Review

Recurring patterns of SDG interlinkages and how they can advance the 2030 Agenda

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The Sustainable Development Goals (SDGs) set a vision for a more sustainable world, to be realized by 2030. Progress to date is insufficient and implementation challenges are many, including the need for strategies that maximize synergies and mitigate trade-offs and conflicts among the goals. This scoping review synthesizes 51 recent scientific articles on interlinkages, with findings that can help decision-makers address this challenge. We identify recurring patterns of SDG interlinkages, including SDGs that promote other SDGs (e.g., SDGs 4, 6, and 17) and those at risk due to negative impacts from progress in other areas (e.g., SDGs 14 and 15). Such patterns can inform national and local implementation. Further research is needed to clarify the systemic roles of some SDGs (e.g., SDGs 10–12), understand causal relationships, and assess policy options. We make six recommendations for science to make interlinkages knowledge more accessible and for decision-makers to systematically use this knowledge.

INTRODUCTION

The 2030 Agenda, adopted in 2015 by United Nations member states, presents a vision of a more sustainable world to be realized by 2030. The 2030 Agenda includes 17 Sustainable Development Goals (SDGs), 169 associated targets, and 231 indicators to track their progress. At the halfway point of implementation, the prospects of realizing the vision of the 2030 Agenda are poor, as most SDGs are far from being achieved.[1] The challenges of implementation are many, including the broad scope of the SDGs, their interconnected nature and potential goal conflicts, their high level of ambition, the short time frame that remains for their fulfillment, competition for resources, and limited attention paid in decision-making to long-term sustainability issues amid immediate crises such as COVID-19, financial turmoil, and escalating conflicts.

Nevertheless, the 2030 Agenda remains a relevant and broadly accepted framework for sustainability, offering guidance also in times of crisis. Recent policy and scientific debates have stressed the need for renewed political commitment to the 2030 Agenda and for accelerating SDG progress by focusing more strongly on practical action, systemic change, and strategic priority setting.[2–5]

One way for decision-makers to turbocharge progress in the remaining years of the 2030 Agenda is to identify interventions that leverage synergies between the SDGs and push simultaneous progress on several of the individual goals. They also need to identify areas where different SDGs conflict, in order to set priorities. Understanding how the SDGs are interlinked will help in developing strategies that maximize synergies and minimize trade-offs.

The scientific community identified this need when the SDGs first came into force, and since then, a growing number of publications focus specifically on identifying and analyzing SDG in-terlinkages.[6] However, this literature is broad, scattered, and rapidly expanding, which makes it increasingly difficult to get an overview of emerging patterns of SDG interlinkages. Existing synthesis and meta-studies focus largely on methods, approaches, and tools[6–8] rather than on collecting and contrasting analyses of general patterns of SDG interlinkages and the resulting policy implications. Recent critiques suggest that analyses of SDG interlinkages could be enhanced by better interpreting their analytical outputs for use by decision-makers to ensure policy relevance and support implementation.[9,10]

To address this gap, this article adopts a scoping review design to identify recurring patterns of SDG interlinkages. The literature sample consists of 51 scientific articles, published between 2019 and 2022. Three research questions guide the study: are there SDGs that universally conflict? Are there SDGs that are consistently synergistic? And finally, what do such general patterns of SDG interlinkages imply for the implementation of the 2030 Agenda?

The sampled literature is limited to studies that provide analysis of SDG interlinkages at the global level or for different country groupings or population segments. By "global," we refer to studies at the global scale as well as non-place-specific analyses of SDG interlinkages. We acknowledge that the relationships between the SDGs are context-specific[11,12] and that the implementation of the 2030 Agenda requires localization of the SDGs to the national and subnational levels.[13,14] Yet we still believe it is useful to explore global or generalized patterns of SDG interlinkages and implications for implementation for several reasons. First, such analysis can serve as a starting point for decision-makers tasked with implementing the SDGs at the national or local levels, highlighting SDGs that are more likely than others to generate synergies or trade-offs and therefore merit special attention. Second, identifying persistent SDG interlinkages can
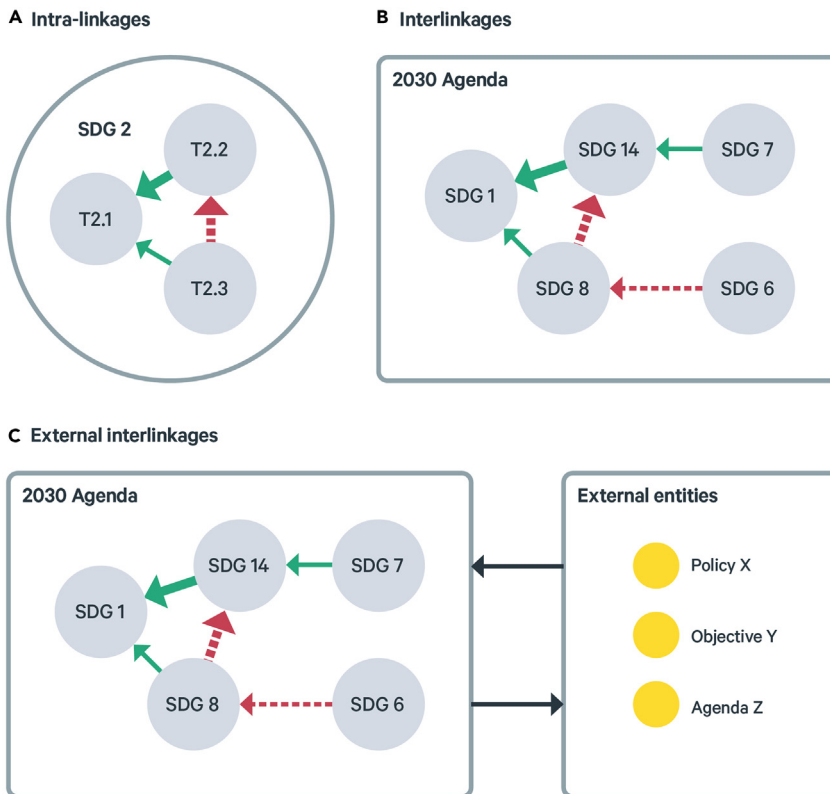
A Intra-linkages

B Interlinkages

C External interlinkages

synergies, and to focus more strongly on policy analysis in relation to SDG interlinkages.

OVERVIEW OF SAMPLED LITERATURE

The literature in our sample illustrates the range of methods to study the interlinkages between the SDGs. The most commonly occurring methods are literature reviews and content analysis (used in 51% of the studies), followed by network analysis (29%), expert mapping (25%), and statistical analysis (20%). Several studies employ a multi-method approach, e.g., combining a literature review with expert mapping. A detailed presentation of methods and their strengths and weaknesses is beyond the scope of the present study but has been assessed elsewhere.[8,15]

facilitate learning across contexts, specifically in terms of sharing best practices for addressing recurring trade-offs and synergies. Third, this type of analysis can help international policy and global goal-setting processes consider inherent contradictions and co-benefits within and between global agendas. Finally, it can yield new insights into how knowledge about SDG interlinkages can be harnessed by decision-makers to accelerate SDG progress.

The findings show how certain SDGs are more frequently associated with synergies and trade-offs than others. Specifically, the findings suggest that progress on SDGs 4 (education), 6 (water), and 17 (partnerships) drive progress also in other areas and that SDG synergies generally outweigh trade-offs. Yet, all SDGs are associated with trade-offs by at least one paper in our sample. SDGs identified as sources of conflicts include SDGs 2 (food), 8 (economic growth), and 11 (sustainable cities). Efforts to meet specific targets under these goals can adversely impact other goals. We also find that the implementation of the SDGs largely promotes other sustainability initiatives and agendas, and vice versa. However, there are non-obvious trade-offs, including between supply-side climate interventions and the SDGs.

Despite the growing research interest in SDG interlinkages, our review shows that important knowledge gaps and uncertainties remain. For the scientific community, our concluding recommendations stress the need to clarify the systemic roles of some SDGs and critically discuss missing perspectives (such as the role of the environmental SDGs in supporting overall SDG progress), identify and communicate the causal relationships and feedback dynamics that create SDG trade-offs and

All studies in our sample analyze interlinkages between the full set of SDGs, but they still differ in scope and focus (Figure 1). We identify three dimensions commonly covered in our sample: intra-linkages (relationships between targets or indicators under a given SDG), interlinkages (relationships between SDGs at the goal, target, or indicator levels), and analysis of the relationships between the SDGs and "external entities." The latter refers to analysis that maps the goals, targets, or indicators of the 2030 Agenda to other themes and topics (e.g., other policy agendas, sustainability initiatives, or sector-specific activities).

The studies in our sample differ in terms of what characteristics of the relationships between the SDGs they focus on (see a simplified representation in Figure 2). Some studies assess interlinkages only by establishing that relationships exist, whereas others classify the relationship as a synergy or a trade-off. Analysis of clusters of mutually interacting goals is also common, though these studies often do not specify if the interlinkages are synergistic or conflicting (see e.g., Smith et al.[16] and McGowan et al.[17]).

Some studies examine the direction of influence, i.e., if a goal is influencing other goals or being influenced by them. Adopting the terminology used in Pham-Truffert et al.,[18] strongly influential goals can be referred to as "multipliers," having compound positive or negative effects on the 2030 Agenda as a whole. Strongly influenced goals can be referred to as "buffers." A goal can play multiple roles at the same time. For example, a goal could serve as a buffer of trade-offs (being negatively affected by other goals), while at the same time being a multiplier of synergies (positively affecting other goals), or a goal could be a buffer of
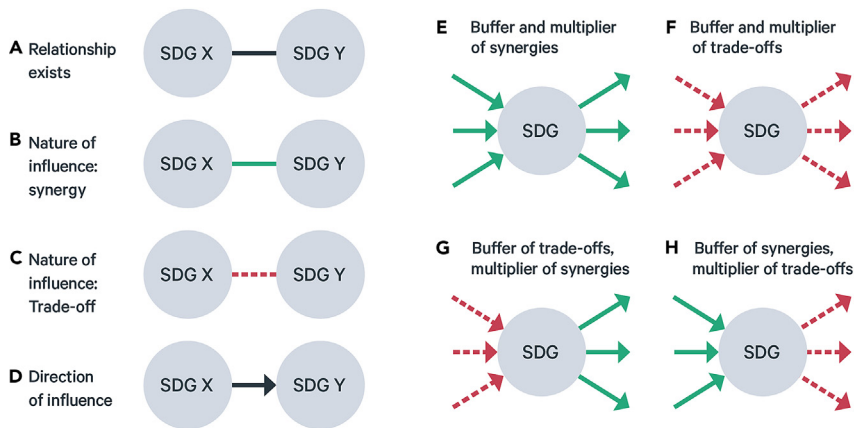
Figure 2. Different types of information about the relationships between the SDGs as provided in the sampled literature

The sampled publications provide different types of information about the relationships between the SDGs. Some studies only state that a relationship exists (A), while other studies provide information about SDG synergies and trade-offs (B and C) and direction of influence (D). Based on an understanding of nature and direction of influence, it is possible to determine if a goal serves as a driver/multiplier or buffer of synergies or trade-offs, see examples in (E)–(H).

synergies (the goal is positively affected by progress in other areas) but a multiplier of trade-offs (progress on this goal negatively impacts other goals).

In the following sections, we focus specifically on the nature and direction of influence between the SDGs, i.e., studies that identify trade-offs and synergies as well as multipliers and buffers. Goals that multiply synergies offer opportunities for decision-makers, as investments in these goals can accelerate SDG progress. Buffers of synergies can be targeted by direct action, or more strategically, by leveraging spillover effects from SDG multipliers. Information about trade-offs points to areas where it might not be possible to find win-win solutions and where democratic deliberation and priority setting are needed.

GLOBAL PATTERNS OF SDG INTERLINKAGES

Out of the 51 publications in our sample, 15 explicitly address SDG interlinkages in terms of identifying synergies and trade-offs (for references, see Tables S2 and S3). Information about the direction of influence (multipliers and buffers) is less frequent in our sample, with 11 studies providing this information. Figure 3 presents the number of studies that associate each SDG with synergies and trade-offs (bars), as well as the share of these publications that describe each SDG as a multiplier or buffer (pie charts). For example, 7 publications provide evidence that SDG 17 is associated with synergies. Of these, 4 publications find that SDG 17 is a multiplier of synergies, i.e., more often positively influencing SDG progress in other areas than being influenced, while the other 3 publications do not provide information about the direction of influence. The interlinkages identified in the sampled literature are between the goals, targets, or indicators. We note that interlinkages at the indicator and target levels contain important information, and that they do not always equate to significant interlinkages at the goal level. However, for comprehensibility, we present results aggregated to the goal level.

Multipliers and buffers of synergies

Figure 3 shows that all SDGs are identified as synergistic with other SDGs by at least two studies in our sample. The SDGs most frequently associated with synergies are SDGs 1–8 and 17. Some of these goals are described as drivers, enablers, or

multipliers of synergies, including SDGs 4 (education), 6 (water), 7 (energy), and 17 (partnerships). For example, SDG 4 has been described as the means and capacity to create enabling conditions for other goals.[19] Further, ensuring safe drinking water for all, as promoted by SDG 6, can generate positive outcomes related to a diversity of areas such as health, nutrition, education, and gender equality.[20]

Other SDGs frequently associated with synergies are described as both multipliers and buffers in different studies. These goals include SDG 1 (poverty) and SDG 3 (health). For instance, progress on SDG 1 can be achieved indirectly through investments in SDGs related to health, education, and peace-building. At the same time, alleviating poverty has been described as a "foundational" goal, by which other goals can be achieved.[19,21] The goals least frequently associated with synergies are SDGs 10 (inequality), 11 (sustainable cities), 13 (climate), 14 (life below water), and 15 (life on land).

Multipliers and buffers of trade-offs

The literature on SDG interlinkages also identifies recurring trade-offs between the goals. All SDGs are associated with trade-offs by at least one study in our sample. However, overall, synergies seem to outweigh trade-offs (Figure 3).

Some SDGs are associated with trade-offs and described as multipliers, including SDGs 2 (zero hunger), 8 (economic growth), and 11. For example, as highlighted by Pham-Truffert et al.,[18] ending hunger in line with SDG 2 is central to the 2030 Agenda, but agricultural production that relies on intensive practices causes harm both in terms of ecosystems and human health. Similarly, growth in economic activities as promoted by SDG 8 can lead to positive impacts such as new jobs, but at the same time, it drives unsustainable patterns of resource use.[18]

Several other SDGs associated with trade-offs are described both as multipliers and buffers, including SDGs 10, 12 (consumption and production), and 13. These goals might be negatively affected by the implementation of other goals but can also impede progress in other areas. For example, SDG 10 has been described as a "systemic buffer" of trade-offs.[18] At the same time, SDG 10 has been identified as a hurdle to sustainability under current development trajectories.[22,23] For example, there is an indication that target 10.6, which aims to ensure enhanced representation of developing countries in decision-making in global international institutions, conflicts with other goals. However, given that this seems unlikely, a better

SDG synergies and trade-offs

Figure 3. The number of publications providing supporting evidence for SDG synergies and trade-offs (bars) and for multipliers and buffers (pie charts)
The bars show the number of publications associating each SDG with synergies and trade-offs. The pie charts show the share of publications that identify each SDG as a multiplier or buffer of synergies or trade-offs. The pie charts also show the share of publications that do not contain information about the direction of influence.

understanding of the causal mechanisms giving rise to such trade-offs is needed.[22]

Finally, SDGs 14 and 15 are associated with trade-offs, but primarily as buffers, which means that they are most at risk when other goals are implemented. For example, Randers et al.[24] show that reaching the 14 socioeconomic SDGs in a business-as-usual scenario hampers progress on the environmental SDGs; the authors stress that "extraordinary efforts" are needed to reach all 17 SDGs simultaneously. Box 1 discusses how to manage SDG interlinkages in practice, using the trade-off between socioeconomic and environmental SDGs as an illustrative example.

SDG intra-linkages

Adding to the complexity of implementing the 2030 Agenda is that each SDG contains multiple and interacting policy objectives. The targets and indicators belonging to a single goal can be both mutually supporting and conflicting. Studies addressing the internal consistency of the SDGs (5 out of 51 studies) find that most targets and indicators are mutually supporting. SDGs 1, 14, and 16 are most frequently assessed as internally consistent. However, there are also examples of goals where the associated targets and indicators internally conflict, including SDGs 2, 3, 5 (gender), 7, 8, and 9 (industry, innovation, and infrastructure).

For example, target 8.3 (promoting formalization and growth of micro-, small-, and medium-sized enterprises) can create trade-offs with target 8.4 (promoting resource efficiency in production and consumption). Informal economic activities may sometimes be less resource-intensive and environmentally harmful than their formal counterparts.[22] Another example is the internal consistency of SDG 7, where Kroll et al.[21] analyze how correlations between indicator pairs have evolved in the past, finding that synergies between the indicators belonging to SDG 7 have turned into trade-offs over time. This highlights that SDG interlinkages are not static and that synergies within Goals might be challenging to maintain over time (see Table S4, for references to the specific studies addressing SDG intra-linkages).

Context-specific patterns of SDG interlinkages

Previous critiques of interlinkages assessments have underscored the importance of considering local contexts.[9,10] This is supported by studies (12 out of 51) in our sample that analyze how patterns of SDG interlinkages differ across country or population groups. Countries are grouped primarily according to region or country income level (e.g., low, middle, and high income).

The findings of these studies include that regions show some similarities in terms of SDG interlinkages, more so

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Box 1. Managing SDG interlinkages in practice

Close to all publications in our sample consider the policy implications of their findings (96%), for example by discussing what SDGs should be prioritized by decision-makers. However, significantly fewer studies propose concrete actions for addressing SDG interlinkages in practice (22%). Yet, there are examples of principles and proposals that can guide action. In this section, we use the trade-off between socioeconomic and environmental SDGs identified in the literature as an illustrative example. How can decision-makers reconcile the seemingly inherent conflict between socioeconomic gains and environmental sustainability? This is a real challenge, and there have been calls both for more cautious policies[25] and for extraordinary action to enable progress on all goals simultaneously.[26] Below are three examples of proposals identified in the sampled literature.

MAKE THE IMPORTANCE OF NATURE IN SDG FULFILLMENT MORE VISIBLE

Nature's essential contributions to SDG progress run the risk of being obscured by the 2030 Agenda's language, indicators, and reporting processes. Making nature's role more visible could help raise awareness among decision-makers and thereby be one step toward reconciling the trade-off between environmental and socioeconomic goals. This could be done, for example, by better and integrated monitoring of nature's role in achieving the SDGs using a combination of integrated indicators (e.g., the Ocean Health Index) and indicators for critical environmental components of importance to the SDGs (e.g., soil health).[27] Another way to make nature's role in SDG progress more visible is to scale up the use of practical interventions such as nature-based solutions and environmental safeguards in planning and implementation.[27,28]

FOCUS ON DEMAND-SIDE INTERVENTIONS

Demand-side interventions involve behavioral shifts, e.g., changes in diets, modes of transport, and energy consumption. Compared to interventions that focus on supply and technologies (e.g., nuclear energy, carbon capture and storage, afforestation for climate mitigation, and electrification of the energy system), demand-side interventions seem to generate fewer trade-offs and unintended side effects.[29–31] Hence, focusing more strongly on behavioral shifts toward more sustainable lifestyles and consumption patterns could be one way of circumventing the conflict between environmental and socioeconomic SDGs.

PAY STRONGER ATTENTION TO THE MIX AND SEQUENCING OF INTERVENTIONS

There is a need to pay close attention to how interventions are combined and sequenced to limit trade-offs. For example, successfully carrying out demand-side interventions in the transport sector (e.g., shared mobility, public transport, and hydrogen buses) is contingent on city planning and infrastructure development.[31] Another example of sequencing is how dietary shifts combined with climate and development finance for poverty reduction offer a way to progress on social SDGs without causing environmental harm.[32]

Despite the benefits of working with sequencing and multiple interventions, this is not always accounted for. For example, when assessing policy changes needed to improve businesses' contribution to the SDGs, several solutions have been proposed in the scientific literature, primarily centered around new business policy, public policy, and innovation. However, integrated solutions across these three domains are not commonly considered.[33]

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than income groups.[22] For example, SDG 17 is central to SDG progress in multiple regions[34] and synergies seem stronger in most regions as compared to trade-offs.[35] However, due to varied levels of SDG progress, vulnerability, and technological development, most studies also find notable differences between regions. For example, combating climate change is critical in countries vulnerable to climate change impacts, whereas it is not as decisive to SDG progress in the countries that caused it.[34] Some studies also identify intra-regional differences, such as Kostetckaia & Hametner,[36] who find different distributions of trade-offs and synergies between Southern, Eastern, Northern, and Western Europe. Due to such differences, Bali Swain and Ranganathan[35] stress that benchmarking is only effective at the regional level since global goals fail to account for how challenges and opportunities differ across contexts.

Warchold et al.[20] explore differences in SDG interlinkages between population groups. Specifically, they look at differences in SDG interlinkages between genders, age cohorts, and rural and urban population groups. They find interlinkages between SDGs are more synergistic when looking at data for young women living in rural areas, compared to elderly men living in urban areas. Since young women living in rural areas represent the most disadvantaged and vulnerable groups in many countries, leveraging these synergies is essential to achieving the SDGs and "leaving no one behind."

The results concerning differences between countries grouped by level of income are varied. Kroll et al.[21] find similar patterns of interlinkages between and within SDGs for all income groups, and Anderson et al.[22] note only small variations between income groups. On the other hand, Warchold et al.[20] and Kostetckaia and Hametner[36] find that low-income countries consistently have a higher share of synergies and a lower share of trade-offs than high-income countries. Lusseau and Mancini[23] highlight the importance of contextualizing targets and goals by income groups to ensure that synergies are being exploited and that the SDGs help meet the needs of all countries.

External interlinkages

⚪ Climate-SDG interlinkages   ⚫ Covid-19 - SDG interlinkages   ⚫ Nature-SDG interlinkages   ⚫ Other
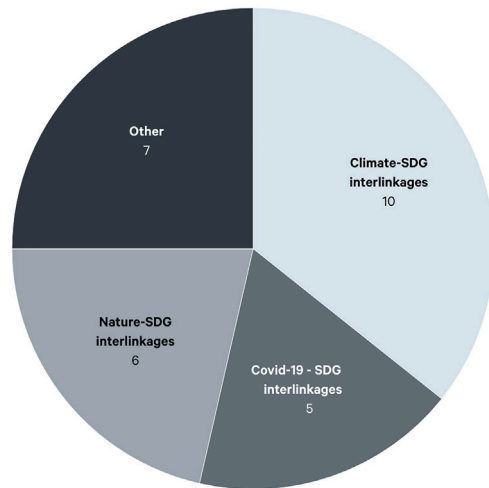

Figure 4. The focus areas of the sampled literature addressing external interlinkages
The studies addressing external interlinkages focus most commonly on climate-SDG interlinkages, followed by nature-SDG interlinkages and COVID-19-SDG interlinkages.

EXTERNAL INTERLINKAGES

Over half of the studies in our sample (28 out of 51) map interlinkages between the 2030 Agenda's goals, targets, or indicators and external themes and topics. As shown in Figure 4, we find that most of these studies focus on various climate-related aspects and the SDGs. The second most common theme is SDG and COVID-19 interlinkages, followed by nature-SDG interlinkages. Other themes include how business and economic activity are interlinked with the SDGs (covered by three studies), as well as how the 2030 Agenda is related to human well-being, the five pillars of sustainability, physical activity, and energy (each theme covered by one publication in our sample). The following sections briefly cover the most frequently occurring themes; how the SDGs are interconnected with climate, nature, COVID-19, and business.

Climate-SDG interlinkages
Failing to scale up climate action will have an adverse impact on all SDGs,[28] but not all strategies to ensure low-carbon societies benefit SDG attainment.[29] Hence, understanding how climate action (or a lack thereof) will impact the SDGs and vice versa is crucial. The studies in our sample focus on how various climate change-related aspects, beyond the indicators belonging to SDG 13 on climate action, are interacting with the SDGs. This includes how the SDGs are affected by climate finance,[37] climate risk,[28] and specific climate initiatives, agendas, or policies.[30–32,38–41]

Generally, these papers suggest that climate action broadly aligns with the SDGs. A review of the nationally determined contributions under the Paris Agreement finds that countries' climate activities mostly contribute to renewable energy, energy efficiency, clean water and sanitation, ending deforestation and

desertification, food systems, and sustainable cities and transport systems (SDGs 7, 6, 15, 2, and 11).[42] Analysis of official development assistance shows that these financial flows mainly target areas with strong mitigation potential, including renewable energy systems, sustainable cities and communities, food systems, and life on land (SDGs 7, 11, 2, and 15). The contribution of nations' climate action and financing to the SDGs sends a positive signal about policy coherence for sustainability, yet there may be potential to broaden the scope and consider how climate action can benefit all aspects of the 2030 Agenda.[37]

While synergies seem to outweigh trade-offs in terms of interlinkages between climate action and the SDGs, some strategies to tackle climate change can create substantial conflicts. Climate action can lead to short-term macro-economic costs, specifically for carbon-intensive and energy-exporting regions and industries.[40] Certain technologies, including nuclear energy, carbon capture, and storage, and biofuels are considered climate-friendly but come with considerable risk. Also, carbon taxes applied to energy and agriculture can cause trade-offs, specifically in terms of negatively affecting poverty alleviation and energy access.[30,32]

Nature-SDG interlinkages
The 2030 Agenda includes dedicated environmental goals that, in theory, should ensure that the environmental dimension is an integral part of SDG implementation. However, several publications in our sample explicitly address the link between nature and the 2030 Agenda. This research is motivated by the observation that the dependency on nature for fulfilling non-environmental SDGs goes largely unstated in the 2030 Agenda[27] and runs the risk of being overlooked in decision-making.[43,44]

To address this, some studies map nature's overall contribution to the SDGs (e.g., Scharlemann et al.[45]), while others focus on specific environmental aspects such as biodiversity,[43] wetlands,[46] and water quality.[44] Taken together, these studies stress how important the environment is for SDG fulfillment. At the goal level, all SDGs are dependent on different aspects of nature, often in non-obvious ways.[22,43] At the target level, at least 50% of the 169 targets are dependent on nature for their achievement.[27] At the same time, business-as-usual implementation of 9% of the targets is likely to harm nature, while progress on 60% of the targets could either harm or benefit nature depending on the strategy used.[27]

COVID-19-SDG interlinkages
Although it was clear from its onset that the COVID-19 pandemic would affect society at large, the full extent of these impacts is yet to be seen. Some publications in our sample link COVID-19 to the SDGs, finding overall negative impacts across most goals.[47,48] These impacts can be direct or indirect. An example of a direct negative impact of the pandemic is that efforts to reduce poverty have been diminishing, in favor of addressing immediate health-related issues. An indirect impact is how the use of biomass-based fuels for cooking increased during the pandemic, as a result of more people falling under the poverty line, with adverse impacts on both human health and the environment.[48] However, not all COVID-19 impacts are assessed to be negative. For example, lockdowns and limited traveling at least temporarily reduced some ecosystem pressures.[49]

Efforts to promote sustainable and resilient cities (SDG 11), tackle climate change (SDG 13), and avoid deforestation (SDG 15) all present opportunities to prevent future pandemics, which makes the case for more ambitious SDG action.[50]

The role of business in SDG attainment

Business sector activities can either help or hinder SDG attainment. A better understanding of the role of business in implementing the 2030 Agenda can point to activities that should be scaled up or cut back to maximize positive SDG outcomes. Based on a literature review, Zanten and Tulder[51] find that important contributions of economic activities lie in boosting economic productivity, industrialization, infrastructure, and innovation (SDGs 8 and 9), while at the same time contributing to meeting basic human needs (SDGs 2, 3, 4, 6, 7, and 11). However, most articles in their review (63%) focus on negative impacts, where economic activities seem specifically detrimental to SDGs related to climate change, ecosystems, and human health.[52] To better align economic activities and sustainability objectives, new economic models and thinking are emerging. One example is the circular economy, for which there seems to be a significant overlap with the SDGs.[53]

DISCUSSION

The relationships between the SDGs are commonly described as context-specific, influenced by factors such as geography and governance.[11] Nevertheless, our review finds recurring patterns of SDG interlinkages in the sampled literature, including SDGs that are associated more frequently than others with synergies and trade-offs. In the following sections, we discuss what the results imply for decision-makers as well as the scientific community working on SDG interlinkages.

Policy implications

At the halfway point of the 2030 Agenda, historical and projected SDG progress is insufficient. Both time and resources are limited, so recent policy and scientific debates have stressed the need for game-changing interventions, systemic change, and strategic priority setting. For decision-makers tasked with SDG implementation at the national and local levels, the results presented in this paper can help in terms of identifying starting points for implementation. These starting points represent areas where targeted action can boost overall SDG progress and mitigate critical conflicts. In this way, the patterns of SDG interlinkages can inform priority setting based on an understanding of the systemic role of the SDGs, to avoid cherry-picking and allowing short-term financial or political interests to decide which SDGs receive attention.

Overall, our assessment of general patterns of SDG interlinkages finds that SDG synergies outweigh trade-offs. This aligns with previous findings at local and national levels (see e.g., Weitz et al.,[54]) and signals to decision-makers that there is much to gain from taking a more systemic approach to SDG implementation. Specifically, our results suggest that investments in a set of social goals (SDGs 4, 6, 7, and 17) will generate compound positive impacts on other goals. These are multipliers of synergies and, apart from SDG 7, seem to represent "safe" investments as they appear not to create conflicts with other goals.

For several goals, including SDGs 2, 8, 10, 11, 12, and 13, results indicate that efforts to meet specific targets belonging to these goals can generate trade-offs in terms of making progress in other areas. Hence, when implementing these goals, specific care and priority setting are needed. Finally, the environmental dimension of the 2030 Agenda needs to be better incorporated into decision-making at all levels. Progress reports show how performance is particularly poor when it comes to delivering on the environmental SDGs; many indicators are far from target and show worsening trends.[1] Our synthesis of the literature on SDG interlinkages provides one explanation as to why: environmental SDGs are most negatively affected when action is taken to implement other goals. This does also call for strong global frameworks for protecting and restoring terrestrial and aquatic ecosystems.

The results concerning intra-linkages and the internal coherency of single SDGs complement the picture. Some of the goals that multiply synergies with other goals are also internally consistent, such as SDG 4. Goals that are internally consistent and simultaneously promote other SDGs offer pathways for coherent implementation. Other goals, such as SDG 2, are both internally conflicting and create trade-offs with other SDGs. Such goals require specific attention by decision-makers, to ensure that progress in one area does not hinder or cancel out progress in other areas. Generally, the assessment of intra-linkages highlights that the SDGs cannot only be understood and treated as single units at the goal level but that stronger focus on the target and indicator levels are needed.

Another important consideration for decision-makers at the local and national levels is that the literature assessing general patterns of SDG interlinkages has limited coverage. The patterns identified should be understood as part of the picture, reflecting available scientific knowledge in a specific domain and not real-world interlinkages between the SDGs. Further, data breakdowns for different country and population groups stress how SDG interlinkages often differ based on context. Finally, the sampled publications offer limited guidance in terms of practical action and concrete proposals for addressing SDG interlinkages, once identified. Taken together, this makes a strong case for carrying out context-specific analyses of SDG interlinkages to guide action, as a complement to generalized or global findings.

The SDGs are also interlinked more broadly with other processes, specific initiatives and other sustainability themes that are not necessarily included in the 2030 Agenda. Our review of the literature addressing such external interlinkages shows that many initiatives positively contribute to the SDGs, including climate action and financing. However, there are also non-obvious trade-offs, including between supply-side climate interventions and the SDGs.

Implications for decision-makers at the global level include that action for the 2030 Agenda and parallel policy processes should be better aligned. Ensuring coherence across multiple agendas and initiatives requires a systematic approach to map and address multiple influences. Conceptual frameworks (e.g., as presented by Cohen et al.[55] and Fuldauer et al.[56]) and new tools and approaches for impact assessments (e.g., Lacobuţă et al.[57]) can support this process.

For decision-makers at the national and local levels, the implications include that the process of localizing the 2030 Agenda

must incorporate discussion about how the SDGs should be interpreted, and if the official targets and indicators sufficiently capture the relevant aspects of sustainability in the decision-making context at hand. In this way, mapping how the SDGs relate to local issues and contexts could be a way of expanding conversations and visions of sustainability.[50]

Furthermore, local and national level action must increasingly ensure that the 2030 Agenda implementation aligns with other global, national, and local policy processes and vice versa. This process might be resource intensive, yet the analysis of such cross-agenda coherence can itself offer opportunities. First, such analysis can support prioritization. For example, the literature assessing climate-SDG interlinkages shows that multiple pathways exist to reach a low-carbon society. However, some of them are more aligned with the SDGs than others, and prioritizing such pathways can be a way of minimizing conflicts and unintended consequences of actions. Second, highlighting synergies between different policy agendas can be a way of raising sustainability ambitions.[42]

Overall, the synthesis of the literature on SDG interlinkages shows that integrated implementation is a complicated task. Luckily, a growing number of science-based tools are available to support context-specific analysis of SDG interlinkages.[6] These tools have often been developed explicitly to support decision-making, but their uptake and use could be improved by better aligning tool developers' ambitions with decision-makers' needs.[7] Science and policy have scope for increased collaboration to overcome some of the challenges of integrated SDG implementation. In this respect, new alliances such as the Group of Friends on Science for Action at the UN can be seen as a step in the right direction.

Ample room also exists for decision-makers at all levels to learn from each other in terms of how SDG interlinkages are assessed and addressed. What tools and methods are used, what policies are implemented to maximize synergies and mitigate trade-offs, and how do they work in practice? This type of knowledge can be exchanged using existing SDG platforms and forums, including the UN High-Level Political Forum and the Voluntary Reviews. A recent review of the Voluntary Reviews shows that there is limited evidence that countries consider interlinkages between all SDGs in strategy development and priority setting.[58]

Previous analyses of SDG interlinkages suggest that many studies fail to link their findings to decision-making.[9,10] The reason may be that knowledge about SDG interlinkages has limited applicability if studies are undertaken separately from decision-making processes. Including these analyses in formal policy and decision-making processes, with a clear expected outcome, can improve their salience.[9] For example, such assessment could be included in formal integrated impact assessment processes for major programs and public investments, and review of new legislation or the review of new legislative proposals or regulatory impact assessments, or common decision-support tools used for prioritizing policies and investments such as multi-criteria analysis. Key objectives of these assessments would include supporting policy coherence and horizontal coordination through a dedicated assessment of trade-offs and synergies associated with a new policy, program, investment, or legislative proposal. As an initial step, our review

in this study can help decision-makers and practitioners identify where common trade-offs and synergies might occur, requiring more in-depth analysis.

Scientists can boost uptake of interlinkages literature

The scientific community working on SDG interlinkages could act in several ways to improve the relevance and uptake of knowledge by policy- and decision-makers. We highlight knowledge gaps and propose ways forward.

The literature on SDG interlinkages aims to inform integrated decision-making, but important perspectives are missing, specifically in terms of the systemic roles certain SDGs play. Such missing perspectives include the roles of SDGs 10 and 11 in supporting progress in other areas. Also missing is the perspective that the environment is the basis for economic and social progress: studies addressing how the goals are related find few synergies from the environmental goals to the remainder of the 2030 Agenda. The incomplete picture of SDG interlinkages and lack of critical discussion might lead to misguided action.

Another area of uncertainty is related to the finding that synergies outweigh trade-offs. This may reflect reality, but there may also be other reasons for the dominance of synergies, including the limited scope of existing studies, that the 2030 Agenda is designed in a way that overlooks critical trade-offs, and that the data are incomplete.[59,60]

Moreover, few studies in our sample offer explanations or hypotheses of why certain relationships between SDGs emerge from the data. For example, SDG 10 is closely linked to the 2030 Agenda's central principle of leaving no one behind. Yet this goal has been identified as an antagonist or a hurdle,[22,23] with little information about why this might be the case. Another example is SDG 12, which has been associated with trade-offs in many studies (e.g., Warchold et al.[20] and Anderson et al.[22]). However, most of these trade-offs are unexplained and lack information about the direction of influence. To better support decision-making, studies of SDG interlinkages should focus more strongly on critical discussion and on the underlying reasons why certain relationships emerge and why others might be missing.

In terms of external interlinkages, the literature covers a broad range of topics. However, we see the potential in more clearly articulating how these studies relate to ongoing decision-making processes, as showcased by the studies on climate-SDG interlinkages. For example, publications addressing nature-SDG interlinkages could more distinctly relate their findings to the Convention on Biological Diversity and related processes.

Another missing perspective is the complexity dimension. Analyses of SDG interlinkages often provide static snapshots of relationships or focus on correlations of historical trends. These studies fail to account for how SDG progress is governed by changes in complex systems. For example, scaling up renewable and clean energy involves changes in interconnected social, technological, and environmental systems. These systems are characterized by feedback loops, non-linear dynamics, and causes and effects that are distant in both time and space. Many approaches to studying SDG interlinkages, including mainstream statistical analysis, are ill-suited to analyze these characteristics of complex systems. This again stresses the need for complementary approaches, including different forms of qualitative and quantitative

systems analysis (e.g., system dynamics, integrated assessment models, conceptual feedback maps). The downside of some of these methods is that results can be difficult to translate and communicate to a non-expert audience. This stresses the importance of participatory methods to ensure shared learning, transparency, and ownership of the scientific results among those responsible for SDG implementation.

Finally, policies and interventions to promote SDGs are themselves sources of synergies and trade-offs. For example, expanding the production of energy crops can help combat climate change (SDG 13). However, this intervention might under some conditions create trade-offs with other SDGs, including when energy crop production harms biodiversity (SDG 15) or competes with food production (SDG 2).[61] Yet, assumptions about strategies are often implicit in the analysis of the relationships between the SDGs, which makes it difficult to assess the relative performance of different policies. As the implementation of the 2030 Agenda moves into a phase of accelerated action, the scientific community could better support this process by

- making assumptions about the strategies used to implement the SDGs explicit and explaining how they impact SDG interlinkages
- expanding discussions about policy implications of identified patterns of trade-offs and synergies, including uncertainties and potential reasons for unexpected results
- focusing more strongly on policy impact assessments and comparative policy analysis in relation to SDG interlinkages.

Outlook and recommendations

While the world is off track in terms of fulfilling the ambitious vision of the 2030 Agenda, every bit of progress matters. Recent policy and scientific debates call for accelerated action and for making smart priorities. The literature on SDG interlinkages can support such efforts.

Our review of recent publications in this domain has identified global or non-place-specific patterns of SDG synergies and trade-offs, pointing to goals that may be specifically important to drive progress across the 2030 Agenda and goals that are sources of conflicts.

Based on our results, we have discussed ways to accelerate SDG implementation and improve the uptake of scientific knowledge about SDG interlinkages. Our recommendations for decision-makers and the scientific community working on SDG interlinkages are summarized here.

Decision-making for accelerated SDG progress needs to actively address both synergies and trade-offs. The global or generalized patterns of SDG interlinkages identified here suggest that decision-makers should focus their efforts on goals that act as multipliers of synergies: SDGs 4, 6, and 17. They should also pay specific attention to the SDGs that generate trade-offs (e.g., SDGs 2, 8, and 11), as efforts to meet specific targets under such goals can adversely impact other goals. Negative impacts must be mitigated, or priorities must be actively made. Better integration of the environmental dimension in decision-making is needed to mitigate trade-offs caused by the implementation of socioeconomic SDGs and to better

acknowledge and maximize the synergies resulting from making progress on the environmental goals.

While generalized patterns of SDG interlinkages can provide a starting point for implementation, pointing to likely trade-offs and synergies, decision-making should be based on a context-specific understanding of SDG interlinkages. We stress the need for decision-makers to work together with researchers to carry out such analysis of context-specific SDG interlinkages using science-based tools and methods. Such analyses should also be integrated into existing formalized decision-making processes (e.g., impact assessments and legislative reviews).

Peer learning and sharing of best practices should be better supported among decision-makers, both in terms of identifying SDG trade-offs and synergies and in terms of designing and sequencing interventions to address them, once identified. This learning could be facilitated through existing SDG platforms and reporting mechanisms, including the UN High-Level Political Forum and Voluntary Reviews.

The scientific community should work to fill the gaps for important perspectives, explanations, and critical discussion that seem to be missing in the sampled literature, which may lead to misguided action. For example, the systemic roles of SDGs 10, 11, and 12 could be clarified.

The scientific community should work to better address the complexity dimension when analyzing SDG interlinkages, including feedback dynamics and how changes in SDG interlinkages play out in the short and long term. New tools and approaches are needed, including a stronger focus on various types of systems modeling and participatory methods. Given the substantial literature in recent years identifying trade-offs and synergies between the goals, researchers should shift their efforts to understanding and communicating the causal relationships and feedback dynamics that generate these effects.

Finally, scientific assessments of global or general patterns of SDG interlinkages need to better incorporate decision-making in the analyses. This entails making assumptions about interventions more explicit, discussing policy implications to a further extent, and focusing more strongly on policy impact assessments that consider SDG interlinkages.

The results and recommendations presented here can accelerate SDG progress in the remaining years of SDG implementation, as well as inform what comes after. We want to highlight three points for the future: first, the 2030 Agenda states that the SDGs should be treated as an integrated and indivisible whole, marking a shift from previous development agendas. This has encouraged researchers and practitioners to take a more innovative and integrated approach to sustainable development, which is something to build on in the post-2030 Agenda. Second, the 2030 Agenda has advanced the knowledge of how social, economic, and ecological sustainability issues affect each other, which may help explain why certain goals are lagging in implementation. This knowledge can help set priorities among goals in the next phase. Finally, if researchers focus on finding causal explanations for synergies and trade-offs, this may help identify both drivers and hinderances to goal attainment, which can make the debate about the post-2030 Agenda more focused.
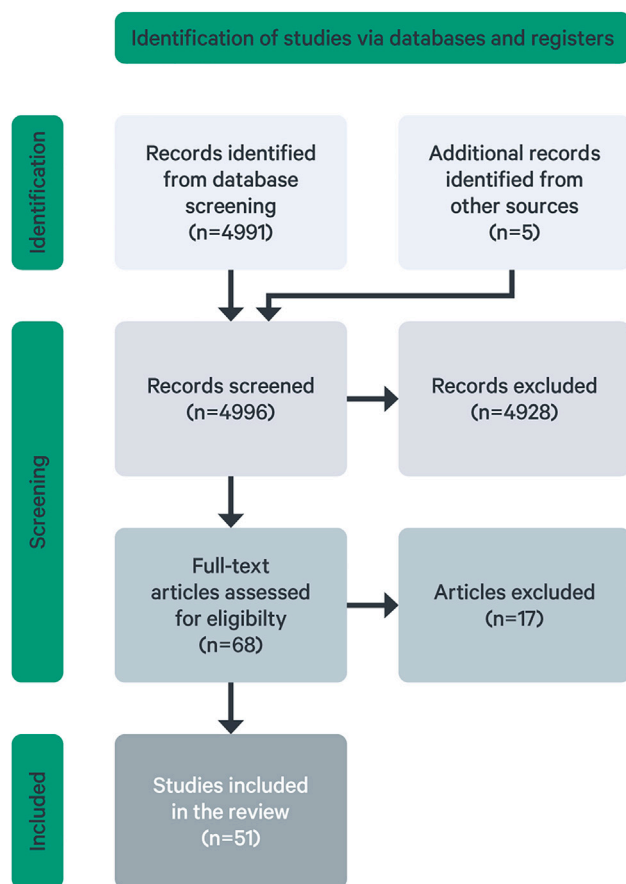
Identification of studies via databases and registers

Identification

Records identified from database screening (n=4991)

Additional records identified from other sources (n=5)

Screening

Records screened (n=4996)

Records excluded (n=4928)

Full-text articles assessed for eligibilty (n=68)

Articles excluded (n=17)

Included

Studies included in the review (n=51)

Figure 5. Steps of the literature search, screening, and selection

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact
Requests and questions should be directed to Therese Bennich (therese.bennich@sei.org).

Materials availability
No materials were used directly as part of this study.

Data and code availability
The supplementary information contains an overview and reference to the sampled literature. Any additional information about the data reported in this paper is available from the lead contact upon request.

Methods
The present study is based on a scoping review of the literature on SDG interlinkages. We carried out a literature search in the Scopus database, using a combination of the keywords "Sustainable Development Goals" and "interlinkages" or closely related terms (e.g., interactions, interconnections, relationships, trade-offs, and synergies). In addition, we included studies using a snowballing approach, based on a screening of reference lists of key publications. We included literature published between 2019 and 2022. The cut-off date for the literature sampling was in October 2022. Our Scopus search generated 4,991 hits. We conducted an initial screening of titles, abstracts, and keywords to narrow down our sample. In total, 68 papers were selected for a full-text read. The final sample consists of 51 publications. A study was included in the final sample if it fulfilled the following three criteria.

i) The study analyses the interlinkages between SDGs, as opposed to using the SDGs to frame or position the paper.
ii) The study focuses on patterns of SDG interlinkages at the global level or for different country groupings or population segments. Global in this context refers to studies at the global scale as well as non-place-specific analyses of SDG interlinkages.

iii) The study addresses the relationships between all 17 SDGs. This is to gain an understanding of the patterns that emerge when considering the 2030 Agenda as a whole, not just a selective subset of individual Goals.

Figure 5 provides an overview of the steps in the literature search, screening, and selection procedure.

After having concluded the literature search and screening, we carried out an in-depth review of the studies in the final sample. We followed a predefined coding scheme, collecting and synthesizing information about the scope and scale of analysis, methods, data sources, key SDG interlinkages highlighted or exemplified in each study, uncertainties, as well as policy recommendations and implications. For a full reference list of the sampled literature, see supplementary information, Table S1.

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