Thematic literature review: identifying empirically investigated SDG interactions

Authors

Martha Kapazoglou, Nicky Pouw, Dzodzi Tsikata
Jonas Jeuning & Sveva Lazzati

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List of Abbreviations

BMI	Body Mass Index
FHH	Female Headed Household
GHG Emissions	Greenhouse Gas Emissions
KBS	Knowledge Brokering and Synthesis
MDD	Minimum Dietary Diversity
MFA	Ministry of Foreign Affairs
MHH	Male Headed Household
NWA	Dutch Research Agenda
NWO	Dutch Research Council
PI	Principal Investor
RCT	Randomized Controlled Trial
SDG	Sustainable Development Goal
SWPER Index	Survey-based Women's Empowerment Index
WEF Nexus	Water Energy Food Nexus

Introduction

The United Nations 2030 Agenda for Sustainable Development consists of 17 Sustainable Development Goals (SDGs), which are defined in a list of 169 targets addressing social, economic and environmental factors that affect sustainable development across the world. These SDG targets are further broken down into a group of 232 indicators, essential for tracking progress towards achieving the goals and targets. While the SDGs are developed as 17 distinct goals, the unifying framework underpinning them clearly stipulates both their indivisible nature—efforts to achieve the 2030 Agenda will be deemed successful only if all 17 goals are met—and their integrated form—actions towards achieving one goal will affect outcomes in another (Barbier & Burgess, 2017; Griggs et al., 2017). It is their integrated – or put differently, interlinked – nature that gives rise to multiple and complex interactions between pairs as well as groups of goals. In practice, interactions among goals manifest in four ways, as: 1) separate effects; 2) contradictions and conflicts, which in this review we refer to as trade-offs; 3) consecutive effects; and 4) spill-over and synergies. Consequently, SDG interactions can be managed—or to use development parlance, governed—to capitalise on opportunities for synergies and to mitigate challenges posed by trade-offs. In conceptualising SDG interaction governance, it is useful to consider the role of mediating factors—mechanisms, including policies and other interventions, that can produce changes in how goals interact with each other—in either mitigating trade-offs or turning them into synergies. Despite the significance of SDG governance and implementation, the SDG framework was not designed to prescribe policy priorities, strategies, implementation sequence, methods and instruments – tasks that fall squarely on the shoulders of policymakers, researchers and other stakeholders. The issue of SDG interactions and their associated governance is thus of high policy and academic relevance, as to undertake any of the above tasks necessitates a firm understanding of how the 17 goals interact across disparate geographic locales and socioeconomic contexts.

Placing the issue of SDG interactions centre-stage, the Dutch Research Council (NWO) initiated the 'Sustainable Development Goals Interactions and Policy Interventions in Developing Countries' program.

Box 1: About the SDGs Interactions Programme

The research program 'SDG Interactions and policy Interventions in Developing Countries' is part of the Dutch Research Agenda (NWA) programme and initiated by the Dutch Ministry of Foreign Affairs (MFA).
The aim of the programme is to gain new insights into the interactions between the SDGs and their effects and impact on policy interventions. For this programme, three central themes have been identified:

1. SDG governance and decision-making
2. Addressing trade-offs between food and nutrition security (SDG 2) and other SDGs
3. Climate change (SDG 13) and conflict (SDG 16)

One research consortium is funded within each theme:

- Beyond cherry-picking: aligning development actors and efforts for inclusive and effective governance of trade-offs and synergies between SDGs in East Africa (theme 1)
- Improving food and nutrition security by enhancing women's empowerment (theme 2)
- From climate change to conflict: mitigation through insurance? (theme 3)

The programme funds a fourth consortium to carry out a 'Knowledge Brokering and Synthesis' (KBS) project which serves to bring insights of the three research consortia together and ensure that the programme's results become more than the sum of its parts.

To facilitate the research activities of the three associated consortia, it is thus essential to identify robust approaches to studying SDG interactions as well as to catalogue and discuss empirically investigated interactions in academic literature. The first knowledge product developed by the KBS team, a methodological literature review, fulfilled the first aim, tracing promising methodological approaches employed in the study of the SDGs (Magendane & Kapazoglou, 2021). To attain the second aim and a clearer picture of empirically identified interactions, the KBS team ventured into crafting a second knowledge product, the thematic literature review you have in front of you. The design of this review has been guided by two interrelated research questions:

1. What are the empirical findings in terms of interactions among SDGs 2 (zero hunger) & 5 (gender equality), SDGs 2, 6 (clean water and sanitation) & 15 (life on land), and SDGs 13 (climate action) & 16 (peace, justice and strong institutions) recorded in academic literature?
2. What are the emerging thematic and methodological gaps in knowledge?

The above questions revolve around three specific groups of SDGs, as these groups neatly fit the thematic foci of each research consortium— the review's focus on SDGs 2, 6 & 15, SDGs 2 & 5, and SDGs 13 & 16 seeks to assist the consortiums working on themes 1, 2 and 3 (see Box 1) respectively.

After a brief explanation of the methodological design underpinning this review, the main body presents the central findings, grouped in accordance with the three SDG clusters identified above. In discussing the main findings, special attention is paid to whether the selected studies make reference to SDG interaction governance to provide relevant policy advice. The conclusion synthesises findings across all three clusters to identify and discuss emerging knowledge gaps and potential avenues to bridging them.

Methodology

The aim of this literature review, as defined by the research questions and the priorities of the three associated consortia, is threefold: 1) scan the existing body of literature for empirically investigated SDG interactions; 2) synthesise and discuss the available SDG interaction findings; and 3) clearly mark and discuss the emerging knowledge gaps. In line with these aims, the authors have conducted a scoping literature review. To enable its design, we started out by setting certain selection criteria. Firstly, we decided to focus only on publications empirically investigating SDG interactions, thus excluding literature reviews, theoretical and opinion articles. Secondly, we have selected papers that systematically incorporate the SDG framework in their methodological design and ground their analysis in SDG goals, targets or indicators. Beyond these selection criteria, we have not limited our scope by adopting any specific country or regional focus. The next step involved the Principal Investigators (PI's) of each consortium creating a set of keywords for each of the six SDGs (SDG 2, 5, 6, 15, 13 and 16) of interest, which were further refined to ensure that all SDG targets and indicators are accounted for.

Next, we used SCOPUS and Google Scholar to elicit relevant literature. First, the focus lay on generating studies related to the specific SDG pairs or groups of interest to each consortium. For example, to identify literature on SDGs 2 (zero hunger) and 5 (gender equality), we simultaneously entered keywords for SDGs 2 and 5 in the two databases, adding the phrases "SDG interaction(s)" and/or "SDGs" to align with our selection criteria. The same process was followed to generate literature investigating interactions among SDGs 2 (zero hunger), 6 (clean water and sanitation) and 15 (life on land), and SDGs 13 (climate action) and 16 (peace, justice and strong institutions). Once suitable publications were obtained, we reviewed the abstract and introduction of each paper to ensure they

fulfil the selection criteria, excluding those that did not. At this point, it is imperative to note that none of the identified studies befitting our selection criteria focused on interactions between SDGs 13 and 16. Therefore, this review will only come back to SDGs 13 and 16 in the limitations and conclusion sections, especially when discussing knowledge gaps. Tangential to the process outlined above, we decided to zoom out and take a more panoramic look at the interactions of each of the SDGs of interest with all other remaining SDGs. To do so, we entered the keywords for each SDG separately into SCOPUS, adding the phrases "SDG interaction(s)" and "SDGs", to source relevant publications. Based on the interactions identified for each SDG, we created two outputs, a matrix table and an infographic, to clearly visualise the information. Finally, to analyse the selected publications, we have looked at seven dimensions: (i) the methodological design ; (ii) the nature of employed data; (iii) the level at which interactions are studied; (iv) the SDGs of focus; (v) SDG interaction findings; (vi) the scope of each publication; and finally (vii) references to SDG interaction governance. The findings, organised along these six dimensions, have been synthesised to respond to the main research questions and are presented in greater detail below.

Main Findings

This part is organised in five sections: the first provides a brief overview of general observations for all selected publications; the second section contextualises the key SDGs of interest withing the wider SDG framework; while the following two sections present the interaction findings for SDGs 2 (zero hunger) and 5 (gender equality), and 2, 6 (clean water and sanitation) and 15 (life on land), respectively. The final section briefly discusses key methodological findings.

Section 1: General observations

Table 1 (see annex, table 1) categorises and summarises observations made about the 38 selected academic articles along 7 dimensions. The articles are listed in the rows, whereas the columns list the dimensions according to which observations were classified. The first dimension regards the broader methodological approach, more specifically whether a study has a quantitative, qualitative or mixed methods design. Here, the total amount of 38 studies can be divided into 20 quantitative, 9 qualitative, and 9 mixed methods studies. Regarding the second dimension, the type of data, the majority (28) employ cross-sectional datasets whereas the remaining (10) papers use time-series. Thirdly, the table notes the level at which SDG interactions were identified within a study – at the goal (21), target (14) or indicator (3) level. The fourth column lists the SDGs of focus in each study. Fifth, the table provides a brief summary of the specific interactions that were identified in each of the articles. The sixth column addresses the geographic scope, which can be divided into country- (16), regional- (10), or global level (12). Here, it should be noted that, if a study was comprised of multiple country case studies, it was identified as a country-level study. Out of all 38 studies, eight were conducted in Sub-Saharan Africa; one in Central America; one in Latin America; five in East Asia; four in Europe; two in Southeast Asia; four in South Asia; and one in Oceania. The seventh and final column in the table marks whether a publication provides policy advice and recommendations on how to govern the identified interaction. In the proceeding sections, the authors make an effort to discuss and analyse each of the studies that address governance issues.

Section 2: Contextualizing SDGs 2, 5, 6 and 15 within the wider SDGs framework

Before discussing specific interaction findings emerging from relevant academic literature, it is imperative to zoom out and contextualise the SDGs of interest (2, 5, 6 and 15) within the wider SDG framework. This step is of great significance considering the SDGs' indivisible nature. We, thus, conducted a supplementary systematic literature review nested within the larger thematic review to

capture the empirically identified interactions between SDGs 2 (zero hunger), 5 (gender equality), 6 (clean water and sanitation) and 15 (life on land) and all other SDGs. The results of this supplementary review have been visualised in two figures (Figure 1 and Figure 2) and are discussed in greater detail in this section.

Figure 1 graphically represents the empirically identified interactions between SDGs 2, 5, 6 and 15 and all other SDGs (excluding 17), noting whether identified interactions are primarily composed of synergies or trade-offs. This way, we calculate the strength of each identified interaction and assign it a numerical value, derived by subtracting the number of trade-offs from that of the synergies. Greater positive values indicate strong synergetic relations, while greater negative values point at strong trade-offs. Several relevant observations can be deduced from Figure 1: Firstly, the number of synergetic relations is much larger than the number of trade-offs - an encouraging trend for SDG interaction governance. Secondly, looking at specific SDGs and their interactions, SDG 2 has either “strong” or “slightly” synergetic interactions with all other SDGs except for 14 (life below water) and 15 (life on land), where the literature primarily notes trade-offs. The predominance of negative interactions between SDGs 2 (zero hunger) and 15 (life on land) constitutes a worrisome trend, which requires the attention of both scholars and policymakers. Moving on, SDGs 5 (gender equality) and 6 (clean water and sanitation) follow the general positive trend, as their interactions with all other SDGs are mostly synergetic.

Figure 1: Interactions between SDGs 2, 5, 6 and 15 with all other SDGs

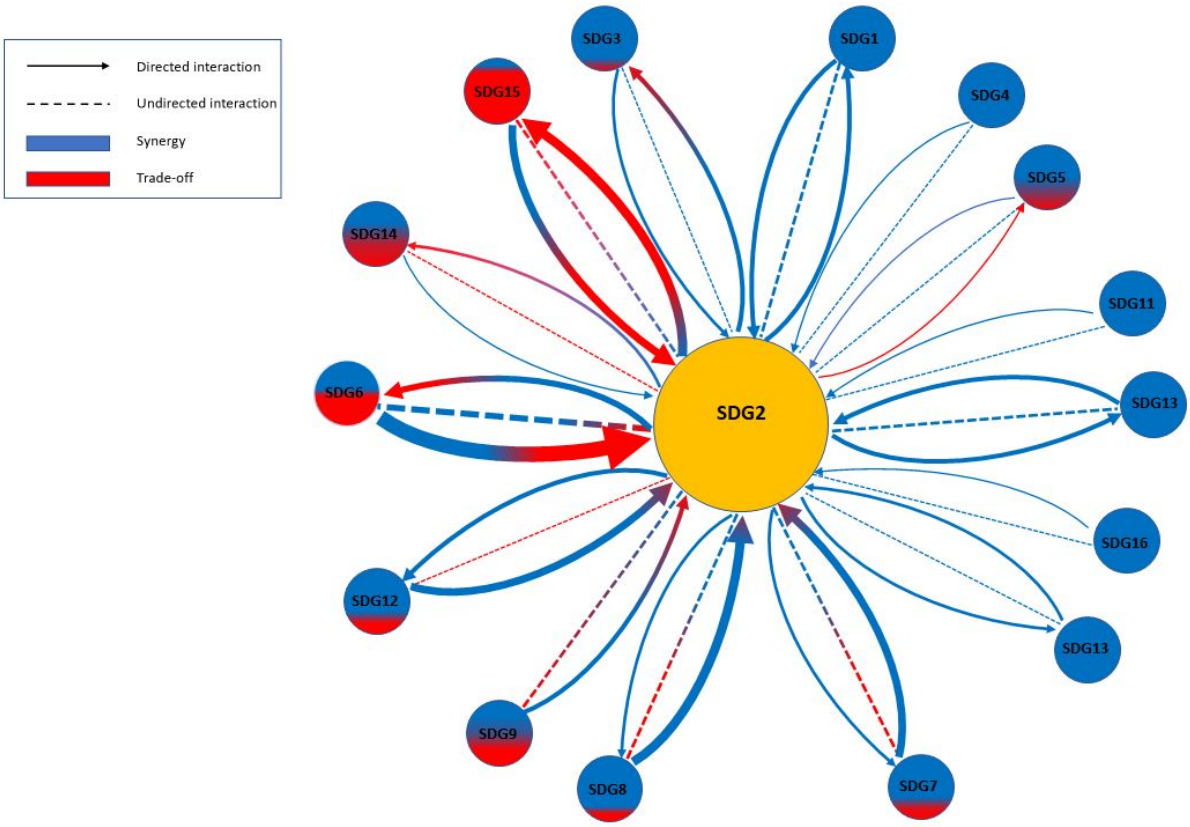
Note: Based on the identified interactions from the systematic review table, this figure visualises the nature of the overall relationship between 4 key SDGs (SDGs 2,5,6,15) and the remaining SDGs. To determine the overall nature of the relationship between two SDGs the total number of trade-offs identified was subtracted from that of the total synergies. Results greater than +3 indicate a strongly synergetic relationship (dark blue); between +1 and +3 a slightly synergetic relationship (light blue); between -1 and -3 a slight overall trade-off (light red); less than -3 a strong overall trade-off (dark red). The value of 0 indicates that the number of identified synergies and trade-offs was equal (yellow). When no interactions were reported the box is marked white, while boxes marked as black simply indicate the graphic convergence of one indicator with itself (no relationship exists).

Figure 2 (a, b, c and d) zooms in on the individual interactions of SDGs 2, 5, 6 and 15 with all other SDGs for which empirical evidence was found in the literature. It shows a more nuanced breakdown of the direction, frequency and sign of the interactions observed. Before unpacking Figure 2 any further, it is imperative to note that the number of studies evaluating a given SDG interaction does not bear any

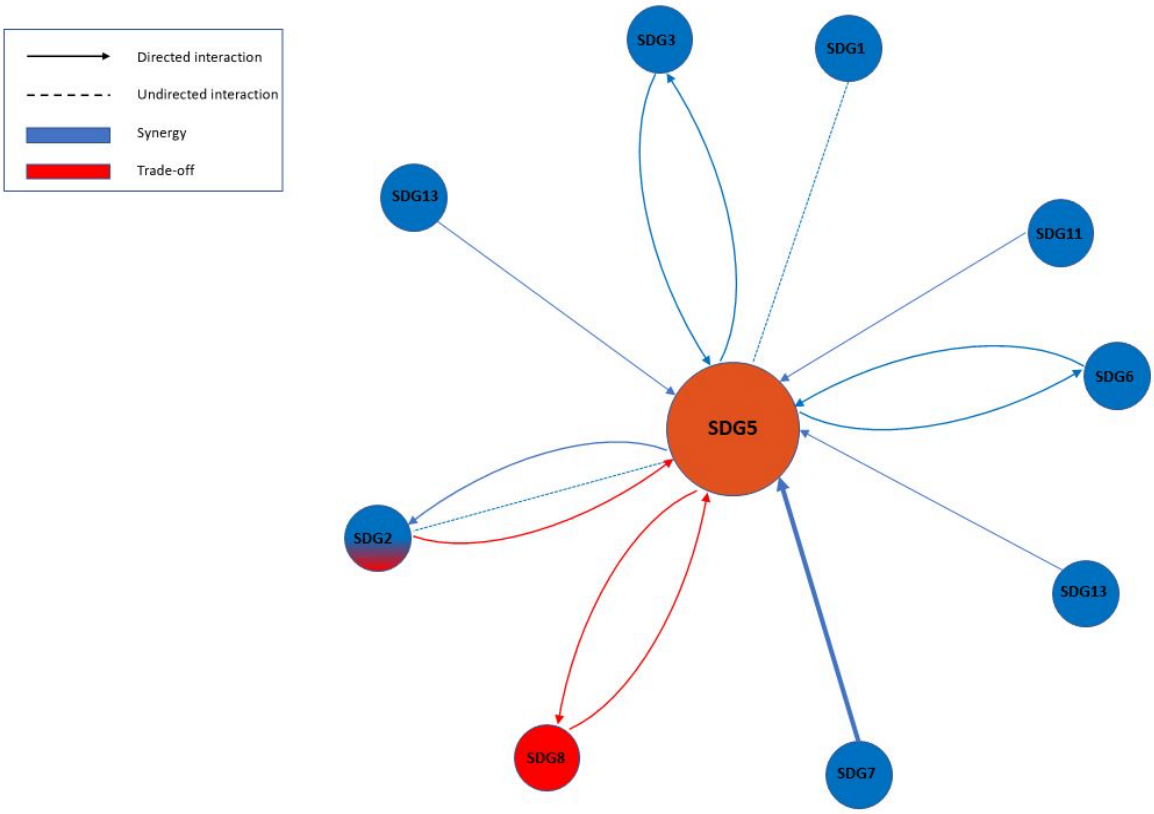
relevance on the significance of the studied interaction. As such, the idea that the number of studies focused on a certain SDG interaction, is indicative of the interaction's strength or significance, does not hold true.

Figure 2 shows that most synergies are found in relation to SDG 2 (zero hunger), which is also one of the SDGs covered most widely in the literature. There are also important trade-offs, however, notably with SDGs 6 (clean water and sanitation), 14 (life below water) and 15 (life on land). For SDG 5 (gender equality) much fewer studies were found, but the interactions that were identified were mostly synergetic, with the notable exception of SDG 8 (decent work and economic growth). SDG6 (clean water and sanitation) is widely studied, and shows a mixture of synergetic interactions and trade-offs. SDG15 (life on land) is showing the most trade-offs, whereas the synergetic relationships it may hold with other goals seem relatively understudied. Most notably, trade-offs can be observed between SDG 15 and SDGs 1 (no poverty), 2 (zero hunger), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure) and 11 (sustainable cities and communities).

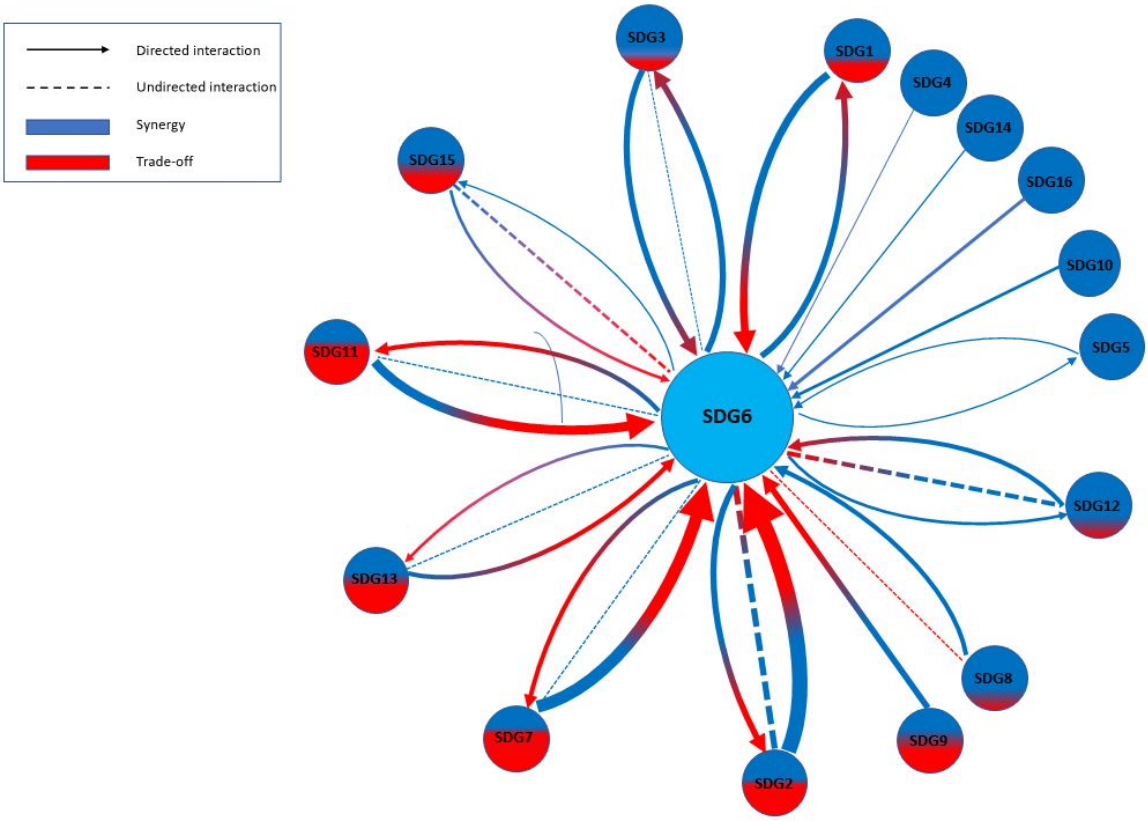
Figure 2: Breakdown of interactions of SDGs 2, 5, 6 and 15 with other SDGs



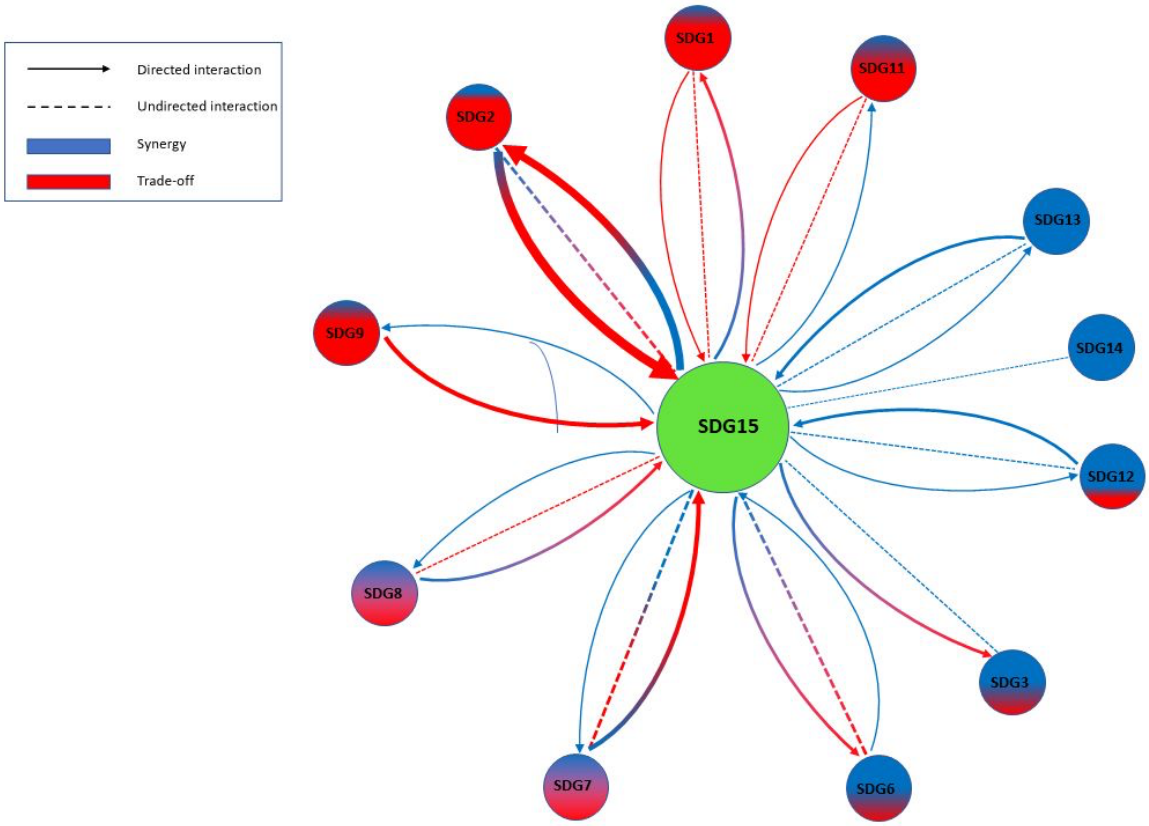
SDG2 interactions: direction, frequency and sign



SDG5 interactions: direction, frequency and sign



SDG6 interactions: direction, frequency and sign



SDG15 interactions: direction, frequency and sign

Note: The figure depicts three pieces of information. Firstly, each pair of SDGs – of which one is always either SDG 2, 5, 6, or 15 – can be connected through either a dotted line, arrows, or both. The dotted lines depict undirected SDG interactions, meaning one or multiple articles identifying an interaction provided no/insufficient information on the direction of the relationship. In contrast, the arrows depict directed interactions. Secondly, the thickness of the lines reflects the number of times an interaction was identified in the literature. Thirdly, the interactions are coloured blue or red (if an interaction was only identified as respectively a synergy or a trade-off) or a combination of both (if an interaction was identified as both). Here, the balance between blue and red depends on the number of times an interaction was identified as a synergy or trade-off. Subsequently, these have been added up for every SDG – except for the SDG at the centre, which is coloured according to the official UN SDG colouring – so that the colour balance of the SDGs reflects the total number of times the different interactions (directed/undirected) between a given SDG and the SDG at the centre were identified as synergies of trade-offs.

Section 3: interactions between SDGs 2 and 5

General findings: type, nature, direction and level of identified interactions

Academic literature on interactions between SDGs 2 (zero hunger) and 5 (gender equality) identifies primarily synergetic relations, to a lesser extent the absence of any association, with no papers noting a trade-off. As will be discussed in greater detail below, the overwhelming number of identified synergies compared to the absence of trade-offs could be explained at least partly by the specific targets authors have chosen to examine. Thus, it would be misleading to view SDGs 2 and 5 as inherently synergetic. Regarding the direction of identified interactions, the majority of selected papers establish SDG 5 as having a positive both direct and mediated effect on SDG 2. With the exception of Besnier (2020), no other publication explores the inverse direction: SDG 2's potential effect on SDG 5. After applying Granger causality tests, Besnier (2020) could not support the existence of a causal relation stemming from SDG 2 and directed towards SDG 5.

Moving on to interaction level, the overwhelming majority of publications employ SDG goals or targets to study interactions, except Bensier (2020), who employs SDG 2 indicators to structure the research design. To operationalise SDG 5, most authors select women's empowerment' as a proxy variable. Thanks to the concept's both multi-level and -dimensional nature, the term has been operationalised along different dimensions, leading to the use of diverse datasets and indexes (Ewerling et al., 2017, p.916). Baye et al. (2021), for example, operationalise women's empowerment along the three dimensions of social autonomy, decision making and attitude to violence, using the SWPER index[1], while Jones et al (2019) pick similar yet distinct dimensions- social and human assets, intrinsic and instrumental agency. Focusing on SDG 2, the selected publications look exclusively at SDG targets 2.1 (access to safe, nutritious and sufficient food) and 2.2 (end all forms of malnutrition), specifically as those relate to child nutritional status. A variety of proxy variables is used to capture the two targets, including: children's Minimum Dietary Diversity (MDD); child nutritional status; and prevalence of stunting among children. There are only two papers that do not adopt a child-centred approach to SDG 2.1, using households as the unit of analysis and household food security as a proxy variable.

Specific interaction findings for SDGs 2 and 5

Beyond general, descriptive observations, this section discusses specific interaction findings for SDGs 2 (zero hunger) and 5 (gender equality). Analysing the relevant literature, the positive effect of improved women's empowerment (SDG 5) on SDG targets 2.1 (access to safe, nutritious and sufficient food) and 2.2 (end all forms of malnutrition) is clearly established. Focusing on Ethiopia, Baye et al. (2021) conduct a logistics regression analysis, which demonstrates the synergetic relation between women's empowerment (SDG 5) and improved MDD for kids (SDG 2.1). Similarly, Besnier's (2020) quantitative study identifies a positive association between women's empowerment and decreased prevalence of stunting among children (SDG 2.2), a relationship that holds the strongest in middle-income countries globally. Jones et al. (2019) zoom in on East Africa and establish a positive link between women's empowerment and children's nutritional status (SDG 2.2). Interestingly, Jones et al. (2019) also factor in for the potential effect of mediating factors, including women's own Body Mass Index (BMI) and household wealth status. The synergetic relation between SDG 5 and SDG 2.2 is the strongest for the lowest and highest wealth categories, while including BMI as a mediator in this relationship diminishes and replaces the direct effect by pathways that operate via maternal BMI. It is important to note that a large body of literature, which lays outside the scope of this review for not systematically incorporating the SDG framework, reaffirms the existence of a synergetic relation between women's empowerment and child nutritional status, further strengthening the validity of these interaction findings (Heckert et al., 2019; Imai et al., 2014; Sethuraman et al., 2006; Shafiq et al., 2019).

As already mentioned, two of the identified studies also explore the relations between SDG 5 and household food security (SDG 2.1). Both publications employ the gender of a household head to capture SDG 5, while neither identifies a statistically significant association between SDG 5 and target 2.1 (Riley& Caesar, 2018; Sgro et al., 2019). Sgro et al. (2019), however, find a positive indirect association mediated through SDG 4 (quality education)[2]. These findings require some closer consideration due to the chosen proxy variable: operationalising SDG 5 through the gender of the household head might be a problematic choice, as it is not gender per se that affects household food security, but rather external, socioeconomic conditions imposed around gender. Moreover, by comparing female headed households (FHH), which usually refer to single female households, to male

[1] The survey-based women's empowerment (SWPER) index, developed and validated for use in Africa by Ewerling et al. (2017), is an individual-level indicator that allows for time-trend analysis and between country comparisons (Baye et al., 2021, p. 2).

[2] Sgro et al. (2019, pg. 23) explain the pathway through which SDG 4 can act as a positive mediator in the relationship between women's empowerment and household food security: ensuring universal access to education can disrupt the vicious cycle of gender inequality and lead to women's empowerment, which in turn can positively affect food security.

headed households (MHH), which mostly consist of couples or polygamous households, these studies do not reveal much about intra-household differences.

Governing identified interactions between SDG 2 and 5

Harnessing synergetic relations between SDG 2 (zero hunger) and 5 (gender equality) requires a 'governance' agenda, whereby all relevant stakeholders consult, coordinate and work with each other to design and implement innovative, future-oriented initiatives and programmes. Despite the key role of governance in leveraging synergies and mitigating trade-offs, only a limited number of papers make a concentrated effort to provide policy recommendations on how to govern identified interactions. Whenever policy advice is included, it is usually short, rather general and lacking the details required to materialise it on the ground. The main recommendations on how to govern SDG 2-5 interactions emerging from the examined publications include the following:

1. After establishing women's empowerment as a critical driver of child nutrition, Besnier (2020) and Baye et al. (2021) advocate for the former to be more boldly addressed and integrated in nutrition interventions. Such an open-ended recommendation, however, leaves several questions pending: how should such interventions become bolder; who should take the lead; where should the required funding come from?
2. Jones et al. (2019) establish household wealth status as a factor mediating the relationship between women's empowerment and children's nutrition, suggesting that policies jointly addressing the two should comprehensively account for households' wealth status.

While the above recommendations provide a substantive starting point, greater and more systematic effort is needed to expand on these recommendations and make them operationalisable and fit to the policy context on the ground.

Knowledge gaps

In examining relevant literature, the authors of this review have marked several knowledge gaps that should be addressed through further research. To investigate the links between SDG 2 and 5, and specifically among child nutrition and women's empowerment, many papers have used married women with underaged kids as their unit of response (Baye et al., 2021; Jones et al., 2019). It would, thus, be more accurate to suggest that such studies capture mothers' rather than more broadly women's empowerment. While the focus on mothers' empowerment is welcome, further research into the potential impact of other female household members (i.e. sisters or grandmothers) as well as women and girls in the community, on child nutrition is needed to capture potentially unobserved SDG 2-5 interactions. Secondly, literature studying interactions between SDG 2 and 5 exclusively focuses on SDG targets 2.1 and 2.2, especially as those relate to children and to a lesser extent to household food security. Researchers should, therefore, explore how unaddressed SDG 2 targets, in particular those associated with agricultural productivity, sustainable food systems and seeds, crops and domestic animal diversity, interact with SDG 5, as there might be unobserved conditional and synergetic effects contained in those factors. Finally, there has been limited attention to mediating factors influencing the relationship between the two SDGs and to factors explaining country-level variations in the identified interactions. More studies at a country-level, accounting for mediating factors, will lead to a better understanding of country-specific links between SDGs 2 and 5, which will allow for more appropriate, context-sensitive policies to emerge.

Section 4: interactions between SDGs 2, 6 and 15

General findings: type, nature, and level and of identified interactions.

Globally, policy approaches to water and land management, as well as to agriculture and food production remain siloed and largely unsustainable, either prioritizing economic benefit over social and environmental considerations or adopting a narrow focus on food security, neglecting pressures on land and water ecosystems/resources (Nhamo et al.,2020; Rasul, 2015; Bandari et al., 2021). Under such conditions, relevant literature mostly identifies trade-offs between SDGs 2 (zero hunger), 6 (clean water and sanitation) and 15 (life on land). The observed negative interactions move in five different directions: SDG 2 having a negative impact on SDG 6 (SDG 2 → SDG 6); SDG 6 having a negative impact on SDG 15 and vice versa (SDG 6→ SDG 15, SDG 15→ SDG 6); SDG 6 having a negative impact on SDGs 2 and 15(SDG 6→ SDG 2 & 15); and SDG 2 having a negative effect on SDGs 6 and 15 (SDG 6 → SDG 2 & 15). Most of the studies included in this review, however, investigate the potential role of several mediating factors in mitigating trade-offs and inducing synergies. As will be discussed in greater detail below, the identified mediating factors include a range of sustainable, nexus or holistic approaches and policies to resource and ecosystem management. Regarding the level of interaction, the analysis of most of the selected publications takes place at a goal-level (14 studies) rather than on target- (9 articles) or indicator-level (3 studies). SDGs 2 and 15 are identified as two of the SDGs showing the greatest number of trade-offs with other SDGs, while SDG 6, and particularly target 6.5 (integrated water resources management), is seen as having predominantly synergetic relations (Baumgartner, 2019).

Specific interaction findings: trade-offs and synergies,

Zooming into specific interaction findings for this SDG cluster, the trade-off between SDG 2 and 6, with an identified negative direction from SDG 2 towards 6, is discussed by Fader et al. (2018). The study concludes that targets 2.1 (access to safe, nutritious and sufficient food), 2.2 (end all forms of malnutrition) and 2.3 (double the agricultural productivity and income of small-scale food producers) have a negative effect on target 6.6 (protect and restore water-based ecosystems). This finding is supported by three more papers, all of which analyse interactions, instead, on a goal level (Wang et al., 2022; Bandari et al., 2021; and Rasul, 2015). Secondly, a trade-off between SDG 6 and 15 is evidenced by several authors. According to Wang et al. (2022), who use China as their case study, SDG 6 can negatively affect the attainment of SDG 15 and vice versa. More specifically, reducing nutrient pollution in rivers (SDG 6) by recycling animal manure on land may lead to higher ammonia emissions from agriculture, resulting in higher atmospheric nitrogen deposition in terrestrial ecosystems (SDG 15). Conversely, SDG 15 can negatively affect SDG 6 by causing water pollution through the atmospheric deposition of air pollutants from energy or industry use. Baumgartner (2019), whose study is instead conducted on a global scale, reaffirms this finding.
Lastly, two of the selected publications investigate more complex interactions among all three SDGs. Looking at the case of the Goulburn-Murray region in Australia, Bandari et al. (2021) conclude that progress on some of the SDG 2 targets can impede the attainment of SDG 6 and 15 targets. In explaining the identified trade-off, the authors point at how boosting agricultural productivity (SDG 2) can negatively affect water quantity and quality (SDG 6), thereby changing the condition of water-related ecosystems and triggering land and natural habitat degradation (SDG 15). As it stems from the above, SDG 2 has a direct negative effect on SDG 6 and an indirect negative effect on SDG 15, mediated through SDG 6. Wada et al. (2019) paint a similar picture for the Indus River Basin: their analysis showcases that under a business-as-usual scenario, the intensification of irrigation for agricultural purposes (SDG 2) will significantly challenge water quality and availability (SDG 6), this way also leading to trade-offs with SDG 15.

Mediating factors in SDG interactions

Table 2 : Mediating factors and their effects on SDG interactions

Article	Mediating factor	Effect on SDG interactions			SDG indicator of mediating factor
		Improvement	*Synergy*	*Trade-off*	
Baumgartner (2019)	Integrated land use management of forests	Improvement on SDG 15, leading to a positive effect on SDGs 2 and 6			SDG 15.2.1
Nath et al. (2020)	Participatory forest management (PFM)		SDGs 2 and 15		SDG 15.2.1
Seifollaki- Aghmuini et al. (2019)	Wetland ecosystem services		SDGs 6, 13, and 15; SDGs 2 and 6		SDG 6.3.2
Philippidis et al. (2020)	Sustainable improvements in land productivity		SDGs 2, 6, 13, and 15		SDG 2.4.1
De Pinto et al. (2020)	Forest Landscape Restoration approach integrateing crop production in land restoration efforts		SDGs 2 and 15		SDG 15.2.1
Visser (2019)	Organic farming and climate smart agriculture		SDGS 2, 6, and 15		SDG 2.4.1
Lal (2020)	Integrating animal husbandry with cultivation and seasonal crops and perennial trees		SDGs 2, 3, 6, 13, and 15		SDG 15.4.1
Banjeree et al. (2019)	Expanding irrigated agriculture		SDGs 2 and 6	SDGs 13 and 15	SDG 2.3.1

Unlike publications investigating SDGs 2-5 interactions, several studies in this cluster have considered a range of mediating factors and their effects on SDGs 2 (zero hunger), 6 (clean water and sanitation) and 15 (life on land) interactions (for an overview of the mediating factors see table 2 above). To make the comprehension and discussion of such factors as clear as possible, an additional analytical step has been taken: we have grouped the factors in accordance with SDGs 2, 6 and 15 indicators. Three mediating factors that relate to indicator 15.2.1 (sustainable forest management) have been noted and include: integrated land use management, participatory forest management and forest landscape restoration approach that integrates crop production in land restoration efforts. Baumgartner (2019) delineates how the integrated land use management of forests can lead to improvements in SDG 15 and push the latter to act synergetically with both SDGs 2 and 6. Additionally, Nath et al. (2020) showcase how the application of participatory forest management projects in south-eastern Bangladesh have enabled SDGs 2 and 15 to function synergetically, as the projects have helped rehabilitate degraded land, thereby enriching agrobiodiversity and leading to the production of healthier food. Similarly, undertaking a forest landscape restoration approach that integrates land restoration efforts with crop production can induce synergies between SDGs 2 and 15, as evidenced by De Pinto et al. (2020) who employ scenario simulation to assess an integrated approach to maize, wheat and rice production globally. A single mediating factor, the integration of animal husbandry with seasonal crops and perennial trees cultivation, relates to indicator 15.4.1 (conservation and biodiversity). Lal (2020) illustrates how the integrated management of livestock and crop production can simultaneously improve the income of smallholder farmers (SDG 1); significantly reduce malnutrition (SDG 2); improve the quality and renewability of water (SDG 6); and reduce livestock-related GHG emissions (SDG 13), especially in developing countries of the tropics.

Moving on, three mediating factors (sustainable improvements in land productivity, climate smart agriculture and organic farming) were found to positively relate to indicator SDG 2.4.1 (agricultural area under productive and sustainable agriculture). Through model simulation, Philippidis et al. (2020) estimate that sustainable land productivity improvements can yield a synergetic effect for realising both food security (SDG 2.1 and 2.2) and responsible planetary management as captured by targets 6.4 (water-use efficiency), 13.2 (integration of climate change measures in national policies) and 15.2 (sustainable forest management). The authors, however, caution that as long as agricultural yield gaps and sectoral subsidy gaps between wealthier and poorer countries ensue, the above synergetic effect is unlikely to materialise for poorer countries and the most vulnerable segments of their populations. In a similar vein, Visser et al. (2019) showcase how a transfer to organic farming in the Netherlands led to the use of less water for irrigation and facilitated groundwater recharge, creating a synergy between SDGs 2 and 6. Additionally, the practice of organic farming has enabled a synergy between SDGs 2 and 15, by reducing the use of fertilizers and pesticides, both of which can be detrimental to soil health. The final mediating factor relating to SDG 2, and specifically to indicator 2.3.1 (agricultural productivity) refers to the expansion of irrigated agriculture. Banerjee et al. (2019) paint a more complex picture: while the expansion of irrigated agriculture can drive a synergy between SDGs 2 and 6, it can also lead to a trade-off between SDG 2, on the one hand, and SDGs 13 (climate action) and 15, on the other.

The final mediating factor identified in the examined literature revolves around wetland ecosystem services and thus relates to indicator 6.3.2 (bodies of water with good, ambient water quality). Seifollahi-Aghmiuni et al. (2019) observe that the protection of wetland ecosystems will strengthen their resilience to weather-related shocks and lead to synergies between SDGs 6, 13 and 15.

Governing SDG interactions

Another matter central to this review and to the examined studies is the governance of identified trade-offs and synergies. How can trade-offs be avoided or mitigated and synergies be stimulated? Specifically, many studies find a central role for national governments in mitigating trade-offs between SDG 2 and 15. Such a role is exercised notably through establishing functioning extension services, guaranteeing land and tree rights, providing reliable information to farmers, and creating reliable institutions (De Pinto et al., 2019). However, if national governments are to undertake a key role, questions of available policy space and autonomy will have to be meaningfully considered and tackled. For example, the location of a country in the global political economy matrix (i.e. level of aid dependence, flows of foreign direct investment, etc.) will significantly affect the available policy space for its national government to manage SDG interactions and the extent to which it will be able to do so autonomously. While national governments are undoubtedly a key piece in the SDG interaction governance puzzle, too much attention on this type of stakeholder can overshadow the potential impact and contributions of other critical actors. Sub-national authorities, for example, have in certain cases been recognized as more pioneering and innovative than national governments, especially when it comes to building coalitions towards SDG implementation and governance (Biermann et al., 2022). Similarly, relevant literature highlights the importance of civil society actors in holding public actors accountable for their commitments to the SDGs and their inclusive implementation (Biermann et al., 2022; Haren et al., 2019).

Additionally, siloed and unsustainable approaches to land, water management and agricultural food production lead to trade-offs among SDGs 2, 6 and 15. In order to mitigate trade-offs and stimulate synergies, a range of practices is advanced in the literature. The most prominent ones include a move towards holistic approaches for sustainable land management and restoration of natural systems (Visser, 2019); the adoption of sustainable agricultural practices (Rasul, 2015); and the pursuit of policies that promote sustainable production and energy sector decarbonisation (Obersteiner et al., 2016). While scholars make powerful cases for the viability and promise of these policies, one still

needs to keep in mind that one-size-fits-all approaches to policy implementation may not work. Thus, identifying mitigating policies is merely the first step that should be coupled with further policy contextualisation to fit specific national and/or local socioeconomic realities. Furthermore, in suggesting such practices, no additional guidance regarding implementation-related challenges is provided and critical questions remain unanswered: which stakeholders should take the lead in enforcing such practices; where should the financing come from; how should local communities be involved; and how can we deal with vested political interests that benefit from the current status quo? In failing to grapple with such queries, policy recommendations remain general and thus of minimal help in actually governing interactions.

Knowledge gaps

The analysis of the literature has evidenced gaps and avenues for further research. When looking at SDGs and the level of analysis, some studies note the need for greater context specificity. Putra et al. (2020) observe some country-level variation in terms of SDG findings for countries in South East Asia, and Lusseau et al. (2019) further note country income-based variations for the identified SDG interaction. Therefore, both studies urge for context specificity, through country-disaggregated data and a regional- or country-level scope of analysis. Tangentially, the authors highlight the need to further contextualise targets and prioritise goals by country income level.

SDG-specific gaps are also identified. The absence of studies investigating how SDG 6 (clean water and sanitation) and its associated targets and indicators may affect SDG 2 (zero hunger) is notable and might signify that there are important unidentified synergies and trade-offs.

On another note, by looking at mediating factors, authors were able to identify pathways and interventions through which to mitigate SDG trade-offs and enhance synergies. However, as it emerges from the relatively small number of articles engaged with this, more attention needs to be paid to the role of mediating factors (this can also provide greater insight into SDG interaction governance). The majority of studies investigated look at mediating factors that only stem from SDG 2 and 15 (life on land) indicators. The absence of focus on SDG 6-related mediating factors, thus, necessitates further research on the pathways that can lead to synergetic relations between SDG 6 and the other goals of interest.

Section 5: Methodological findings

The final section of the main body turns its attention to emerging methodological findings. While this literature review has adopted a concrete thematic focus, some attention to the research designs, methods and tools employed in the selected publications can potentially reveal additional knowledge gaps. As already mentioned in section 1, quantitative studies constitute the overwhelming majority in our sample and will be further discussed in the following sub-section. Before moving on, however, it is worth noting that mixed methods and qualitative approaches are far less widely applied compared to dominant quantitative ones, while no study has employed political economy as an entry point into SDG interaction analysis. This observation already points to a significant methodological gap, as qualitative, mixed methods and political economy approaches can yield greater insight into the context-specific processes and mechanisms through which change occurs and the ways in which individuals experience them.

Quantitative studies: evaluating correlation, making predictions and causal inferences

Zooming in on quantitative publications, which make up the majority in our sample, it is imperative to take stock of whether they establish correlations between SDG pairs; or calculate the capacity of one or several SDGs to predict the occurrence of another; or whether they make causal inferences.

Most papers evaluate pairwise correlations to establish the existence of SDG interactions, and some papers use that as a starting point to performing more complex analyses. Regarding the latter category of papers, these typically employ various forms of regression analysis[3] to estimate and subsequently explain the relations between one SDG, acting as a dependent variable, and one or more SDGs, functioning as independent variables. Sgro et al. (2019), for example, couple logistic regression with a decision matrix model to estimate which of the three SDGs, SDG 4 (quality education), 5 (gender equality) and 8 (decent work and economic growth), are most effective in predicting instances of food security (SDG 2). Not but one study, however, attempts to evaluate causality in identified interactions. Bensier (2020), in the context of a fixed-effects regression analysis, performs Granger causality tests to explore whether child health and nutritional status (SDG 2) is driving and/or is driven by women's political empowerment.

What emerges from the above is a clear methodological gap relating to the lack of studies making causal inferences. In attempting to fill this gap, scholars could explore the use of a more quantitative (e.g. randomized control trials or variance theory) or more qualitative research strategies (e.g. process tracing) that are increasingly gaining acceptance for tracing causality (Maxwell, 2004).

Types of data: cross-sectional, time series or panel data?

Among the publications selected for this literature review, the ones employing cross-sectional data, which include observations of multiple entities at a single point in time, constitute the clear majority. Only ten studies utilize time series data, which consist of observations on a single entity over time, while a single paper uses data organised in both dimensions, also known as panel data[4]. The underrepresentation of time series data in our pool of selected publications constitutes a complex matter. In theory, the relative absence of time series data highlights the need to gather and use such data to detect longer term patterns regarding SDG interactions, also allowing for the occurrence of emergent effects, and make relevant predictions that can enhance governance. However, recognising practical realities on the ground reveals impediments to materialising such a data gathering approach: the institutional challenges as well as the significant costs involved in having panels and gathering time series data, particularly for developing countries, should push researchers to reflect and innovate on how else we might account for change in the absence of reliable panel data.

The SDGs' indivisible nature and nexus approach: a match made in heaven?

Looking specifically at the papers investigating interactions among SDGs 2 (zero hunger), 6 (clean water and sanitation) and 15 (life on land), an interesting trend emerges: a considerable number of authors employ the Water Energy Food (WEF) nexus as an analytical tool to conduct an integrated assessment of SDG interactions (Fader et al., 2018; Nhamo et al., 2020; Putra et al., 2020; Rasul, 2016; Ribeiro et al., 2021; Wada et al., 2019). The three pillars of the nexus correspond neatly to SDGs 2, 6 and 7 (affordable and clean energy), and the nexus' integrated approach, aiming to transcend myopic sectoral approaches to resource management, complements the SDGs' indivisible nature. Scholars, however, have also noted some potential problems with employing the WEF nexus to studying SDG

[3] For more information on the types of research methods and tools used, including types of regression analysis, please consult the literature review table in the annex.
[4] To see which studies employ cross-sectional data and which use time series or panel data, please refer to the literature review table.

interactions. More specifically, the nexus is criticised for having a narrow cross-sectoral focus on water, energy and food, ignoring other relevant dimensions, such as land, the environment and gender (Purwanto et al., 2021). To ensure a broader sectoral outlook, some scholars have proposed and operationalised the inclusion of additional sectors and dimensions in the nexus. Wada et al. (2019), for example, have extended the traditional WEF nexus to include land, as codified in SDG 15, into the nexus. Additionally, scholars note that the mainstream nexus discourse relies mainly on a natural scientific framing of environmental challenges, which leads to a technical conception of water, energy and food as global trade goods that necessitate close monitoring, management and control (Wiegleb & Bruns, 2018). Such a technical framing neglects social scientific perspectives, which engage with the social, political and economic elements of the nexus, potentially masking insidious power dynamics in resource governance, social inequalities and distributional justice (Allouche et al., 2015). The WEF nexus could thus be greatly strengthened, critics argue, by acknowledging the political nature of resource governance. Both the study and governance of SDG interactions, which hinge on the timely identification of unintended consequences, unforeseen trade-offs and opportunities to harness synergies, could thus greatly benefit from interdisciplinary innovations and expansions of the WEF nexus.

Limitations

Despite the review's substantive contributions, several limitations are also evident in our study of the literature. Firstly, the body of literature empirically investigating SDG interactions is still rather small, albeit rapidly growing, owing to the relatively short existence of the SDG framework, which dates back to 2015. As some interactions and their effects might take a longer period of time to materialise, there might be several unobserved interactions missed both by SDG scholarship and this review. At the same time, the small body of empirical literature on SDG interactions translates into a narrower scope for our review, which limits our approach. This shortcoming could have been remedied by less stringent selection criteria and the inclusion of empirical publications implicitly studying SDG interactions without systematically incorporating the SDG framework in their methods and analysis. That would have made papers prior to 2015 eligible and significantly widen our scope. However, it would have also pushed us into a methodologically murky territory, whereby we would have to infer specific SDG interactions, when they were merely implied. Additionally, it is important to note that this review has not considered already existing national plans, frameworks and budgets, and the extent to which those align with the SDG framework. While this kind of exploration lies outside the scope of this review, it should still be observed as a limitation, given that efforts to align national plans and the SDGs might create unforeseen opportunities and challenges for the SDG governance agenda (Fourie, 2018). Such an exploration is all the more urgent, considering that: 1) observable institutional change to achieve the SDGs tends to replicate existing national priorities; and 2) as of yet governments have not reallocated funding towards SDG implementation—two potential challenges to the SDG governance agenda and its political impact (Biermann et al., 2022). A third limitation relates to the fact that some interactions receive greater scholarly attention than others, limiting the availability of data on relatively understudied interactions. Consider, for example, that out of the 38 publications included in this review only 10 investigate SDGs 2-5 interactions, while 28 focus on the SDGs 2, 6 and 15 cluster. There could be several explanatory factors underpinning the above. For one, what gets measured—and in that sense, what is easier to measure—is generally studied more often. In regards to SDG 5, for example, the concept of women's empowerment is central and yet official metrics on the concept are lacking. While feminist scholars have made significant progress in forging a conceptual framework for the term, translating it into standardised measurements is proving a daunting task (Pryor &Seck, 2019) and reflecting a mismatch with alternative national/regional guiding frameworks that set their own priorities. This is further compounded by an overall gender gap in data (Dhar, 2018). Another explanatory factor relates to the currently dominant policy and research agendas and to which interactions are seen as priorities by influential development stakeholders.

Conclusion

This scoping literature review has scanned relevant academic publications in pursuit of two aims: 1) identify and discuss empirically investigated interactions between SDGs 2 (zero hunger) and 5 (gender equality), SDGs 2, 6 (clean water and sanitation) and 15 (life on land), and SDGs 13 (climate action) and 16 (peace, justice and strong institutions); and 2) bring to the fore thematic as well as methodological knowledge gaps in the study of SDG interactions.

In terms of specific interaction findings, the literature notes predominantly synergetic relations between SDGs 2 and 5, whereby the latter exerts positive effects on the former. It is important to highlight that no publication identifies trade-offs between these two SDGs. The opposite, however, is the case for SDGs 2, 6 and 15, whose interactions are riddled with trade-offs. Literature records SDG 2's negative effect on both SDGs 6 and 15; a trade-off between SDG 6 and 15, moving in both directions; and SDG's 6 negative effects on both SDGs 2 and 15. This gloomy picture changes considerably once authors account for a range of mediating factors, which are mostly capable of mitigating trade-offs and inducing synergies. This implies the relevance and significance of considering mediating factors in the study of SDG interactions, as they can bear critical consequences for SDG 17 (partnerships for the goals) and interaction governance.

Turning our attention to knowledge gaps, the first relates to the few documented interactions between SDGs 13 and 16. This literature review excludes much of the relevant literature by design, because the studied interactions were not operationalised within the SDG framework. This marks a significant gap in knowledge, considering that climate change could undermine actions to achieve 72 targets across 16 SDGs and constitute a potential driver of increased migration and thus also conflict (Chirico, 2017; Nerini et al., 2019). Additionally, there is a lack of research on how SDG 2 can potentially affect SDG 5. On top of that, literature has overwhelmingly focused on targets 2.1 (access to safe, nutritious and sufficient food) and 2.2 (end all forms of malnutrition), neglecting how remaining SDG 2 targets might interact with SDG 5. This gap could be particularly troubling, as there might be unobserved unconditional and synergetic effects embedded in those factors. Furthermore and in regards to SDGs 2-5 interactions, most relevant studies employ mothers rather than women more broadly as their unit of analysis, ignoring the potential impact other female household members (i.e. grandmothers and sisters) as well as women and girls in the community might have on household food security and child nutritional status.

Moving on, several studies have shown that geographical level matters, observing country-specific variations in identified interactions, without however accounting for potential factors explaining such variation. This requires a context-specific understanding of social-ecological-economic dynamics and policy priorities, which can be achieved through the use of country-disaggregated data and more studies at the country- and regional-level (Bennich et al., 2020). Considering insights generated in regards to SDG 17 (partnerships for the goals), studies entailed in this review have provided some policy advice and recommendations on how to govern SDG interactions, which lack in detail and comprehensiveness. This could partly be the result of the thorough conceptualisation of governance and its sub-themes, such as governance fragmentation, institutional interlinkages and integration, which has not been followed up by equally robust empirical work on the matter (Biermann et al., 2022). Consequently, the conduct of comparative in-depth empirical studies into how different governance parameters play out in practice across different contexts could be of great added value in developing impactful SDG governance recommendations (Biermann et al., 2022). Finally, and related to the above point, the study as well as governance of SDG interactions could benefit from studies designed to explain causality, either through more quantitative or qualitative research methodologies. They should be complemented by political economy analysis to better understand the underlying mechanisms and

processes of change and thus establish a closer link to policymaking (Barrett & Carter, 2010; Bédécarrats et al., 2019).

Annex: Overview of selected publications

Reference	Methodology	Employed Data	Level of interaction	SDG Focus	SDG interactions findings (synergies or trade-offs)	Scope	Links to SDG 17 (SDG interaction governance)
Mollier, Ludovic, Frédérique Seyler, Jean-Luc Chotte, and Claudia Ringler. "SDG 2 END HUNGER, ACHIEVE FOOD SECURITY AND IMPROVED NUTRITION AND PROMOTE SUSTAINABLE AGRICULTURE." In A GUIDE TO SDG INTERACTIONS: FROM SCIENCE TO IMPLEMENTATION, 52. International Council for Science, 2017. https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers17-10/010070608.pdf.	quantitative	cross-sectional data	goal and target level	SDG 2 and SDGs 1, 3, 5, 6, 7, 13, and 15	SDG 2-5 synergy	global level	yes
Chisadza, Carolyn, Eleni Yitbarek, and Nicky Nicholls. "Women Empowerment and Child Obesity: Evidence in Comoros, Malawi, and Mozambique." In Women and Sustainable Human Development: Empowering Women in Africa, edited by Maty Konte and Nyasha Tirivayi. Cham: Springer International Publishing, 2020. https://doi.org/10.1007/978-3-030-149	quantitative	cross-sectional data	goal level	SDG 2 and SDG 5	Mixed results pertaining to country context	regional level (sub-Saharan Africa)	no
Baye, Kaleab, Arnaud Laillou, and Stanley Chitekwe. "Empowering Women Can Improve Child Dietary Diversity in Ethiopia." Maternal & Child Nutrition, November 4, 2021. https://doi.org/10.1111/mcn.13285.	quantitative	time series data	goal level	SDG 2 and SDG 5	SDG 2-5 synergy	country level (Ethiopia)	yes, but limited
Glazebrook, Tricia, and Emmanuela Opoku. "Gender and Sustainability: Learning from Women's Farming in Africa." Sustainability 12, no. 24 (December 15, 2020): 10483. https://doi.org/10.3390/su122410483.	mixed methods	panel data	goal level	SDGs 1, 2 and 5	SDG 1-2-5 synergy	regional level (Sub-Saharan Africa)	yes, but limited
Riley, Liam, and Mary Caesar. "Urban Household Food Security in China and Mozambique: A Gender-Based Comparative Approach." Development in Practice 28, no. 8 (November 17, 2018): 1012–21. https://doi.org/10.1080/09614524.2018.1505829.	quantitative	cross-sectional data	goal level	SDGs 2, 5 and 11	SDG 2-4 synergy	country-level (China and Mozambique)	no
Besnier, Elodie. "Women's Political Empowerment and Child Health in the Sustainable Development Era: A Global Empirical Analysis (1990–2016)." Global Public Health, December 13, 2020, 1–23. https://doi.org/10.1080/17441692.2020.1849348.	quantitative	panel data	goal level	SDGs 2, 3 and 5	SDG 2-5 synergy	global level	no
Banerjee, Onil, Martin Cicowiez, Mark Horridge, and Renato Vargas. "Evaluating Synergies and Trade-Offs in Achieving the SDGs of Zero Hunger and Clean Water and Sanitation: An Application of the IEEM	quantitative	cross-sectional data	target level	SDGs 2 and 6 and their interactions with SDGs	SDG 2-6 synergy; SDG 2-15 trade-off; SDG 2-13 trade-off	country-level (Guatemala)	no

Platform to Guatemala." Ecological Economics 161 (July 2019): 280–91. https://doi.org/10.1016/j.ecolecon.2019.04.003.				1, 7, 8, 10, 12, 13 and 15			
Ji, S., and Y. Lee. "Food Security and Agroforestry from the Perspective of the SDGs: A Case Study of the Democratic People's Republic of Korea." International Forestry Review 23, no. 4 (2021).	qualitative	cross-sectional data	target level	SDG 2 and SDG 15	SDG 15-2 trade-off	country-level (North Korea)	yes, but limited
Jones, Rebecca, Regine Haardörfer, Usha Ramakrishnan, Kathryn M. Yount, Stephanie Miedema, and Amy Webb Girard. "Women's Empowerment and Child Nutrition: The Role of Intrinsic Agency." SSM - Population Health 9 (December 2019): 100475. https://doi.org/10.1016/j.ssmph.2019.100475.	quantitative	cross-sectional data	target level	SDG 2 and SDG 5	SDG 2-5 synergy	regional level (Sub-Saharan Africa)	yes, but limited
Obersteiner, Michael, Brian Walsh, Stefan Frank, Petr Havlík, Matthew Cantele, Junguo Liu, Amanda Palazzo, et al. "Assessing the Land Resource–Food Price Nexus of the Sustainable Development Goals." Science Advances 2, no. 9 (September 2, 2016): e1501499. https://doi.org/10.1126/sciadv.1501499.	quantitative	time series data	goal level	SDGs 2, 12, 13 and 15	SDG 2-12-15 synergy	global level	yes, but limited
Stevenson, Samuel, Alexandra Collins, Neil Jennings, Alexandre C. Köberle, Felix Laumann, Anthony A. Laverty, Paolo Vineis, Jeremy Woods, and Ajay Gambhir. "A Hybrid Approach to Identifying and Assessing Interactions between Climate Action (SDG13) Policies and a Range of SDGs in a UK Context." Discover Sustainability 2, no. 1 (December 2021): 43. https://doi.org/10.1007/s43621-021-00051-w.	qualitative	cross-sectional data	target level	SDG 13 and its interactions with SDGs 3, 7, 8, 9, 11, 14 and 15	SDG 2-13 both trade-offs and synergies; SDG 8-13 both synergies and trade-offs	country level-UK	no
De Pinto, Alessandro, Nicola Cenacchi, Richard Robertson, Ho-Young Kwon, Timothy Thomas, Jawoo Koo, Salome Begeladze, and Chetan Kumar. "The Role of Crop Production in the Forest Landscape Restoration Approach—Assessing the Potential Benefits of Meeting the Bonn Challenge." Frontiers in Sustainable Food Systems 4 (May 12, 2020): 61. https://doi.org/10.3389/fsufs.2020.00061.	quantitative	time series data	target level	SDGs 2, 13, and 15	SDG 2-15 synergy	global level	yes
Sgro, James, Bruce Frayne, and Cameron McCordic. "Linking the Sustainable Development Goals through an Investigation of Urban Household Food Security in Southern Africa." Journal of Sustainability Research, 2019. https://doi.org/10.20900/jsr20190004.	quantitative	cross-sectional data	goal level	SDG 2 and SDGs 4,5 and 8	SDG 2-5 indirect synergy	regional level (Sub-Saharan Africa)	yes

Visser, Keesstra, Maas, de Cleen, and Molenaar. "Soil as a Basis to Create Enabling Conditions for Transitions Towards Sustainable Land Management as a Key to Achieve the SDGs by 2030." Sustainability 11, no. 23 (November 29, 2019): 6792. https://doi.org/10.3390/su11236792.	qualitative	cross-section data	goal level	SDGs 2, 6, 8, 11, 12, 13, 15	Synergy between SDG 6 and SDGs 2, 8, 12, 13 and 15, mediated through organic famring; synergy between SDG 13 and SDGs 6, 11, and 12, mediated through climate smart agriculture.	country level (Netherlands)	yes, but limited
Putra, Muhammad Panji Islam Fajar, Prajal Pradhan, and Jürgen P. Kropp. "A Systematic Analysis of Water-Energy-Food Security Nexus: A South Asian Case Study." Science of The Total Environment 728 (August 2020): 138451. https://doi.org/10.1016/j.scitotenv.2020.138451.	quantitative	time series data	indicator level	SDGs 2, 6 and 7	mixed results pertaining to country context	regional level (Southeast Asia)	yes, but limited
Ronzon, Tévécia, and Ana I. Sanjuán. "Friends or Foes? A Compatibility Assessment of Bioeconomy-Related Sustainable Development Goals for European Policy Coherence." Journal of Cleaner Production 254 (May 2020): 119832. https://doi.org/10.1016/j.jclepro.2019.119832.	quantitative	cross-sectional data	goal level	SDG 2, 4, 6, 8, 9, 11, 12, 13, 14 and 15	SDG 7-11synergy; SDG 7-6 synergy; SDG 11-6 synergy; SDG 7-13 synergy; SDG 11-13 synergy; SDG 12-14 trade-off; and SDG 6-SDG 8 trade-off	regional level (European Union)	yes, but limited
Fader, Marianela, Colleen Cranmer, Richard Lawford, and Jill Engel-Cox. "Toward an Understanding of Synergies and Trade-Offs Between Water, Energy, and Food SDG Targets." Frontiers in Environmental Science 6 (November 12, 2018): 112. https://doi.org/10.3389/fenvs.2018.00112.	quantitative	cross-sectional data	target level	SDGs 2, 6, and 7	SDG 2-6 trade-off	global level	yes, but limited
Lal, Rattan. "Integrating Animal Husbandry With Crops and Trees." Frontiers in Sustainable Food Systems 4 (July 29, 2020): 113. https://doi.org/10.3389/fsufs.2020.00113.	qualitative	cross-sectional data	goal level	SDGs 1, 2, 6, 13, 15	SDGs 2, 3, 6, 13 and 15 synergy mediated through site-specific integration of livestock with crops and trees	global level	yes
Nhamo, Luxon, Tafadzwanashe Mabhaudhi, Sylvester Mpandeli, Chris Dickens, Charles Nhemachena, Aidan Senzanje, Dhesigen Naidoo, Stanley Liphadzi, and Albert T. Modi. "An Integrative Analytical Model for the Water-Energy-Food Nexus: South Africa Case Study." Environmental Science & Policy 109 (July 2020): 15–24. https://doi.org/10.1016/j.envsci.2020.04.010.	quantitative	time series data	indicator level	SDGs 2, 6, and 7	SDG 2-6 trade-off	country level (South Africa)	yes, but limited

Pereira Ribeiro, João Marcelo, Sthefanie Aguiar da Silva, Samara da Silva Neiva, Thiago Soares, Carlos Montenegro, André Borchardt Deggau, Wellyngton Silva de Amorim, Celso Lopes de Albuquerque Junior, and José Baltazar Salgueirinho Osório de Andrade Guerra. "A Proposal of a Balanced Scorecard to the Water, Energy and Food Nexus Approach: Brazilian Food Policies in the Context of Sustainable Development Goals." Stochastic Environmental Research and Risk Assessment 35, no. 1 (January 2021): 129–46. https://doi.org/10.1007/s00477-020-01769-1.	mixed methods	cross-sectional data	goal level	SDGs 2, 6, 7, and 13	SDG 6-7 trade-off; SDG 2, 7 and 13 trade-off	country level (Brazil)	yes
Atkin, Martin, and Funnelweb Media, eds. "Inclusive Insurance for a Sustainable Future." Microinsurance Network's Annual Journal, The state of microinsurance: the insider's guide to understanding the sector, no. 4 (2018): 40.	qualitative	cross-sectional data	goal level	SDGs 2, 5, 8 and 13	SDG 5-13 synergy	global level	yes, but limited
Aheeyar, Silva, Senaratna-Sellamuttu, and Arulingam. "Unpacking Barriers to Socially Inclusive Weather Index Insurance: Towards a Framework for Inclusion." Water 11, no. 11 (October 25, 2019): 2235. https://doi.org/10.3390/w11112235.	qualitative	cross-sectional data	goal level	SDGs 2, 5, 10 and 13	SDG 5, 10 and 13 trade-off	regional level (Southeast Asia)	yes
Baumgartner, Rupert J. "Sustainable Development Goals and the Forest Sector—a Complex Relationship." Forests 10, no. 2 (February 11, 2019): 152. https://doi.org/10.3390/f10020152.	mixed methods	cross-sectional data	goal level	SDG 15	trade-offs between SDG 15 and SDGs 1, 3, 4, 6, and 10	global level	no
Nath, Tapan Kumar, Mohammed Jashimuddin, and Makoto Inoue. "Achieving Sustainable Development Goals through Participatory Forest Management: Examples from South-Eastern Bangladesh." Natural Resources Forum 44, no. 4 (November 2020): 353–68. https://doi.org/10.1111/1477-8947.12209.	mixed methods	cross-sectional data	goal level	SDGs 1, 2, 3, 4, 5, 7, 8, 10 and 13	synergy between SDG 15 and SDGs 1, 2, 3, 5 and 10, 7 and 13 mediated through participatory forest management.	country level (south eastern Bangladesh)	yes, but limited
Rasul, Golam. "Managing the Food, Water, and Energy Nexus for Achieving the Sustainable Development Goals in South Asia." Environmental Development 18 (April 2016): 14–25. https://doi.org/10.1016/j.envdev.2015.12.001.	qualitative	cross-sectional data	goal level	SDGs 2, 6, 7, 8, 14, and 15	SDG 2 trade-off with SDGs 6, 7, 8 and 13	regional level (South Asia)	yes
Wada, Yoshihide, Adriano Vinca, Simon Parkinson, Barbara A. Willaarts, Piotr Magnuszewski, Junko Mochizuki, Beatriz Mayor, et al. "Co-Designing Indus Water-Energy-Land Futures." One Earth 1, no. 2 (October 2019): 185–94. https://doi.org/10.1016/j.oneear.2019.10.006.	mixed methods	cross-sectional data	goal level	SDGs 2, 6, 7, 13, and 15	SDG 2-15 synergy; SDG 2-6 trade-off; SDG 2-7 trade-off; SDG 6-12 synergy	regional level (Indus River Basin)	yes, but limited

Samaneh Seifollahi-Aghmiuni, Minnoka Nockrach and Zahra Kalantari. "The Potential of Wetlands in Achieving the Sustainable Development Goals of the 2030 Agenda". Water, 11, no. 609 (March 2019): 1-14. doi:10.3390/w11030609.	mixed methods	cross-sectional data	target level	SDGs 1-3; 6-7; 11-15	Synergetic interactions between SDGs 7.1, 11.B, 14.1, 14.3; 2.4, 3.9, 12.2; 1.5, 6.1, 6.3, 6.4, 6.6, 13.1, 13.2, 15.1, 15.5, 15.A.	country level (Sweden)	yes, but limited
Kate Elizabeth Gannon, Laetitia Pettinotti, Declan Conway, Swenja Surminksi, Edward Ndilanha, Tobias Nyumba. "Delivering the Sustainable Development Goals through development corridors in East Africa: A Q-Methodology approach to imagining development futures". Environmental Science and Policy, 129 (March 2022): 56-67. https://doi.org/10.1016/j.envsci.2021.12.013.	mixed methods	cross-sectional data	target level	All SDGs	SDG14-15 and SDG11-13 trade-offs	country level (Kenya and Tanzania)	yes, but limited
Sunil Prasad Lohani, Bipasyana Dhungana, Harald Horn, Dilip Khatiwada. "Small-scale biogas technology and clean cooking fuel: Assessing the potential and links with SDGs in low-income countries – A case study of Nepal". Sustainable Energy Technologies and Assessments, 46 (May 2021): 1-14. https://doi.org/10.1016/j.seta.2021.101301.	mixed methods	cross-sectional data	goal level	SDG 7	SDG 1-3, 7-8, 15, and 5 synergies mediated through the use of liquified petroleum gas	national level (Nepal)	yes
Bandari, R., Moallemi, E.A., Lester, R.E., Downie, D., Bryan, B.A.; "Prioritising Sustainable Development Goals, characterising interactions, and identifying solutions for local sustainability" Environmental Science and Policy 127, 2022 DOI:10.1016/j.envsci.2021.09.016	qualitative	cross-sectional data	target level	SDG 2, 6, 8, 13 and 15	Authors found 307 interactions, of which 126 (41%) were synergistic, 19 (6%) were trade-offs, and 162 (53%) were benign	country level (Australia)	no
Momblanch, Andrea, Nachiket Kelkar, Gill Braulik, Jagdish Krishnaswamy, and Ian P. Holman. "Exploring Trade-Offs between SDGs for Indus River Dolphin Conservation and Human Water Security in the Regulated Beas River, India." Sustainability Science, October 11, 2021. https://doi.org/10.1007/s11625-021-01026-6.	quantitative	time series data	indicator level	SDGs 2, 6, 7, 11 and 15	synergies: SDG6-12; tradeoffs: SDG 15-7 and SDG 6-15	regional level (Indus River, India)	no
Philippidis, George, Lindsay Shutes, Robert M'Barek, Tévécia Ronzon, Andrzej Tabeau, and Hans van Meijl. "Snakes and Ladders: World Development Pathways' Synergies and Trade-Offs through the Lens of the Sustainable Development Goals." Journal of Cleaner Production 267 (September 2020): 122147. https://doi.org/10.1016/j.jclepro.2020.122147.	quantitative	time series data	target level	SDGs 2, 6, 7, 8, 13 and 15	synergies: SDG 2-15; SDG 15-7; SDG 2-6; SDG 2-13	global level	yes, but limited
Wang, Mengru, Annette B. G. Janssen, Jeanne Bazin, Maryna Strokal, Lin Ma, and Carolien Kroeze. "Accounting for Interactions between Sustainable Development Goals Is Essential for Water Pollution Control in China." Nature Communications 13, no. 1 (December 2022): 730.	qualitative	cross-sectional data	target level	SDGs 6 and 14	319 interactions between SDGs 6 and 14, of which 286 are synergies and 33 are trade-offs	national level (China)	no

https://doi.org/10.1038/s41467-022-28351-3.							
Lusseau, David, and Francesca Mancini. "Income-Based Variation in Sustainable Development Goal Interaction Networks." Nature Sustainability 2, no. 3 (March 2019): 242–47. https://doi.org/10.1038/s41893-019-0231-4.	quantitative	time series data	target levels	all SDGs	SDG 2-6 synergy; SDG 6-15 synergy	global level (focus on low income countries)	yes, but limited
Onah, I., Nyong, A. and Ayuba, K.H. (2021). A case study of improved cookstoves and clean fuel use by selected Nigerian Households. World Development, 142, p.105416.	quantitative	cross sectional data	goal level	SDGs 1,2,4,7,13 and 15	SDG 2-4 synergy; SDG 2-7 synergy	national level (Nigeria)	yes
Zhang, Yuchen, Rebecca K. Runting, Edward L. Webb, David P. Edwards, and L. Roman Carrasco. "Coordinated Intensification to Reconcile the 'Zero Hunger' and 'Life on Land' Sustainable Development Goals." Journal of Environmental Management 284 (April 2021): 112032. https://doi.org/10.1016/j.jenvman.2021.112032.	quantitative	time series data	goal level	SDGs 2 and 15	trade-off between SDG 2 and 15	global level	yes
Taka, M., Ahopelto, L., Fallon, A., Heino, M., Kallio, M., Kinnunen, P., Niva, V. and Varis, O. (2021). The potential of water security in leveraging Agenda 2030. One Earth, 4(2), pp.258–268.	mixed methods	cross-sectional data	goal level	SDG 6	synergy between SDG 6, 3 and 2	global level	yes
Xu, Jiren, Fabrice G. Renaud, and Brian Barrett. "Modelling Land System Evolution and Dynamics of Terrestrial Carbon Stocks in the Luanhe River Basin, China: A Scenario Analysis of Trade-Offs and Synergies between Sustainable Development Goals." Sustainability Science, July 16, 2021. https://doi.org/10.1007/s11625-021-01004-y.	quantitative	cross-sectional data	target level	SDGs 2, 6, 11, 13 and 15	trade-off between SDGs 6, 2 and 11	national level (Luanhe River Basin (LRB), China)	yes

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