and Social Benefits

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Key Points:

- The state of the environment globally continues to decline despite increasing environmental policy responses
- The Sustainable Development Goal indicators provide no evidence that environmental policies deliver secondary social benefits
- Protected areas and sustainable forest certification are linked with environmental improvements, mainly in forest and water ecosystems

Supporting Information:

Supporting Information may be found in the online version of this article.

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Abstract The Sustainable Development Goals (SDGs), aiming for global targets by 2030, are tracked by a monitoring framework comprising 231 environmental, social, and economic indicators. The framework provides data to assess whether, across countries, environmental policies are: (a) Addressing environmental pressures, (b) Linked to environmental improvements, and (c) Linked with social benefits delivered by healthy environments. While several studies have analyzed the implementation and impacts of the SDGs, there remains a critical research gap in assessing the linkage between environmental policies and their potential to deliver multiple ecological and social benefits. This study examines the efficacy of environmental policies and their implications for global environmental health and social wellbeing. We use a generalized linear modeling approach to test for correlations between SDG indicators. We show that some environmental policies, particularly protected areas and sustainable forest certification, are linked with environmental improvements, mainly in forest and water ecosystems. However, we find no evidence that environmental improvements are linked with positive social impacts. Finally, environmental pressures, including freshwater withdrawal, domestic material consumption, and tourism, are linked with environmental degradation. Environmental policy responses are generally increasing across countries. Despite this, the state of the environment globally continues to decline. Governments must focus on understanding why environmental policies have not been sufficient to reverse environmental decline, particularly concerning the pressures that continue to degrade the environment. To better track progress toward sustainable development, we recommend that the SDG monitoring framework is supplemented with additional indicators on the state of the environment.

Plain Language Summary Governments implement environmental policies to reduce ecological degradation and sustain environmental benefits to humans, such as food and clean water. The Sustainable Development Goals (SDGs) commit all countries to adopt sustainable development pathways. Progress toward achieving the SDGs is reported by governments using 231 indicators. The SDG indicators track the implementation of environmental policies, the state of the environment, and environmental benefits such as food security and drinking water access. Using the data underlying the SDG indicators reported by governments to date, we investigate whether the implementation of environmental policies correlates with improvements in the environment and the provision of environmental benefits to humans. Results show that most environmental policies are not associated with environmental improvements; worse, we find no evidence that environmental policies lead to wider social benefits. However, we see two types of environmental policies, protected areas and sustainable forest certification, that lead to increasing the size of forest and water ecosystems which are essential for sustaining the lives of plants, animals, and humans that rely on them. Our findings highlight that governments must improve their use of environmental policies to achieve environmental improvements and the wider social benefits that humans derive from the environment.

1. Introduction

In September 2015, the United Nations Sustainable Development Summit adopted an international framework to guide development efforts, entitled Transforming our World: the 2030 Agenda for Sustainable Development (United Nations, 2015). The Agenda is built around 17 Sustainable Development Goals (SDGs), divided into 169 targets, which are a call to action from all countries to move the world onto a sustainable development trajectory. An underlying monitoring framework composed of 231 unique indicators (a further 13 are repeated under different targets) tracks progress toward the goals and targets. The environmental dimension of the SDG

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monitoring framework is composed of 92 indicators (UNEP, 2021). These indicators encompass a range of topics, such as sustainable consumption, ocean acidification, and environmental education, and a range of environments, such as marine, freshwater, and mountain ecosystems. A data set underlies the SDG monitoring framework and is composed of indicators reported to the UN by the Member States or derived by the UN from global data sets when nationally produced indicators are unavailable. However, some indicators still need more data, as discussed further below.

Environmental policies are intended to reduce environmental damage, incentivize positive environmental behavior, and guide practices toward a more sustainable future (Schwartz & Goubran, 2020). The umbrella term "environmental policy" encapsulates various environmental policy types, including regulatory instruments, market-based instruments, voluntary agreements, and information provision (Jordan et al., 2003). In addition, innovation policy may also be used to improve the environment (OECD, 2011). Most recently, a class of policy instruments called nature-based solutions has been defined as "actions to protect, sustainably manage and restore natural or modified ecosystems that address social challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016).

However, the critical question is, do these environmental policies work? Environmental policies aim to "prevent or reduce harmful effects of human activities on ecosystems" (Bueren, 2019) and to "address social challenges… by providing human well-being benefits" (Cohen-Shacham et al., 2016). If policies are achieving these intended outcomes, we would expect environmental improvements to follow policy implementation. We would also expect social benefits to accrue from these environmental improvements, mediated through the ecosystem services that environments provide. Ecosystem services, such as provisioning food and fiber, regulating extreme weather events, and enabling cultural connections to nature, allow the environment to meet various human needs (Watson et al., 2019). In this study, we use the SDG monitoring framework data to investigate, at the national scale, the relationships between the use of environmental policies, the state of the environment, and the provision of environmental benefits to society.

In recent years, a growing body of literature has examined interactions between the SDGs using various techniques. Several studies have investigated relationships between SDG goals and targets qualitatively or at aggregate levels (Anderson et al., 2022; Breuer et al., 2019; Fuso Nerini et al., 2018; ICSU, 2017; PwC, 2016; Scharlemann et al., 2020; Weitz et al., 2019). Others have started to quantify interactions through correlation analysis on the indicator level (Pradhan et al., 2017; Warchold et al., 2021), network analysis (Pham-Truffert et al., 2020), regression modeling (Cling & Delecourt, 2022), and causal mapping (Laumann et al., 2022). However, most examine only select indicators or goals and lack a comprehensive framework for investigating policy impacts. The study by Pradhan et al. (2017) is the only one analyzing all possible indicator pairs, but uses a simple correlation approach.

Crucial gaps remain in understanding dynamics along the policy impact pathway from environmental pressures to policy responses to environmental and social outcomes. Most studies do not adopt a perspective focused on environmental policy efficacy and implications for human wellbeing. Our study helps fill this gap by selecting indicator pairs along a DPSIR (Driving forces to Pressures to States to Impacts to Responses) framework, using generalised linear regression modeling, and incorporating supplementary economic and geographic data. Our targeted approach evaluating the efficacy and impacts of environmental policies provides novel insights compared to prior broad correlation analyses. Our policy-oriented perspective elucidates where efforts are falling short in delivering environmental progress and human wellbeing.

Pradhan (2023) has recently emphasized the current state of underachieving the SDGs and the urgent need to rescue them from failing. Building on Pradhan's work, this study seeks to fill the gap in understanding the effectiveness of environmental policies and their ability to deliver both primary environmental and secondary social benefits.

To this end, we leverage the SDG monitoring framework data to investigate these relationships at a national level. However, we differ from the Pradhan et al. study by focusing on selected indicator pairs along the DPSIR chain, where scientific literature suggests potential correlation or causation. Our methodological approach, detailed in the following section, utilizes generalised linear regression analysis while controlling for factors such as economic development, demographics, or geographic region of a country.

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In doing so, we aim to answer critical questions: What impact do environmental policies have on environmental improvements? How do environmental improvements translate into social benefits? What are the negative impacts resulting from environmental pressures? And, which areas require the most focus for mitigation efforts in the face of environmental pressures? The answers to these questions will provide insights that can help redirect political efforts, optimize policy impacts, and ultimately further sustainable development.

2. Materials and Methods

In this study, we first apply the DPSIR framework to identify SDG indicators representing environmental "pressures," policy "responses," environmental "states," and social "impacts." Second, we identify from the scientific literature plausible relationships between indicators of environmental pressures, environmental policy responses, the state of the environment, and secondary social impacts. Finally, we use statistical tests and generalised linear regression analysis to test relationships between SDG indicators while controlling for confounding factors of countries' state of development, demographics, and geographic region.

2.1. Classifying SDG Indicators and Assessing Data Availability

We classified the 231 unique SDG indicators and their underlying sub-indicators into one of four categories following the DPSIR (Driving forces-Pressures-States-Impacts-Responses) framework (Kristensen, 2004; UN Environment, 2019). This framework is a system-oriented concept that dissects the interactions between society and the environment into these five components. Our study aimed to utilise the data from the SDG monitoring framework to explore potential relationships, at the national level, between these components.

The SDG indicators span social, economic, and environmental dimensions. However, this study focuses specifically on the environmental indicators in order to investigate relationships between environmental policies, environmental pressures, environmental states, and social impacts. We intentionally limited our classification and analysis to the environmental indicators most relevant to our research questions regarding environmental sustainability. While the economic aspects of the SDGs are important, they were excluded from this classification and analysis because our research aims centered on the environmental dimension. Figure 1 shows the four indicator categories we used for classifying the environmental indicators: environmental policy responses, environmental states, social impacts, and environmental pressures. We focused specifically on the environmental indicators in order to leverage the SDG monitoring framework to understand if environmental policies are linked to improvements in environmental states and benefits to society. Analysing relationships between economic, social, and environmental SDG indicators would provide a more holistic picture but was outside this study's scope.

Each SDG indicator or sub-indicator was assessed for data availability. Data collection efforts to support the SDG monitoring framework vary significantly across the Targets and Indicators (UNEP, 2019), and are classified in three Tiers. A Tier 1 indicator is "conceptually clear, has an internationally established methodology and standards are available, and data are regularly produced by countries for at least 50% of countries and of the population in every region where the indicator is relevant"; Tier 2 indicators differ from Tier 1 in that they are not yet supported by regular data collection; and Tier 3 indicators still need an agreed methodology for collecting data (UNSD, 2023). Even though the Inter-agency and Expert Group on SDG Indicators (UNSD, 2023) says in its most recent report that no SDG indicators are now in Tier 3, it remains the case that many SDG environmental indicators do not have the necessary data sets for robust statistical analysis (UNEP, 2019). Between January and June 2020, we extracted the data underlying the SDG indicators from the UN's SDG Indicators Database. However, some underlying data was unavailable on the SDG Indicators Database, and we sourced this additional data from UNEP in July 2020.

Given the scope and nature of our study, we employed a longitudinal data analysis approach. This approach allows us to track and understand changes in the SDG indicators across different countries over time. To ensure robustness in our analysis, we set a criterion that any included indicator or sub-indicator must have data available for at least two distinct years since 2000 and for at least 20 countries. By utilising longitudinal data, our study can better capture temporal changes and trends in the SDG indicators across a broad range of countries, thus providing a more comprehensive understanding of the progression and impacts of environmental policies.

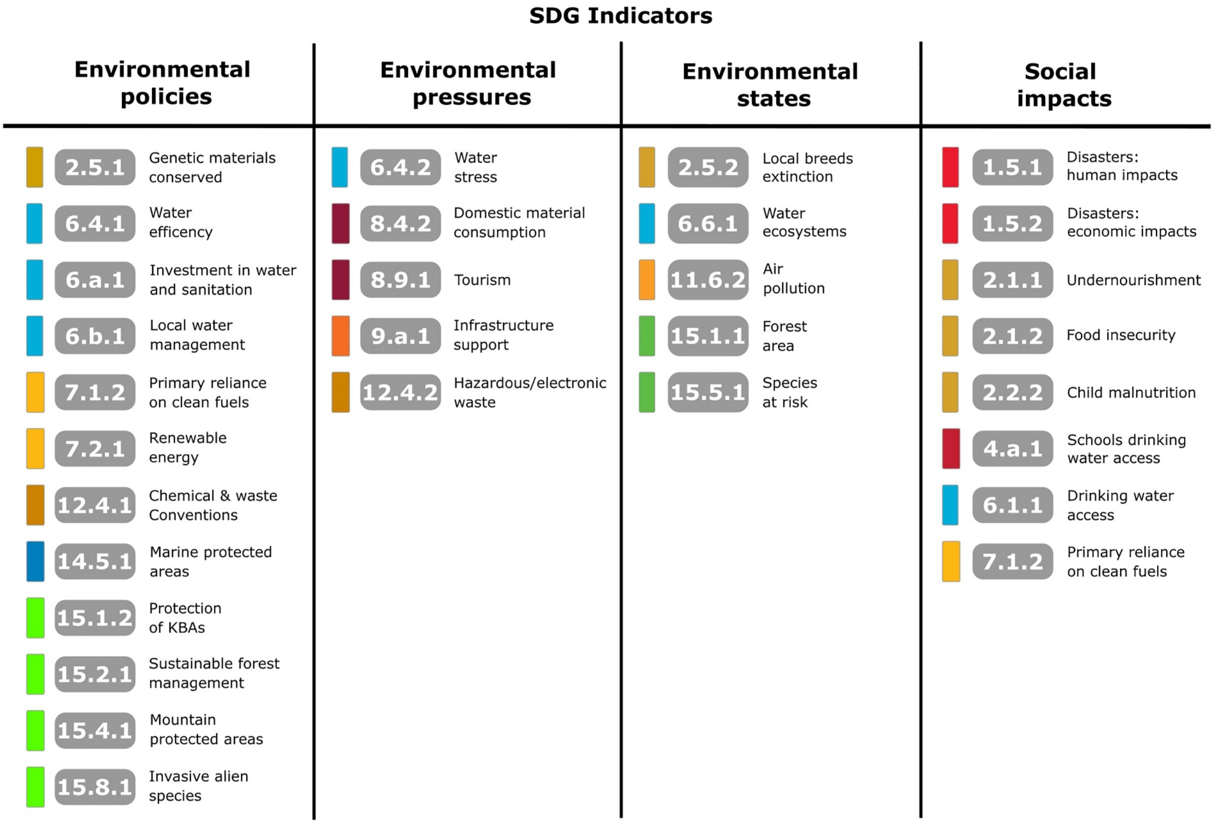

Figure 1. The investigated SDG indicators are classified into four groups: environmental policies, pressures, states, and social impacts. Only indicators with identified potential synergies between pairs are shown.

Some SDG indicators are composed of a single indicator, and others are disaggregated into sub-indicators. For example, SDG indicator 2.5.1 "Secure genetic resources for food" is produced by aggregating two underlying sub-indicators: (a) The number of local breeds for which sufficient genetic resources are stored for reconstitution, and (b) Plant breeds for which sufficient genetic resources are stored. In contrast, SDG indicator 6.6.1 includes sub-indicators related to water body extent, wetland extent, and mangrove extent, which are used without aggregation.

2.1.1. Group 1: Environmental Policy Responses

The SDG monitoring framework uses SDG indicators to track the national use of environmental policy instruments. However, most policy indicators are based on proportions, percentages, or counts. For example, indicator 15.1.2 is the proportion of a country's important biodiversity areas that are protected. Indicator 7.2.1 is the percentage of a country's energy consumption derived from renewable sources. And indicator 15.8.1 is a binary yes/no indicator of whether a country has implemented invasive species control policies. Very few SDG policy indicators actually track on-the-ground implementation or environmental outcomes. This is a major limitation in using these indicators to understand links between policy responses and environmental state. The policy indicators quantify policy adoption, but rarely policy effectiveness or resulting environmental impacts. This is an important caveat in interpreting our results, as the indicators provide limited insight into how well policies are implemented or their tangible consequences. We were constrained to using the available SDG indicators, but recognize their shortcomings in capturing real-world policy effects and environmental change.

We identified 50 unique SDG indicators related to environmental policies that cover issues such as sustainable agricultural management, renewable energy use, and action plans for sustainability. In addition, at the time of our analysis, the SDG monitoring framework contained sufficient data to include 22 environmental policy indicators in this analysis.

2.1.2. Group 2: Environmental States

We identified 11 SDG indicators that relate to the state of the environment. These state of the environment indicators measure the quality and quantity of water resources, marine eutrophication, plastic concentration and acidity, fish stocks, forest cover, land degradation, green land cover in mountain ecosystems, and extinction risk of wild and domesticated species. The SDG monitoring framework contained sufficient data to include five environmental state indicators in this analysis.

2.1.3. Group 3: Social Impacts

We identified 16 SDG indicators that relate to the social impacts of the environment. These social impact indicators include the human impacts of natural disasters, food, and water access, and mortality attributed to air pollution. The SDG monitoring framework contained sufficient data to include 11 social impact indicators in this analysis.

2.1.4. Group 4: Environmental Pressures

We identified 20 SDG indicators related to environmental pressures. These environmental pressure indicators include water stress, domestic material consumption (DMC), tourism, and infrastructure development. The DMC indicator comprises numerous material-specific sub-indicators including, but not limited to, DMC of wood, minerals, fossil fuels, crops, wild catch, and harvested materials. The SDG monitoring framework contained sufficient data to include 18 environmental pressure indicators in this analysis.

2.2. Identifying Potential Synergies Between Indicator Pairs

To investigate the relationship between environmental "pressures," policy "responses," environmental "states," and social "impacts," we identified potential relationships between SDG indicators and their underlying sub-indicators in a systematic way, following these steps:

1. Given its comprehensive review of the environmental and social impacts of various environmental pressures and policy responses, we drew evidence from the IPBES Global Assessment (Watson et al., 2019) to identify these potential relationships. We compiled a list of hypothesized relationships between SDG indicators based on this evidence review. For example, the IPBES report details the effectiveness of protected areas in reducing deforestation. Therefore, we hypothesized a positive relationship between indicators on protected area coverage and forest extent.
2. We supplemented the evidence presented in the IPBES Global Assessment through consultation with experts from various environmental and social stakeholder groups. This consultation on selecting SDG indicator relationships took the form of an online meeting held on 21–22 April 2020 and an online survey held from 29 May to 13 June 2020. We provide the minutes of this meeting and an overview of the responses received from experts to the online survey in the Supporting Information S1.
3. We combined the hypothesized relationships identified through the evidence review and expert consultation to create a comprehensive list of 618 potential relationships between the SDG indicators relevant to our DPSIR framework categories of environmental pressures, policy responses, environmental states, and social impacts.
4. Finally, we identified a subset of hypothesized relationships to investigate further using statistical analysis based on data availability.

This systematic process, grounded in established evidence and expert opinion, allowed us to identify and focus on SDG indicator pairs with potential synergies relevant to our research questions (Figure 1).

2.3. Determining How to Interpret SDG Indicators to Identify Improvements in Environmental and Social Conditions

A good indicator has a clear relationship to the situation about which it is reporting. For the environmental state and social impact indicators included in this analysis, we identified whether an increase or decrease represents an improvement in conditions. Some indicators show improvement when they increase, such as forest area and schools with drinking water access. Other indicators show improvement when they decrease, such as air pollution levels and food insecurity prevalence. The desirable direction of correlation between an environmental pressure, policy, state, or impact indicator depends on whether an increase or decrease denotes improvement for each indicator. For example, for a policy-state indicator pair, if the state indicator improves when increasing, it should correlate positively with a policy indicator that also shows improvement when increasing. If the state indicator improves when decreasing, it should correlate negatively with a policy indicator that shows improvement when increasing. We used this interpretative framework to identify results which suggest that environmental policies and reductions in pressures are achieving improvements in environmental states and social impacts.

2.4. Investigating Relationships Between Indicator Pairs

We used generalized linear regression modeling (GLRM) to investigate whether there is evidence for a statistically significant relationship between our chosen indicator pairs. In addition to the indicators of interest, we included two country-level characteristics, population and GDP, as potential confounding factors in the models. Prior research has shown population and economic development may influence relationships between SDG indicators across countries (Breuer et al., 2019). Countries with larger populations or more advanced economic development may have greater resources to implement environmental policies and reduce environmental pressures. At the same time, larger populations and economic expansion can also drive greater pressures on the environment. To isolate the relationships between our indicators of interest, population and GDP were included in the models to control for their potential confounding effects. This approach aims to detect correlations between the environmental policy, pressure, state, and impact indicators that are not simply due to differences in countries' demographics and economic status. In addition to GDP and population, we included a fixed effect in our regressions to account for regional differences between the countries.

This methodology adapts the analysis we present in UNEP (2021), in which we combined a GLRM and correlation test to investigate SDG indicator interactions. Here we report only the results of our investigation of SDG indicator interactions using a GLRM approach, as this approach enables us to investigate correlations while considering some confounding factors that a correlation test cannot account for.

There are several points to note about our approach: (a) The GLRM approach is characterized by the assumption that the relationship between two indicators is linear. Therefore, any non-linear associations between the two indicators will not be captured adequately by the GLRM. (b) We applied a log transformation to several indicators to control for the substantial differences between some countries. The log transformation is appropriate to the data underlying the indicators because the values are generally positive, such as percentages and square kilometres. The log transformation also mitigates the impact of outliers by compressing the data. (c) We needed at least two data points at different times to estimate the relationships between our indicators (d) Finally, for each indicator pair we investigated, our analysis was limited to the number of countries reporting data for both indicators.

2.4.1. Generalized Linear Regression Model (GLRM)

The complete model formulation is as follows:

$$\log(Y) = \beta_1 \log(X) + \beta_2 \log(\text{pop}) + \beta_3 \log(\text{GDP}) + I_{\text{region}}$$

where:

- Y: an indicator of either the environmental state OR a social impact
- X: an indicator of either the environmental pressure OR an environmental policy OR the environmental state
- pop and GDP: national population and GDP for each year, the potential confounding factors
- I_{region}: a fixed effect variable for each country or geographical region
- $\beta 1$, $\beta 2$, and $\beta 3$: maximum likelihood estimates of the model coefficients. These measure the relationship between each independent variable in the model and the dependent Y variable.

We conducted a hypothesis test on the coefficient of interest ($\beta 1$) to assess whether there is evidence of a relationship between a pair of indicators (using a significance level of $\alpha = 0.05$) after accounting for the influence of the potential confounding factors. The GLRM model also calculates the R^2 value, which shows how much of the variance in the dependent variable the model captures. We did not consider regressions with an R^2 of less than 0.2, which was our minimum goodness of fit threshold (Warchold et al., 2021). We conducted all statistical analyses using R software (R Core Team, 2021).

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3. Results

We identified some significant correlations between indicators that depict environmental states and those representing environmental policies and pressures. While some of these relationships align with our initial hypotheses, others present unexpected correlations, inviting further exploration. Interestingly, our study did not find any significant correlations between indicators of environmental states and those depicting social impacts. Consequently, the results discussed in this section pertain solely to environmental policy, pressure, and state indicators.

3.1. Relationships Between Environmental Policies and the State of the Environment

Table 1 shows significant correlations between the environmental policy and the environmental state indicators. Correlations that show environmental improvement, and align with our hypotheses, are presented in the upper half of the table. Correlations that show environmental degradation, and contradict our hypotheses, are presented in the lower half of the table. The middle column describes the hypothesized causal relationship between environmental policies and environmental improvements based on scientific literature. The right-hand column describes how to interpret the results of the statistical analysis. While all environmental policies should improve environmental states, our results show that in a substantial number of cases (the orange cells in the right hand column) there is no evidence from the correlations that this is the case. There follows a description of the environmental policy-environmental state correlations summarized in Table 1.

3.1.1. Extinction Risk of Local Breeds (2.5.2)

In respect of the extinction risk of local breeds, despite increasing numbers of genetic resources secured in conservation facilities, the proportion of local breeds at risk of extinction is increasing. To illustrate, in Brazil, despite efforts to conserve livestock genetic resources (Mariante & Bem, 1992; Mariante et al., 2009), the proportion of local breeds classified as being at risk continues to increase. This result suggests that policymakers must do more to conserve domesticated species from the threat of extinction. Indeed, the latest reports from the Food and Agriculture Organisation (FAO) on this topic highlight numerous shortcomings in the state of genetic resource conservation, including missing risk status assessments for the majority of breeds and a lack of early warning systems for genetic erosion (Scherf et al., 2015). In addition, SDG indicators 2.5.1 and 2.5.2 need more data for many countries (Gil et al., 2019). Ultimately, conservation efforts, and the indicators used to monitor them, must be improved to mitigate and monitor the genetic extinction risk of economically and socially valuable species (Gandini & Hiemstra, 2021).

3.1.2. Water Ecosystem Extent (6.6.1)

Our analysis suggests that protecting Key Biodiversity Areas (KBAs) is linked with an increase in the extent of water ecosystems (15.1.2). It is particularly difficult to evaluate the impact of protected areas on freshwater ecosystems (Adams et al., 2015) so it is interesting to find evidence of potential benefits of protected areas on the extent of freshwater ecosystems. Conversely, we found a negative correlation between water ecosystem extent and development assistance spending for water supply and sanitation (6.a.1), suggesting that increased investment in water and sanitation may inadvertently be causing a reduction in water ecosystems. We observe his phenomenon in Asia, where wetland loss is highest globally (Boretti & Rosa, 2019), and water and sanitation development assistance has increased in most, albeit not all countries. Furthermore, no significant relationship existed between water ecosystem extent and water use efficiency (6.4.1).

3.1.3. Air Pollution (11.6.2)

Air pollution levels in cities, assessed by measuring outdoor fine particulate matter, correlated positively with the proportion of the population relying primarily on clean fuels and technology (7.1.2). This suggests that even though the adoption of clean fuels and technologies is on the rise, urban air pollution levels continue to increase. To illustrate, in rapidly developing countries like India, despite an increased reliance on clean fuels (WHO, 2023), air pollution in major cities remains a significant concern (IQAir, 2023). In contrast, there was a negative correlation between air pollution and the share of renewable energy in a country's total final energy consumption (7.2.1), suggesting that an increased reliance on renewable energy may help reduce air pollution levels.

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Table 1
Significant Correlations Between the Environmental Policy and Environmental State Indicators

Environmental policy indicator	Environmental state indicator	Hypothesized outcomes of environmental policy, leading to environmental improvements	Evidence for the hypothesized relationship	What our results suggest (green/orange shading indicates agreement/disagreement with our hypotheses)
7.2.1 Renewable energy	11.6.2 Outdoor air pollution in cities	Greater reliance on clean fuels leads to less combustion of dirty fuels, which reduces the amount of air pollutants produced and leads to improvements in air quality	IEA et al. (2022, p. 7)	*Increasing* renewable energy use correlates with *decreasing* levels of fine particulate matter in cities
7.2.1 Renewable energy	15.1.1 Forest area	Greater reliance on clean fuels reduces reliance on wood resources for energy which leads to less deforestation and a greater extent of forest ecosystems	IEA et al. (2022, p. 7)	*Increasing* renewable energy use correlates with *increasing* forest area
15.1.2 Protection of Key Biodiversity Areas (KBAs)	6.6.1 Water ecosystems	Protection of KBAs reduces the abstraction of water from protected water ecosystems and leads to an increase in water ecosystem extent	Chan et al. (2006) and IUCN (2012)	*Increasing* protection of KBAs is correlated with *increasing* water ecosystem extent
15.1.2 Protection of Key Biodiversity Areas (KBAs)	15.1.1 Forest area	Protection of KBAs reduces deforestation in protected forest ecosystems and leads to an increase in forest area	Carranza et al. (2014) and Geldmann et al. (2013)	*Increasing* protection of KBAs is correlated with *increasing* forest area
15.2.1 Sustainable forest certification	15.1.1 Forest area	Sustainable forest certification reduces unsustainable deforestation, which increases forest area	Auld et al. (2008), Damette and Delacote (2011), Potapov et al. (2017), and Rametsteiner and Simula (2003)	*Increasing* sustainable forest certification is correlated with *increasing* forest area
15.2.1 Sustainable forest certification	15.5.1 Species at risk	Sustainable forest certification reduces human disturbance of biodiversity in forest ecosystems which leads to a reduction in the number of species threatened with extinction	Burivalova et al. (2017), Kalonga et al. (2016), and van Kuijk et al. (2009)	*Increasing* sustainable forest certification is correlated with *increasing* Red List Index, which indicates *decreasing* species extinction risk
15.2.1 Protected forest area	15.1.1 Forest area	Protection of forest ecosystems reduces unsustainable deforestation, which increases forest area	Carranza et al. (2014) and Eklund et al. (2016)	*Increasing* the protection of forests correlates with *increasing* forest area
2.5.1 Secure genetic resources for food	2.5.2 Local breeds extinction	Conservation of genetic resources reduces the extinction risk of domesticated species	Coping with Climate Change (2015) and Enjalbert et al. (2011)	*Increasing* conservation of genetic resources for food correlates with an *increasing* proportion of local breeds at risk of extinction
6.a.1 Investment in water and sanitation	6.6.1 Water ecosystems	Investment catalyzes improved water resource management which reduces demand for, and abstraction of, water from water ecosystems and leads to an increase in water ecosystem extent	Turral et al. (2010)	*Increasing* investment in water and sanitation correlates with *decreasing* water ecosystem extent
7.1.2 Primary reliance on clean fuels	11.6.2 Air pollution	Greater reliance on clean fuels and technologies leads to less non-renewable resource combustion, which reduces the amount of air pollutants produced and leads to improvements in air quality	IEA et al. (2022, p. 7)	*Increasing* reliance on clean fuels correlates with *increasing* levels of fine particulate matter in cities

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Table 1
Continued

Environmental policy indicator	Environmental state indicator	Hypothesized outcomes of environmental policy, leading to environmental improvements	Evidence for the hypothesized relationship	What our results suggest (green/orange shading indicates agreement/disagreement with our hypotheses)
15.1.2 Protection of Key Biodiversity Areas (KBAs)	15.5.1 Species at risk	Protection of KBAs reduces human disturbance of biodiversity, which leads to a reduction in the number of species threatened with extinction	Barnes et al. (2016), Butchart et al. (2006), Coad et al. (2015), Geldmann et al., 2013; Gray et al., 2016)	*Increasing* protection of KBAs is correlated with *decreasing* Red List Index, which indicates an *increasing* species extinction risk
15.2.1 Sustainable forest long-term management	15.5.1 Species at risk	Sustainable forest management reduces human disturbance of biodiversity in forest ecosystems which leads to a reduction in the number of species threatened with extinction	Burivalova et al. (2017)	*Increasing* the forests under sustainable long-term management correlates with *decreasing* Red List Index, which indicates an *increasing* species extinction risk
15.2.1 Protected forest area	15.5.1 Species at risk	Protection of forest ecosystems reduces human disturbance of biodiversity in forest ecosystems which leads to a reduction in the number of species threatened with extinction	Barnes et al., 2016; Butchart et al. (2006), Coad et al. (2015), Geldmann et al. (2013), and Gray et al. (2016)	*Increasing* protection of forests correlates with *decreasing* Red List Index, which indicates an *increasing* species extinction risk
15.4.1 Mountain protected areas	15.5.1 Species at risk	Protection of mountain ecosystems reduces human disturbance of biodiversity in mountain ecosystems which leads to a reduction in the number of species threatened with extinction	Barnes et al. (2016), Butchart et al. (2006), and Gray et al. (2016)	*Increasing* protection of mountain ecosystems correlates with *decreasing* Red List Index, which indicates an *increasing* species extinction risk
15.8.1 Invasive alien species	15.5.1 Species at risk	National legislation and adequate resourcing for the prevention or control of invasive alien species leads to a reduction in the negative impacts of invasive alien species on biodiversity and a reduction in the number of species threatened with extinction	Butchart et al. (2006)	*Increasing* prevention and management of alien invasive species correlates with *decreasing* Red List Index, which indicates *increasing* species extinction risk.

Note. Results that align with our hypotheses about the relationship between environmental policies and the state of the environment are highlighted in green. Conversely, results that contradict our hypotheses are highlighted in orange.

3.1.4. Forest Area (15.1.1)

The SDG data showed a positive correlation between forest area and the share of renewable energy in a country's total final energy consumption (7.2.1). This suggests a possible relationship where increased renewable energy use might lead to larger forest areas, possibly because of reduced deforestation due to less reliance on timber for energy production.

Our findings yielded no evidence to suggest a direct relationship between forest area and the population primarily reliant on clean fuels and technology (7.1.2). This finding indicates that, within the timeframe and parameters of this study, the adoption of cleaner energy solutions does not have a quantifiable impact on forest coverage.

However, our analysis suggests that protecting KBAs is linked with an increase in the extent of forest area and water ecosystem extent (15.1.2) aligning with the evidence of previous research (Geldmann et al., 2013; Joppa & Pfaff, 2011). In addition, the area of forest receiving certification from independently verified bodies (15.2.1), and the total area of forest under some form of protective measure (15.2.1) demonstrated a positive correlation with forest area. We saw this relationship across many countries, including Gabon, Vietnam, China, Cuba, the Dominican Republic, and several European countries. This result suggests that, with each expansion of a protected area or the certification of a new forest section under rigorous, sustainable standards, we anticipate a related increase in overall forest coverage.

3.1.5. Species at Risk (15.5.1)

Our results regarding the relationship between species extinction risk and environmental responses were sobering yet not unexpected. Only a single environmental response (forest certification) correlated in a direction that suggests that extinction risk is declining in response to an environmental policy, which aligns with empirical evidence that forest certification contributes positively to biodiversity conservation (Lehtonen et al., 2021). However, the extent of protected areas of forest ecosystems, mountain ecosystems, and KBAs all correlated with an *increase* in species extinction risk. This may reflect that countries with greater biodiversity threats have implemented more protections for biodiversity in an effort to mitigate species declines, rather than protections causing extinction risk to increase. Nonetheless, the results align with the criticisms that protected areas have fallen short of their conservation goals over the past decade (Gardner et al., 2023; Maxwell et al., 2020). Despite the implementation of these policies by many countries, the number of species at risk of extinction continues to increase. This indicates that the current conservation strategies may not be effective enough for safeguarding biodiversity.

3.2. Relationships Between Environmental Pressures and the State of the Environment

Table 2 shows the environmental pressure indicators that correlate significantly with the environmental state indicators. It is to be expected that an increase in environmental pressure would result in a environmental degradation, that is, a worsening environmental state. In Table 2, correlations that show environmental degradation, and align with our hypotheses, are presented in the upper half of table. Correlations that show environmental improvements, and contradict our hypotheses, are presented in the lower half of table. The middle column describes the hypothesized causal relationship between the environment and society based on scientific literature. The right-hand column describes how to interpret the results of the statistical analysis. The analysis of the correlations that follows shows, as with Table 1, a number of counter-intuitive correlations in our results.

3.2.1. Water Ecosystem Extent

The extent of water ecosystems was negatively correlated with water stress (6.4.2), measured as the proportion of freshwater withdrawals to available freshwater resources, and with tourism (8.9.1), measured as the proportion of tourism GDP in a country's total GDP. This result suggests that the extent of water ecosystems declines as freshwater withdrawals and tourism activities increase. On the other hand, the extent of water ecosystems was positively correlated with domestic material consumption (DMC) of crops (8.4.2), DMC of metal ores and non-metallic minerals, and international financial support for infrastructure (9.a.1). This result suggests that the extent of water ecosystems increases as consumption of domestically produced crops increases, perhaps due to increased area used for irrigation, with increasing consumption of domestically produced metal ores and non-metallic

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Table 2
Significant Correlations Between the Environmental Pressure and Environmental State Indicators

Environmental pressure indicator	Environmental state indicator	Hypothesized outcomes of environmental pressures, leading to environmental degradation	Evidence for the hypothesized relationship	What our results suggest (green/orange shading indicates agreement/disagreement with our hypotheses)
6.4.2 Water stress	6.6.1 Water ecosystems	More significant water stress increases demand for, and abstraction of, water from water ecosystems and leads to a decrease in water ecosystem extent	Arroita et al. (2017), Pekel et al. (2016), and Rosen et al. (2000)	*Increasing* water stress correlates with *decreasing* water ecosystem extent
8.4.2 DMC of crops	15.5.1 Species at risk	Greater consumption of crops promotes increased agricultural production, which increases human disturbance of natural ecosystems and biodiversity, which pushes more species toward extinction	Foley et al. (2005) and Lambertini (2020)	*Increasing* consumption of domestically produced crops correlates with *increased* species extinction risk
8.4.2 DMC of fossil fuels	11.6.2 Air pollution	Greater consumption of fossil fuels involves the combustion of fossil fuels which produces air-borne pollutants which reduce air quality	De Longueville et al. (2014)	*Increasing* consumption of domestically produced fossil fuels correlates with *increased* air pollution in cities
8.4.2 DMC of wild catch and harvest	15.5.1 Species at risk	Increased exploitation and consumption of wildlife reduces the population sizes of species and pushes more species toward extinction	Bradshaw et al. (2009), Butchart et al. (2006), Fa et al. (2003), Nasi et al. (2011), and Vliet et al. (2007)	*Increasing* consumption of wild-caught and harvested species correlates with *increased* species extinction risk
8.9.1 Tourism	6.6.1 Water ecosystems	Increased tourism increases demand for, and abstraction of, water from water ecosystems and lead to a decrease in water ecosystem extent	Gössling and Peeters (2015)	*Increasing* tourism correlates with *decreasing* water ecosystem extent
8.9.1 Tourism	15.1.1 Forest area	Increased tourism promotes deforestation through the development of tourism infrastructure	Gössling and Peeters (2015)	*Increasing* tourism correlates with *decreasing* forest area
8.9.1 Tourism	15.5.1 Species at risk	Increased tourism leads to land use change to develop tourism infrastructure, which disrupts ecosystems. Furthermore, it leads to more significant numbers of people visiting areas of high biodiversity value, which increases biodiversity disturbance and pushes more species toward extinction. Alternatively, nature-based tourism can promote biodiversity conservation.	Bookbinder et al. (1998) and Gössling (2002)	*Increasing* tourism correlates with *increasing* species extinction risk
8.4.2 DMC of crops	15.1.1 Forest area	Greater consumption of crops promotes increased agricultural production, which increases demand for land, which drives deforestation and decreases forest area	Foley et al. (2005), Geist and Lambin (2002), Gibbs et al. (201), and Potapov et al. (2017)	*Increasing* consumption of domestically produced crops correlates with *increasing* forest area
8.4.2 DMC of metal ores and non-metallic minerals	6.6.1 Water ecosystems	Mining uses large quantities of freshwater. Therefore an increase in the DMC of minerals extracted by mining will decrease the extent of water ecosystems.	Palmer et al. (2010)	*Increasing* consumption of domestically produced metal ores and non-metallic minerals correlates with *increasing* water ecosystem extent
8.4.2 DMC of metal ores and non-metallic minerals	15.1.1 Forest area	Mining drives deforestation. Therefore an increase in the DMC of minerals extracted by mining will decrease forest area.	Potapov et al. (2017), Schueler et al. (2011), and Sonter et al. (2014)	*Increasing* consumption of domestically produced metal ores and non-metallic minerals correlates with *increasing* forest area

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Table 2
Continued

Environmental pressure indicator	Environmental state indicator	Hypothesized outcomes of environmental pressures, leading to environmental degradation	Evidence for the hypothesized relationship	What our results suggest (green/orange shading indicates agreement/disagreement with our hypotheses)
8.4.2 DMC of metal ores and non-metallic minerals	15.5.1 Species at risk	Mining has a negative local effect on biodiversity due to habitat destruction and pollution. Therefore an increase in the DMC of minerals extracted by mining will increase the number of species at risk of extinction.	Deikumah et al. (2014)	*Increasing* consumption of domestically produced metal ores and non-metallic minerals correlates with *decreasing* species extinction risk
8.4.2 DMC of wood	15.1.1 Forest area	Greater consumption of wood resources promotes deforestation, which reduces forest area. Conversely, greater wood consumption promotes the conversion of non-forested land to timber plantations which increases forest area	Geist and Lambin (2002), Payn et al. (2015), and Potapov et al. (2017)	*Increasing* consumption of domestically produced wood correlates with *increasing* forest area
9.a.1 Infrastructure support	6.6.1 Water ecosystems	Support for dam infrastructure will increase the water ecosystem extent due to the creation of reservoirs associated with dams. Alternatively, support for, and construction of, other forms of infrastructure, such as urban development, degrades natural ecosystems and reduces water ecosystems' extent.	Davis and Froend (1999), Lehner et al. (2011), Wang et al. (2008), Zhang (2009), and Žganec (2012)	*Increasing* financial support for infrastructure correlates with *increasing* water ecosystem extent.

Note. Results that align with our hypotheses about the relationship between environmental pressures and the state of the environment are highlighted in green. Conversely, results that contradict our hypotheses are highlighted in orange.

minerals, and with increasing financial support for infrastructure, perhaps due to the construction of dams and the reservoirs created by them.

3.2.2. Air Pollution (11.6.2)

We identified a positive correlation between air pollution levels and DMC of fossil fuels (8.4.2). This result affirms that as societies rely more heavily on domestically produced fossil fuels, air quality in urban areas tends to deteriorate, contributing to increased levels of harmful pollutants.

3.2.3. Forest Area (15.1.1)

Our analysis revealed a positive correlation between forest area and DMC of crops, wood, metal ores, and non-metallic minerals (8.4.2). This result counter-intuitively suggests an increase in forest area as the consumption of these domestically produced materials escalates, although it is possible that the result arises from an increase in agroforesty, where crops are grown in tandem with forest regeneration.

However, the picture changes when we consider tourism. Our results show a negative correlation between forest area and tourism (8.9.1). This result could be due to land clearance for constructing hotels, resorts, and other tourist attractions, leading to decreased forest cover.

3.2.4. Species at Risk (15.5.1)

Regarding the environmental pressures that drive biodiversity loss, our results agree with the contemporary evidence that agricultural land use change and direct exploitation of wildlife remain the main drivers of terrestrial biodiversity declines (Balvanera et al., 2019; Jaureguiberry et al., 2022). Our results highlight that countries need to do more to holistically tackle the multiple drivers of biodiversity loss using environmental policies that are socially just and align with countries' climate change ambitions.

4. Discussion

In this study, we used the global SDG indicators data set and a novel statistical modeling approach to investigate the relationships between environmental policy responses, environmental pressures, the state of the environment, and social impacts of the environment. We found that specific policies like protected areas and sustainable forest certification correlate with some environmental progress, but we could find no evidence of wider social benefits.

Our study makes a novel contribution by investigating SDG interactions through the lens of environmental policy efficacy. Our targeted DPSIR approach differed from the more comprehensive systems perspectives of Pradhan et al. (2017) and Warchold et al. (2021) who analyze all possible SDG indicator pairs. While these studies have examined statistical correlations between SDG indicators, our research focuses explicitly on hypothesized relationships along the policy impact pathway from environmental pressures to policy responses to environmental and social outcomes. In this way, we can evaluate whether environmental policies achieve their objectives.

A key innovation in our study is using the DPSIR framework to select and analyze hypothetical causal relationships between SDG indicator pairs. Guided by scientific literature and expert judgment, we identified specific indicator pairs representing plausible causal pathways along the DPSIR spectrum. This targeted approach enabled us to investigate policy efficacy and impacts along a theorised causal chain. The policy-oriented nature of our study provides a useful complement to the broader system-level analyses by Anderson (2021) and Warchold et al. (2021). While their approaches are better suited for understanding indirect effects and macro-level influences, our targeted investigation generates focused insights into the efficacy of environmental governance efforts specifically. Our results provide an empirical basis for pinpointing where along the DPSIR continuum environmental progress is falling short and how policies and pressures are contributing to environmental state and social impact indicators. This distinguishes our approach from previous correlation studies and offers a novel systems perspective on environmental policy efforts under the SDG framework.

Our finding that only specific environmental policies like protected areas and forest certification correlate with environmental improvements contrasts with more optimistic perspectives from some previous SDG interaction studies. For instance, Pham-Truffert et al. (2020) highlight the potential for synergies across most SDG goals and targets. Similarly, Cling and Delecourt (2022) find predominantly positive associations between SDGs. The divergence suggests that effectiveness may vary across policy domains, with biodiversity and ecosystem-focused interventions demonstrating more significant limitations than progress in other areas like poverty reduction. Our results concur more with critiques from Breuer et al. (2019) and Laumann et al. (2022) on the need for nuanced, contextual understanding of interactions and caution against simplistic generalisations. While not proving policy ineffectiveness, our findings underscore the importance of robust impact evaluation to identify and enhance policies that demonstrably improve the state of the environment. Our findings also demonstrate the value of a targeted DPSIR perspective focused on the environment-policy nexus. Further research can build on this approach using additional indicators and data sources to provide fuller insights into policy efficacy across SDG objectives.

We investigated the environment's social impacts but found no evidence for relationships between the state of the environment and its impacts on society. This finding aligns with Pham-Truffert et al. (2020), who found limited linkages between environmental and social SDG indicators. The need for more explicit connections is unsurprising, given the complexity of ecosystem-society linkages, as noted by Mace (2019). Our national-level analysis may also miss subtler dependencies at local scales, an issue also highlighted by Breuer et al. (2019). The aggregated SDG indicators cannot capture the nuances of how specific populations rely on local environments, as critiqued by Walter and Andersen (2016), Warchold et al. (2021), and Anderson et al. (2022). Nonetheless, the absence of detectable social impacts of environmental policies is concerning and suggests that governments need more integrated assessments encompassing environment-society interdependencies, as Johnson et al. (2022) advocate. While our study provides baseline evidence on this issue, further research is needed to understand how environmental progress translates into human well-being using more localized data and perspectives.

4.1. Policy Implications of Our Findings

Policy responses and environmental pressures continue to increase while the state of the environment continues to decline (Lambertini, 2020; UN Environment, 2019), which illustrates that, to improve the environment, national governments need to do more. Existing policies must do more to achieve their goals and require greater stringency or redesign (UN Environment, 2019). Others need to be implemented correctly or enforced adequately. Moreover, policies must tackle the underlying drivers of environmental change, such as values, technology, demography, the economy, and governance, which often subvert well-meaning environmental policies. In addition, countries must respond holistically to environmental declines by integrating environmental policies into agriculture, fisheries, and energy policies that drive environmental change (European Habitats Forum, 2019).

4.2. Reflections on the SDGs and Their Future

We make some recommendations for future improvements to the SDG monitoring framework. First, indicators on policy responses dominate the environmental dimension of the SDG monitoring framework (50 out of 92 indicators), while only 11 measure the state of the environment (Campbell et al., 2020). We recommend supplementing the framework with additional environmental state indicators to track better whether policy responses lead to environmental improvements. Second, we recommend that indicator 15.5.1, the Red List Index on wild species extinction risk, is disaggregated into multiple sub-indicators of terrestrial, freshwater, and marine species. Currently, indicator 15.5.1 only includes terrestrial species, so it is unsuitable for assessing the success of indicator 14.5.1 on marine protected areas and sub-indicator 15.1.2 on the protection of freshwater KBAs. The Red List Index for marine species (see, for example, Nieto et al. (2015)) and a sub-indicator for freshwater species would be more suitable for monitoring the success of marine and freshwater conservation interventions than indicator 15.5.1 in its current form. Finally, national environmental monitoring agencies should adopt science-based standards for the environmental state indicators to provide clear targets for achievement (Usubiaga-Liaño & Ekins, 2022). Standards for some indicators will be uniform across all countries, such as the WHO's safe air pollution levels (World Health Organization & WHO European Centre for Environment, 2021). The standards of other indicators will need to be country-specific and defined through scientific investigation of environmental thresholds in the unique environmental context of each country.

At the 15th Conference of Parties to the UN Convention on Biological Diversity (CBD), UN Member States agreed to a new set of Goals and Targets to address biodiversity loss and restore natural ecosystems (CBD, 2022a), progress toward which will be tracked by an underlying monitoring framework of indicators (CBD, 2022b). Adopting the monitoring framework is a significant achievement as it is the first time an officially agreed monitoring framework has accompanied the CBD's international biodiversity agreements. A rigorous mechanism for tracking countries' progress on biodiversity will push governments to prioritize the effective design and implementation of environmental policies that bend the curve of biodiversity decline.

4.3. Limitations and Future Research

While our national-level statistical analysis provides valuable insights, some studies, like Breuer et al. (2019), note the importance of local contexts in fully understanding SDG interactions. Our globally generalized approach could miss critical nuances and non-linear relationships detectable through more localized modeling. However, our inclusion of GDP and population as covariates somewhat accounts for country-specific differences.

However, there are limitations to the breadth of indicators we analyzed, our reliance solely on UN data, our use of national-level analysis, and the assumption of linear relationships between indicators imposed by our modeling approach. As such, our conclusions are tentative, pending further research on policy impacts using more comprehensive data. Nonetheless, our study provides a valuable initial quantitative analysis of the connections between environmental policies and outcomes using the common framework of the SDG indicators. Our study sets up an approach that could be extended and refined to strengthen the monitoring and accountability mechanisms of the SDG framework.

In light of the recent study by Warchold et al. (2022), it is essential to reflect on the implications of data selection in understanding SDG interactions. Our research used SDG indicator data from the UN. However, Warchold et al.'s study suggests that the choice of data source can significantly alter the interpretation of SDG interactions. They demonstrated that data from other sources, such as the World Bank Group (WBG) or the Bertelsmann Stiftung & Sustainable Development Solutions Network (BE-SDSN), could yield different results and lead to different conclusions. This finding highlights the critical role of data selection in SDG research and the potential for bias introduced by using a single data source.

Warchold et al.'s argument for a unified SDG database is particularly compelling. They propose a framework amalgamating data from various sources, providing a more comprehensive and nuanced view of SDG interactions. Unfortunately, such a unified database was not available during our study. However, the insights from Warchold et al.'s research underscore the importance of considering multiple data sources and the potential value of a unified database in future research. If we repeated our study, we would strongly consider using data from this unified database to ensure a more comprehensive and balanced view of SDG interactions. This approach could lead to more robust and reliable findings, thereby enhancing the validity and impact of future SDG research.

4.4. Conclusions

Our study makes an essential contribution by investigating the efficacy of environmental policies and their impacts on environmental and social outcomes using the novel lens of the SDG indicator framework. Our findings have several critical implications for the research gaps this study aimed to address.

First, the limited evidence that current environmental policies are linked to tangible improvements in the state of the environment indicates a need to re-evaluate policy design and implementation. More ambitious efforts are essential to reverse ongoing environmental degradation. This urgency is embodied by the declining global trends across various environmental state indicators, as the latest SDG progress report from the United Nations Department of Economic and Social Affairs (2023) makes clear. This troubling trend highlighted by the UN report affirms the need for more effective governance to curb environmental deterioration swiftly. Delivering on the 2030 Agenda requires moving beyond incremental efforts to transformative policy and governance innovation.

Second, the lack of detectable relationships between environmental state and social impacts underscores the complexity of environment-society linkages. A more nuanced understanding of these connections is vital to ensure environmental progress translates into human well-being rather than solely environmental gains. This requires more integrated conceptualisations and assessments of environment-society interactions.

Third, using the SDG monitoring framework, our results provide a baseline analysis of policy efficacy and impacts. This sets the stage for additional research, strengthening the framework's utility for tracking progress and informing policy adjustments needed to achieve the SDGs. Supplementing state indicators and applying more sophisticated causal inference and experimental techniques would enhance the framework's accountability function.

Overall, while highlighting limitations, our findings affirm the value of analyzing environmental governance efforts through the unifying lens of the SDG indicators. This study sets an empirical foundation to stimulate policy changes and governance innovations that can bridge sustainable development policy gaps revealed by the data. Realising the integrated vision of the 2030 Agenda is within reach with a commitment to evidence-based, adaptive policymaking and multi-dimensional progress assessments.

Data Availability Statement

The data on which this article is based are available in (Fairbrass et al., 2024) and the SDG Database (United Nations Department of Economic and Social Affairs, 2024). The R code used to conduct the statistical analysis is available in (O'Sullivan, 2024).

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