THIS IS AN INTRODUCTION TO

***Special Feature*: Exploring Interactions among the Sustainable Development Goals: Case Studies from Three Continents**

ISSN: 1862-4065 (Print) 1862-4057 (Online)

Analysing Interactions among the Sustainable Development Goals: Findings and emerging issues from local and global studies

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Abstract.

The topic of SDG interactions is a relatively new research area with many knowledge gaps. Some of these gaps are addressed in this summary of a *Special Feature* of *Sustainability Science*, including new findings and emerging issues on: 1) the characteristics of SDG interactions; 2) methods/methodology to analyse these interactions; and 3) the elaboration of drivers that influence SDG synergies. The importance of scale is clear in two emerging issues. First, there is evidence of a disconnect between national planning for SDGs and their implementation at the local scale which is leading to SDG trade-offs between these scales. Second, the concept of a "critical transition zone" is introduced where SDG trade-offs pose a particular challenge to SDG implementation. These are areas (e.g. peri-urban and forest margin areas in the Global South) undergoing rapid biophysical and/or socio-economic changes and inhabited by populations especially vulnerable to these changes. While trade-offs occur among the SDGs, there are also many examples of synergies which provide opportunities for advancing multiple goals. To distinguish between synergies and the actions that exploit them, the term "synergy driver" is introduced to refer to policies and measures that positively advance two or more goals. Several examples of synergy drivers are presented, including sustainable global supply chains, people-centred early warning systems, and joint conservation-public health programmes. To make synergy drivers relevant to the broader policy community, the research community (working with stakeholders) should first consolidate knowledge about these drivers and then evaluate their effectiveness/applicability to different policy settings.

Introduction

The Sustainable Development Goals (SDG) are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. Adopted by all UN Member States in 2015 as part of the 2030 Agenda for Sustainable Development, the 17 Goals form a framework for national action and global cooperation for transformative change (UN, 2015). Because the goals were endorsed by every country in the world and have broad coverage, they have the potential to serve as a road map for 'building back better' after the Covid-19 pandemic (OECD 2020).

With just under ten years left to achieve the SDGs, the UN recently declared a "Decade of Action" (2021-30) and pledged to mobilize financing, enhance national implementation and

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strengthen institutions to achieve the goals by the target date of 2030, leaving no one behind (UN, 2019).

The preamble to the goals declares that they are “integrated and indivisible”, but in practice their implementation has focused almost entirely on single goals. For example, the UN’s inventory of multi-stakeholder partnerships to support the SDGs shows that a vast majority of all partnerships focus on individual goals (UN, 2020a). On one hand this “individual goal” approach is understandable since interest groups, government agencies and communities cluster around the topics represented by specific goals, such as water, food, health, or poverty alleviation. On the other hand, this approach neglects opportunities for transformative actions and multi-stakeholder collaborations that would advance more than one goal at the same time. Evidence is accumulating, some presented later in this paper, that some policies and measures advance multiple goals. Indeed, an alternative way of implementing the SDGs would be to take an “integrative approach” which would minimise “trade-offs” and promote “synergies” among the goals. Support for an integrative approach to the SDGs has been expressed in many political declarations (UN, 2019; UN, 2020b), academic papers (Sachs, et al., 2019; Le Blanc, 2015), and is promoted by an OECD-initiated partnership for “Policy Coherence for Sustainable Development” (OECD, 2019). In particular, as national income decreases as an outcome of the Covid-19 crisis, an integrative approach to the SDGs has the potential to be a cost-effective way for countries to advance many SDGs simultaneously.

Although there is a growing body of literature around the concepts of SDG interactions and an integrative approach to the SDGs (e.g. Breuer, et al., 2019; Scharlemann, et al., 2020) the study of SDG interactions is still a relatively new area of research with many knowledge gaps. The objective of this *Special Feature* of *Sustainability Science* is to reduce this gap by providing findings and emerging issues about three key topics: 1) characteristics of SDG interactions; 2) methods/methodology to detect and analyse SDG interactions; and 3) the elaboration of drivers that influence SDG synergies. Six of the ten papers in this *Special Feature* have a place-based perspective and provide empirical evidence from case studies in several countries in the Global South, plus the United Kingdom. Four of the papers have a global/international perspective.

The common focus of these papers is on interactions among the SDGs, in particular trade-offs and synergies. A “trade-off” is defined here as a condition by which an action to achieve one goal or target makes it more difficult to achieve one or more other goals or underlying targets; a “synergy” is a condition by which an action to achieve one goal helps achieve one or more other goals or targets.

1. Characteristics of SDG Interactions

1.1 Critical transition zones for SDG interactions

A main assertion coming from studies of SDGs is that they are “context specific”, i.e. to achieve the goals it is advisable to take into account the social, political and environmental circumstances at particular locations (Oliveira, et al. 2020; Weitz, et al. 2018). This raises the question, are there specific types of locales where SDG interactions are particularly important for their implementation? Research in this *Special Feature* provides two possible examples of such locales, peri-urban areas and forest margins.

The areas surrounding cities, “peri-urban areas”, contain about one-third of the world’s cropland (assuming a 10 km buffer around cities; Nicholls et al. 2020) and are therefore very relevant to SDG 2 (end hunger). These areas are also undergoing rapid biophysical and/or socio-economic changes because of the continuing rapid expansion of cities, especially in Africa and Asia (UN DESA, 2018). This threatens not only agricultural land and other ecosystem services in these areas (Marshall et al., 2018; Dolley et al., 2020) but also their large

vulnerable populations. These include, for example, migrant farmers in Wuhan's peri-urban region (Dolley et al., 2020). The pressure of urbanisation and the mixture of rapid physical change and vulnerable populations leads to important trade-offs among the SDGs, especially among those related to food production (SDG 2), urban development (SDG 11), poverty alleviation (SDG1) and protecting terrestrial ecosystems (SDG 15). Marshall (2016) also classifies peri-urban areas as "sustainability frontiers" because they are "hot spots of social learning and innovation, as well as frontiers of transition and social transformation" with considerable potential to realize synergies between apparently conflicting urban development priorities (Marshall and Dolley, 2019).

Many tropical forest margin areas are also undergoing rapid change which is eroding social-ecological resilience at the local and global levels, and threatening the livelihoods and culture of local and indigenous inhabitants of these areas (Rodrigues, et al., 2009; Rasmussen, et al., 2017). In the year spanning 2018-19, development destroyed in excess of 9700 km^2 of the rainforest in the Brazilian Amazon, an increase of 30% over the previous year (Escobar, 2019). Delabre et al. (2019) describe injustices that arise in Brazil from differing interpretations of 'sustainability' by various multi-stakeholder initiatives. Menton et al (2020) describe the conflicts and environmental injustices that often arise in these regions due to expansion of extractive industries and large-scale agriculture (see also below). In sum, these studies articulate trade-offs occurring between economic growth (SDG 8), forest conservation (SDG 15), and the rights of local communities and indigenous peoples living in these areas (SDGs 3 and 10).

We propose that peri-urban and forest margin areas are members of a class of locations particularly relevant to SDG implementation which we call "critical transition zones". We define such a zone as a category of land (continental, coastal or island) on which biophysical and/or socio-economic changes are rapid relative to surrounding areas, and which have inhabitants particularly vulnerable to social or environmental impacts associated with the changes. This concept could also be expanded to cover non-settled areas where ecosystems are undergoing rapid change and at particular risk. Critical transition zones could therefore include not only sensitive terrestrial areas, but also aquatic and cryosphere settings.

We propose that these locations in the Global South merit special attention in the policy arena because of the intersection of rapid change and vulnerable populations (e.g. farm migrants in peri-urban areas, indigenous peoples in forest margins) coupled with degradation or loss of natural environments which creates barriers to achieving the SDGs. Trade-offs in these areas will have a particular impact on vulnerable social groups.

To further develop the concept of critical transition zones the research community should next work with stakeholders to develop criteria for these areas, and then use these criteria to compile an inventory of these zones. These data should then be conveyed to the policy arena.

Criteria are needed for the two aspects of critical transition zones – "rapid rates of change" and "vulnerable people". Possible criteria for "rapid rates of change" could be critically high rates of land use change, number of vulnerable people displaced, or number of vulnerable people losing livelihoods. All of these would be defined per unit area and time. The question arises, for a particular location, which of these metrics is most suitable, and what is "critically high"? A simple criterion for "vulnerable population" could be income level, but this neglects other important, locale-specific factors identified in the literature such as gender, age, livelihood situation, power relations, and type of threat (e.g. Thomas et al., 2019; Akmam et al., 2020). A preliminary conclusion is that criteria for both "rapid rates of change" and "vulnerable people" are best selected by considering local and national contexts and by working with stakeholders.

1.2 Closing the gap between national SDG planning and local implementation

Although responsibility for implementing the SDGs lies with national governments, the implementation itself takes place in local communities, businesses, and schools throughout each country. Of concern, recent research has provided examples of a gap between national planning for SDGs and local implementation of the goals.

- In Tanzania, there is evidence that national policies to boost food production through commercialisation of agriculture are resulting in the development of arable land by commercial operators at the expense of most local smallholder farmers (Newell et al. 2019). Although smallholders produce a third of the world's food supply and disproportionately more in sub-Saharan Africa (Ricciardi et al. 2018) they are still underrepresented in national planning. In terms of the global goals, this leads to tensions and trade-offs between the national planning for SDG 2 (end hunger) and local realisation of SDG 8 (decent work) and SDG 10 (reduced inequalities). An important dynamic here are the power relationships between different social groups (Newell et al. 2019).

- There is evidence from Kenya that local groups most affected by national plans for introducing "climate-smart agriculture" (smallholder farmers, fisher communities, pastoralists) (SDGs 2 and 13) are not engaged in national decision-making processes about how to implement this type of agriculture in their communities (Newell, et al. 2018).

- In Ecuador, research has shown that national policies to advance economic growth (SDG 8) via increased oil extraction have caused environmental degradation and health impacts near extraction sites that harm poor and indigenous people. Furthermore, oil extraction has not markedly improved their economic condition (Menton, et al. 2020; Larrea, et al. 2020). As a result, striving to achieve SDG 8 (economic growth) at the national and international levels is making it more difficult to achieve SDG 3 (good health) and SDG 15 (life on land) at the local level, sometimes leading to violence (see below).

These are not isolated examples but symptomatic of a widespread disconnect between national SDG planning and its local implementation. For example, as of 2019, only 42% of national governments gave local or regional governments an active role in preparing the voluntary national reviews of the SDGs (Lieberman, 2019).

On the positive side, there are cases in which national governments have worked successfully with local stakeholders to help implement the goals. For instance, the Australian government in the context of the SDGs has supported a major greening programme in the city of Melbourne, as well as school nutrition projects in the Northern Territory aimed at "improving school attendance and local Aboriginal and Torres Strait Islander employment through the provision of healthy meals to students on school days" (Australian government, 2018). Meanwhile, the German Federal Ministry for Economic Cooperation and Development has provided support to the city of Bonn for developing a municipal sustainability strategy to "localise" the SDGs. This strategy will help the city provide affordable housing, develop sustainable transport, and maintain its green areas (OECD, 2020). More examples of "vertical coordination to align local, regional, national and global priorities" are given in OECD (2020).

Further case studies and surveys would help clarify the extent of national-local disconnects, and conversely, the progress being made to coordinate national SDG planning with local SDG implementation.

The more serious examples of national-local disconnects can lead to environmental and social injustice. Dolley et al (2020) found trade-offs between the benefits of urbanisation to a wider

population and the negative impacts of displacement on migrant farmers in peri-urban areas in Wuhan, China (see below). As Orchard et al. (2020) highlight, efforts to increase income and food production through agricultural intensification (SDG 1 and 2) can lead to loss of socio-ecological resilience in households.

In some cases, support for extractive industries and large-scale agriculture (SDGs 2 and 8) are linked to violence against local communities and indigenous peoples, including murders of environmental and land defenders and other physical and structural violence (Menton et al. 2020). Butt et al. (2019) found that killings of environmental defenders were highest in countries with weak rule-of-law and high levels of corruption. In a global study of 2743 cases of environmental conflicts, Scheidel et al. (2020) found high rates of criminalisation of activists (20%) and physical violence against them (18%).

The prevalence of environmental, land and resource conflicts, and the consequent social and environmental injustices and violence experienced by marginalised and vulnerable communities, highlights the importance of rights-based approaches to the SDGs and the role of governance (SDG16) in mitigating these injustices (Menton et al 2020).

2. Different entry points, different methods to explore SDG interactions

To be relevant to the national policy arena and implementation of the SDGs, researchers must be able to identify and prioritise SDG interactions. Yet this is a non-trivial task since there are over 10,000 pairwise combinations of the 169 SDG targets, with a much larger number if three-way or higher-level interactions are included.[2]

Several frameworks have been developed to identify and prioritise SDG interactions, but the research community has not converged upon a single method or methodology. Each approach has its advantages and limitations, and there is an ongoing need for methodological development. The SDG Conceptual Network Diagrams developed at the UN Department of Economic and Social Affairs (Le Blanc, 2015) is useful for identifying targets that are central nodes in a network of SDGs, but the framework is qualitative and does not provide the means to quantify or interrogate the importance or nature of the trade-offs and synergies. The Framework for Understanding SDG Interactions created by the International Science Council (ICSU, 2017) provides insight into the intensity and direction of relationships between SDGs but is reliant upon expert judgement. The SDG Interlinkages Analysis and Visualisation Tool devised by the Institute for Global Environmental Strategies (IGES) (Zhou, et al., 2019; Zhou, et al., 2017) is quantitative in nature, and visually maps and assigns strengths to linkages between SDGs. However, the IGES tool does not simulate specific policies over the SDG time horizon, and therefore cannot be used to assess synergies associated with different policy mixes. A review of methods is given by Scharlemann et al. (2020) and Breuer et al. (2019).

One way to simplify the task of identifying and prioritising interactions is to select a specific "entry point" to the interactions and to focus on connections specific to this entry point. For

[2] The general formula for computing the number of combinations in a set without repetition is $C(n,r) = \frac{n!}{k!(n-k)!}$ where *n* is the set size, and *k* the sample set. The "!" symbol denotes a factorial. To calculate the total number of unique pairwise combinations in the entire set of SDG targets, *n* = number of targets = 169 and *k* = 2 for *pairwise* combinations of targets. Therefore $C(n,r)$ = 14,196. For combinations of three targets, k = 3, and $C(n,r)$ = 790,244.

example, Alcamo (2019) uses water quality as an entry point to SDG interactions and identified the interlinkages of the SDG water quality target with other SDG targets. This approach limits the number of interactions to a manageable number and provides substantive information about where joint actions could achieve multiple SDGs. However, the "single entry point" approach may not provide the data needed in a particular policy setting. For example, it will not indicate the most important interactions among the entire set of SDGs.

The body of research presented in this *Special Feature* highlights numerous entry points, and here we present three examples: 1) human-environment interactions; 2) poverty alleviation; and 3) peri-urban agriculture. For each of these the authors use a different method for analysing SDG interactions, with new methodological elements. In the first example, Scharlemann (2020) et al. apply an "influence matrix" in a unique fashion to identify the importance of SDG interactions through the lens of human-environment interlinkages. In the second, Antoniades et al. (2019) present a new application of econometrics to identify the relationships between the SDG on poverty alleviation with other SDGs. In the last example, Dolley et al. (2020) present a new web-based GIS tool to examine SDG trade-offs spatially.

2.1 Environment-human interlinkages as entry point and influence matrix as method

Several authors have used an "influence matrix" or conceptually similar methods to identify priority SDGs interactions. For example, matrices have been used to investigate SDG interactions for different geographic areas (e.g. Allen et al., 2019) and subsets of goals (e.g. Weitz et al., 2018).

In this *Special Feature*, Scharlemann et al. (2020) use an influence matrix to examine pairwise interactions among 16 goals (excluding the "enabling" SDG 17). They investigate two aspects of SDG interactions: 1) The degree to which an action to achieve one goal (e.g. research, innovation, policy, management) influences the achievement of other goals; and 2) How deliberately taking a particular perspective (geographic, political, temporal, sectoral or social group) influences SDG interactions (interdependencies, co-benefits and trade-offs). For their particular application they use "environment-human interlinkages" as an entry point and show that the environment is integral to almost all goals (13 SDGs and 62 out of 150 SDG targets mention environmental-related words) and identify 20 pairwise goal interactions where environment-human interlinkages may be most influential.

This approach provides a useful tool to guide decision making in practice because it focusses on actions and allows consideration of different sectoral perspectives. Comparing influence matrix assessments on SDG interactions conducted from multiple perspectives will explicitly highlight the potential influences of a decision made in one sector on other sectors, encouraging cooperation across sectors to achieve multiple goals.

Table 1: Characteristics of three methods presented in the *Special Feature* to identify and prioritise SDG interactions

Method	**Level of external data requirements**	**Level of expert judgement**	**Interactive?**	**Spatially explicit results?**	**Application presented in *Special Feature***	**Reference from *Special Feature***
Influence matrix	low	high	yes	No, but can be applied at various spatial scales, village – country-global	Identifying opportunities for linking environmental policies and measures with other sectors for advancing multiple SDGs.	Scharlemann et al. 2020
Econometrics	medium	low-medium	no	no	Estimating how changing economic conditions affect interactions between the poverty goal and other SDGs	Antoniades et al. 2019
Web-based GIS tool	high	medium	yes	yes	Investigating impacts of land use changes on SDG interactions	Dolley et al. 2020

2.2 Poverty alleviation as entry point and econometrics as method

Human-environment interlinkages, as discussed above, are only one of the many entry points for investigating SDG interactions. Another important entry point is poverty alleviation, declared by Signatories of the SDGs (UN, 2015) as “the greatest global challenge”. Using this as an entry point, Antoniades et al. (2019) estimate the impact of financial distress on multidimensional poverty dynamics in the context of SDG implementation, which provides new information about the interlinkages between SDG 1 (no poverty) and other SDGs.

Their approach was to use econometrics to investigate how more than 400 international financial crises since 1980 have simultaneously affected SDG indicators for poverty and related variables. Antoniades et al. found that episodes of financial distress, as currently experienced in many Global South countries, are associated with an increase in the poverty headcount and the poverty gap, a decrease in access to basic sanitation (SDG 6), a decrease in access to electricity (SDG 7), an increase in maternal mortality (SDG 3), an increase in particulate pollution (SDGs 3 and 11), a higher number of children out of school and a decrease in the education expenditure (SDG 4). In addition they are associated with an increase in CO_2 from forest removals and forest rents (SDG 13), and a decrease in terrestrial land protection (SDG 15). The impact is stronger on low income countries and there are particularly strong negative feedback loops between income poverty and education. Financial crises had a deleterious effect on both government policies (a 27.5% average reduction of global education expenditures) and directly on households (children out of school at primary school age). This is of critical relevance to attaining the SDGs since a lack of education locks countries and individuals into a vicious cycle of poverty.

With regards to solutions, Antoniades et al. note that the high level of debt of some low-income countries is a barrier to meeting SDG targets. The authors note that if wealthier countries were to “assist developing countries in attaining long-term debt sustainability through coordinated

policies", as called for in SDG target 17.4, poor countries would have substantially greater resources to invest in poverty alleviation.

2.3 Peri-urban food production as entry point and spatial analysis as method

The preceding examples of methods to evaluate SDG interactions are not spatially-explicit. But Dolley et al. (2020) show with an example from Wuhan, China (see below) that spatial analysis has the potential to provide unique data for analysing SDG trade-offs and synergies that occur between different locations.

Intensive vegetable production in the peri-urban areas of Wuhan provide a significant fraction of the fresh produce consumed by the city's population and essential livelihoods to the migrant farmers who make up a large proportion of farmers in this area. But land here is being converted to infrastructure uses and greater economic activity at the expense of vegetable farming and its benefits. To correctly assess the scale of these potential trade-offs it is necessary to take into account the spatial location of new infrastructure relative to population, farming areas, and sensitive natural areas. Hence, the value of spatial analysis. Based on this thinking, Dolley et al. (2020) developed a new interactive web-based GIS tool with the aim to visualise trade-offs related to SDGs that play out spatially for different land use changes in a peri-urban setting. Their approach combines high resolution, top-down remote sensing data with bottom-up knowledge and diverse stakeholder perspectives. Making the tool web-based gives stakeholders an opportunity to use it interactively, e.g. to customise land use classes or to specify the value of different land use changes (see below).

Dolley et al. (2020) tested and applied the tool to a peri-urban district of Wuhan, using it to assess the loss of vegetable farms and other land uses resulting from new housing and industrial development. They demonstrated how users (e.g. stakeholders) of the tool can assign positive or negative values to different changes in land use. This allows users to quantify the trade-offs between gains in economic activity associated with the new infrastructure (SDG target 8.2) and losses of specific vegetable growing areas together with their knock-on effects on food production and food safety (SDG target 2.1) and displacement of farmers and their livelihoods (SDG target 10.7). Hence, this spatial approach provides both visual and quantitative data for assessing SDG interactions in a policy setting and can incorporate stakeholder views.

Comparing Methods

In comparing the method of Dolley et al. (2020) with the two methods described earlier (Table 1), the web-based GIS tool probably has the largest external data requirements. Although the econometrics approach used by Antoniades et al. (2019) also requires a substantial amount of time series data, it does not need the spatial resolution of data used by the GIS tool (therefore the external data requirements of the econometrics approach are set at "medium" in Table 1). The SDG influence matrix, as applied by Scharlemann et al. (2020), uses expert judgement for ranking the importance of SDG interactions whereas the other methods use statistical methods. All three methods use expert judgement to decide on which variables are to be included in the analyses.

Both the influence matrix and web-based GIS tool are partly interactive. With the influence matrix, experts can specify values and apply various perspectives. With the web-based GIS tool, stakeholders can intervene in ways described above. In the econometrics approach, once the data to be used are specified, it cannot be said to be "interactive" in the same way.

As noted above, the web-based GIS tool produces spatial data which have certain advantages in SDG trade-off analysis. The other methods do not produce spatially-explicit results, although influence matrices can be prepared, and compared, at multiple spatial (and temporal) scales from local to national to global.

With their unique characteristics the three methods have been applied to different issues associated with SDG interactions (Table 1) and are likely to have potential applications in other settings. Also, these methods are not mutually exclusive, but it is expected that they can be used in combination or with other methods to investigate SDG synergies and trade-offs. For example, constructing an influence matrix can help identify the GIS layers to be included in a spatially-explicit assessment.

3. Synergy Drivers

Here we briefly review results about synergies from the *Special Feature* and introduce the idea of synergy drivers as a vehicle for applying synergies in the policy arena.

Several authors have estimated that synergies occur more frequently than trade-offs among SDGs (Donoghue and Khan 2019; Langou, et al., 2020; Weitz, et al., 2018) which is a promising result for an integrative approach to the SDGs. But there has been less research on how to actually exploit synergies in the policy sphere and how to advance multiple goals on a practical basis. There has also been a lack of clarity as to the difference between "synergies", which are relationships among goals, and actions that take advantage of these synergies. Typical approaches to studying SDG interactions, such as influence matrices and statistical analyses of historical indicators, are very valuable in identifying the state of relationships between SDGs, but do not necessarily provide information about the effectiveness of actions to exploit the goals.

To distinguish between "synergies" and the actions that exploit these synergies, the term "synergy driver" is introduced here. We define "synergy driver" as a policy or measure carried out locally, nationally, or internationally that helps achieve two or more SDGs at the same time by capitalising on the positive interconnections among the goals. (We use "policies and measures" in the sense it is used by the UN and other international institutions.[3]) By advancing multiple goals at the same time, synergy drivers have the potential to save resources in achieving the SDGs by harmonising, coordinating, or combining efforts to achieve the different SDGs. (Farhan and Niaz, 2016; Alcamo et al. 2018).

Papers in the *Special Feature*, or from authors conducting research associated with it, contain several examples of synergy drivers:

- In peri-urban areas in India and the UK there is evidence that **sustainable agricultural practices** can promote not only the goal for ending hunger (SDG 2), but also goals for poverty (SDG 1), health (SDG 3), land biodiversity (SDG 15) and sustainable cities (SDG 11) (Marshall et al., 2018; Marshall and Randhawa, 2017; Nicholls et al. 2020). Evidence

[3] "Policies … refer to objectives, together with the means of implementation … Measures can be individual interventions or they can consist of packages of related measures. Specific measures might include actions that promote the chosen policy direction, such as implementing an irrigation project …" (UNDP, 2004, p. 249)

"A policy is commonly understood as the overarching framework to achieve certain objectives, which sets the overarching frame for actions. A policy may include several measures. Examples are: Renewable Energy Strategy, Green Fund … A measure is commonly understood as concrete actions undertaken to implement a certain policy. A measure is more concrete than a policy. Examples are: Introduction of a carbon tax, insulation of buildings…" (EEA, 2019, pp. 55-56).

from peri-urban areas as widely-separated as Wuhan in China (Dolley et al. 2020) and Brighton in the UK (Nicholl et al. 2020) indicate that peri-urban farms, owing to their proximity to urban markets, provide a disproportionate amount of high-nutrition fresh fruits and vegetables to nearby city dwellers. In addition, sustainable agricultural practices in peri-urban areas contribute to climate resilience (SDG 13) by reducing the physical exposure to floods and droughts and minimizing climate change risks through increased socio-economic resilience to hazard impacts and provision of a carbon sequestration function. (Mngumi, 2020).

Table 2. Examples of "synergy drivers" from the *Special Feature*.

Synergy driver	**Reference from *Special Feature* or associated literature explaining synergy driver in context of SDG interactions**	**SDGs positively influenced by synergy driver. See text for explanation.**
Sustainable agriculture applications to peri-urban areas	Marshall and Randhawa, 2017; Marshall et al., 2018; Nicholls et al. 2020.	SDGs 1, 2, 3, 11, 13, 15
Sustainable nutrient management (an element of sustainable agriculture)	Alcamo, 2019	SDGs 2, 3, 6, 13, 14
Sustainable supply chain management	Alexander and Delabre, 2019	SDGs 8, 12, 13, 14, 15, 16, 17
Jurisdictional approach to integrated landscape development	Delabre et al. (2019)	SDGs 2, 15, 16
Integrated conservation and health programmes	Middleton et al. (2020)	SDGs 3, 5, 14, 15
Sustainability assessment reports in trade agreements	Amos and Lydgate (2019); Lydgate and Amos (2020)	SDG 6, 8, 13, 14, 15
People-centered early warning systems for agriculture and fisheries	Martin and Osella, 2019; Wilkinson et al., 2018	SDGs 2, 8, 13

- **Sustainable nutrient management** is a specific example of a sustainable agricultural practice and has a high potential for reducing the runoff of nitrogen from cropping and livestock areas which is causing local and coastal water pollution. In this way it helps achieve targets for reducing freshwater pollution (SDG 6) and marine pollution (SDG 14). Moreover, it reduces nitrate levels in water supplies, helping to achieve health objectives (SDG 3). Sustainable nutrient management also frequently increases crop yields (SDG 2), and reduces emissions of the greenhouse gas nitrous oxide, helping to achieve the climate goal (SDG 13). (Alcamo, 2019; UNEP, 2013).
- **Sustainable supply chain management** is an approach to ensure transparency of international supply chain operations and support corporate social responsibility. It aims to honour the rights of local and indigenous communities, protect worker's rights and safety, and reduce or avoid the carbon footprint and other environmental impacts of the supply chain including deforestation. In forest margin areas of Brazil, Ecuador and elsewhere sustainable supply chain management has the potential to advance the SDGs for decent work (SDG 8), social justice (SDG 16), and land biodiversity (SDG 15), and enhance international partnerships (SDG 17). (Alexander and Delabre, 2019). Furthermore, transforming the management of supply chains has been shown to contribute to better use of materials and resources (SDG 12) (Yagi and Kokubu, 2020), significantly deliver climate

benefits (SDG 13) (Campbell, et al., 2018), and help improve fisheries management (SDG 14) (Zelasney, et al., 2020).

- **Jurisdictional approaches to landscape development** have been applied in Brazil and elsewhere and are broadly defined as "…frameworks that seek to align governments, businesses, NGOs, and local stakeholders in specific administrative jurisdictions around common interests in land use governance" (Brandao, et al. 2020). They are synergy drivers in the sense that they support sustainable agriculture (SDG 2), forest conservation (SDG 15) and help to "develop effective, accountable and transparent institutions at all levels" as well as other targets of SDG 16 (Delabre et al., 2019).
- In Papua New Guinea and elsewhere **integrated forest conservation and health programmes** have been organised in low income villages in deforestation zones. These projects have the potential to support both the health (SDG 3) and land biodiversity (SDG 15) goals, as well as improving access of women to reproductive and sexual health services (an SDG 5 gender equality target). (Middleton et al. 2020).
- In the UK and elsewhere, researchers have found that international trade agreements are leading to major trade-offs among the SDGs (Amos and Lydgate, 2019). To counter these trade-offs, it has been proposed to **embed Sustainability Assessments into existing and new trade agreements.** This can be an effective policy to support greater compliance with the decent work and economic growth aspects of SDG 8, and help advance the goals for clean water (SDG 6), climate (SDG 13), marine protection (SDG 14), and biodiversity (SDG 15). (Amos and Lydgate, 2019; Lydgate and Amos, 2020).
- In farming communities in Kenya and fisher communities in South India, research has found that **"people-centered early warning systems"** for extreme weather events (national early warning systems tuned to the needs of specific communities and locales) can help these communities adapt to extreme weather conditions related to climate variability (SDG 13), as well as protect their livelihoods (SDG 8). Consequently, these early warning systems also increase the food security of farmers and fishers and the communities they provide food for (SDG 2). (Martin and Osella, 2019; Wilkinson et al., 2018).

This list of synergy drivers is significant because it shows that specific actions exist to advance multiple SDGs and that they arise in many different local settings and policy contexts around the world. This list also illustrates their diversity, showing that some drivers are policies (e.g. embedding sustainability assessments in new trade agreements) while others are socio-technical measures (e.g. sustainable agriculture). Some synergy drivers are a combination of the two (e.g. integrated conservation and health programmes). Some have a local focus (e.g. people-centred early warning systems) whereas others have a national or global focus (e.g. sustainable supply chain management). Clearly, to make synergy drivers relevant to the broader policy community two major tasks are necessary:

First, knowledge about synergy drivers should be consolidated. This includes compiling and categorising these drivers and building up a publicly available evidence base of their performance. For example, in this issue, Middleton et al. (2020) note the inadequacy of the published evidence base to support the scaling up of integrated conservation and health programmes.

Second, the effectiveness of synergy drivers must be evaluated. This has two aspects – evaluating their applicability to specific geographic and sectoral settings; and assessing the degree to which they can be scaled up and applied to many different settings.

The evaluation of synergy drivers should address the following issues:

- ***Applicability to location*.** To which location and circumstance is a particular synergy driver applicable? For some approaches, e.g. integrated forest conservation and health

programmes, the target location (forests) is clear, but this is not the case for all synergy drivers.

- ***Added value of integrated vs. individual goal approach***. How effective is a synergy driver in advancing several SDGs as compared to advancing the goals individually? For example, to what degree can sustainable agricultural practices in peri-urban areas contribute to the national or local implementation of goals for food production, conservation of biodiversity, and livelihoods of vulnerable farmers as opposed to alternative actions to address these goals individually?

- ***SDG priorities.*** Which synergy driver is relevant to local-national SDG priorities? These priorities are likely to vary substantially between locales and countries. For example, a survey of 34 African countries indicated agreement among most countries on their first priority (SDG 8, decent work and economic growth), but wide disagreement on second and third priorities (Coulibaly et al., 2018)

- ***Costs vs. benefits.*** What are the costs vs. benefits of implementing the synergy driver? In deciding on a particular policy or measure, decision makers usually assess costs and benefits, either formally or informally. Costs could include conventional costs of labour and materials to implement a policy or measure. For benefits, one criterion could be the extent to which a synergy driver improves the wellbeing of the most vulnerable social groups, in line with the intent of Agenda 2030 to "Leave no one behind". Another could be the number of people, or area of land or marine area, or area of sensitive ecosystem, positively affected by the synergy driver.

- ***Metrics for evaluation.*** What metrics should be used for assessing synergy drivers? One option is to use the official set of indicators used by countries to track their progress in reaching the SDGs (IAEG-SDGs, 2020). In an example mentioned earlier, Antoniades et al. (2019) used several SDG indicators including poverty headcount, access to safe drinking water, and terrestrial protected areas, in their analysis of SDG interactions.

Finally, considering that 2030, the target year for SDGs, is fast approaching and that it usually takes several years to translate research results into policy action, it is urgent to address the preceding questions as quickly as possible.

To accelerate this process, these tasks could be partly accomplished by expert-stakeholder workshops organised by academia, national governments, the UN or as a collaboration between these and other actors. Because synergy drivers encompass so many different disciplines, these workshops should be organised in an interdisciplinary fashion and the organisers should anticipate the difficulties of carrying out interdisciplinary research (Cairns et al., 2020). Ultimately, the workshops could also be vehicles for conveying results quickly to policy fora.

Concluding Remarks

While there is political support for an integrative approach to the SDGs and a growing body of literature on the goals, many gaps remain in our understanding of the dynamic interactions among the SDGs and how these may cause trade-offs or foster new synergies. This *Special Feature* helps fill in a few of these important knowledge gaps.

Carrying out multiple place-based case studies in several countries in Latin America, Africa, and Asia (as well as the UK) has provided data for comparing findings from diverse settings. It has yielded insights that could have been overlooked in a national study or single case study.

For example, we have identified two emerging issues that have an important place-based aspect. First, evidence from case studies in Latin America and Africa indicates a disconnect at some locations between national planning for SDGs and their implementation at the local

scale which is leading to SDG trade-offs between these scales. Second, case studies in Latin America and Asia have suggested the occurrence of “critical transition zones” that pose particular challenges to SDG implementation. Peri-urban and forest margin areas in the Global South are proposed as two examples of these zones.

Both issues merit attention from policymakers and stakeholders. An inventory of critical transition zones might provide useful input to the setting of priority areas for SDG implementation. Meanwhile, the disconnect between national planning and local implementation can be addressed by engaging local stakeholders more directly in national decision-making processes. We recognise, however, that this is a complex process that requires careful preparation and sensitivity to contending actors and interests.

There are also many gaps in methodologies to identify and prioritise SDG interactions. The three methods presented herein show the diversity of methods that can be useful in investigating SDG interactions. One of the three showed that spatial analysis of land use change has the potential to provide an entirely new perspective on trade-offs and synergies among the SDGs.

Finally, the recent Covid-19 pandemic and its impact on all 17 SDGs has shown that what began as a health crisis has quickly become a global socio-economic and environmental crisis. (Although levels of greenhouse gases and other pollutants have temporarily decreased during the pandemic, there is early evidence that environmental pollution is returning to earlier or higher levels; Gardiner, 2020. However, there are also many efforts underway to “build back better” which may lead to a greater emphasis on sustainability in public policy).

Since this crisis endangers progress towards the SDGs, a transformative recovery from Covid-19 is needed, and one that mitigates the current pandemic, reduces risks from future potential crises, and relaunches the implementation efforts to deliver the SDGs during the UN Decade of Action. Given this background, an integrative approach to the SDGs is more relevant than ever; in the ensuing economic downturn, countries will face significant resource constraints which will limit their capacity to implement the SDGs effectively. This increases the attractiveness of finding new efficiencies and “making the most of the least” by exploiting synergistic interactions among SDG goals and targets.

It is time, therefore, to clarify and act on the concepts around SDG synergies. In order to distinguish between “synergies” and the actions that exploit them, we have introduced the term “synergy driver” to refer to policies and measures that advance two or more goals. Countries will now ask, *"Which synergy drivers save resources for implementing the SDGs? In which contexts and at what geographic levels will they work?“* These and other related questions should be high on the agenda of researchers working on SDG interactions, and the community of policy makers and practitioners seeking to make the most of this research.

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* Part of the *Special Feature* of *Sustainability Science* on "Exploring Interactions among the Sustainable Development Goals: Case Studies from Three Continents"