The use of computer-based tools to support policy coherence and systemic thinking in the implementation of the 2030 Agenda: experiences with the SDG Synergies tool in Colombia

Abstract:

SDG implementation requires systemic thinking and actions that harness synergies and minimise trade-offs. Approaches and tools are needed to support more systemic thinking and to facilitate the understanding of complex and interconnected issues. The SDG Synergies tool is based on a decision-support approach designed to guide priority-setting and policy coherence amongst key stakeholders. It aims to support decision-making processes that deal with multiple and often interlinked targets, such as with the SDGs. The methodology uses cross-impact analysis and a 7 point-scale to score interactions – the most positive linkages are scored as +3, while the most negative are -3. This scoring allows to identify trade-offs and synergies. Scoring is accompanied by a network analysis that helps to identify second-order interactions and clusters. The SDG Synergies tool, developed by SEI Latin America, speeds up this process, as it provides a user-friendly interface and allows the scoring of interactions in an online matrix – the web platform then creates graphics that enable a quick visualisation of results. The tool enables time-efficient analysis to support decision-making and systemic thinking in a learning-by-doing way. This paper present the results of applying the SDG Synergies tool with a broad set of stakeholders in two case studies in Colombia. It propose a discussion about the implications of using web-based tools in promoting policy coherence and in fostering systemic thinking amongst stakeholders, along with ideas for future tool development and uses.

Keywords: synergies, interactions, tools, policy coherence, system thinking, decision making

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1. Introduction

The Sustainable Development Goals (SDGs), were adopted in September 2015 by the United Nations General Assembly to address the significant socio-environmental challenges the world faces (UN, 2015). The SDGs are to be met by 2030, and they are the policy compass that will direct the development strategies for many countries during the next decade. The 2030 Agenda is a follow-up to the Millennium Development Goals (MDGs), and, in this way, it represents a continuation of the global effort to achieve sustainable development through the articulation of environmental, social, and economic policy targets. However, the 2030 Agenda contains more objectives and covers a broader range of issues than the MDGs, which only included 8 goals and 21 targets (UN, 2000). Moreover, the SDGs were designed as an “integrated and indivisible” set, where every goal is to be met equally if sustainable development is to be attained (UN, 2015). This complexity signifies a higher level of difficulty for policymaking, as the implementation of the agenda must take into account the possible interactions that occur between the various policy outcomes of the SDGs. The existence of these interlinkages means that progress or hindrance in one SDG will affect every other target through systemic interactions – some targets being affected negatively, producing trade-offs, while others positively, creating synergies (Weitz, Carlsen, Nillson, & Skanberg, 2018).

Most countries have begun to implement the SDGs in their national development strategies (UN, 2019), with governments and decision-makers recognising the need to use science-based approaches for the governance of interlinkages (Nillson, Stevance, & McCollum, 2017). At the same time, the international community has recognised that national institutions need support to be better equipped to address interlinkages, synergies and trade-offs between the Goals and targets (UN, 2019). Therefore, there is still a need to apply methods that help identify the different interlinkages among and within countries (Allen, Metternicht, & Weidmann, 2018). This is a challenging endeavour, as the nature of these policy interactions differs between geographical contexts and scales, and the interlinkages exist in particular political and institutional arrangements that entail different budgets, objectives and interests (Nilsson & Weitz, 2019).

Much of the academic discussion regarding the integrated implementation of the SDGs has focused on how to facilitate the analysis of interlinkages in order to support decision-making for policy coherence (for detailed discussions about policy coherence and the SDGs, see Smith-Stafford, et al., 2017; Collste, Pedercini, & Coronell, 2017; Weitz, Carlsen, Nillson, & Skanberg, 2018). In this sense, there is an ongoing debate regarding the methods that should be used in identifying these connections, including qualitative/subjective approaches, quantitative methodologies, or a combination of both (for a detailed state-of-the-art of SDG interaction methodologies, see Bennich, Weitz, & Carlsen, 2020). In addition, online decision-support tools developed by research groups can display SDG connections. For example, the Institute for Global Environmental Strategies’s “SDG Interlinkages Analyisis & Visualisation tool” (IGES, 2019), which shows synergies and trade-offs between SDG targets for various Asian countries, based on correlations between national development indicators. The European Commission’s “KnowSDGS platform” (European Comission, 2019), displaying the interlinkages identified on reviewed literature. And the UN Environment Management Group’s “Nexus Dialogues Visualization Tool” (UN EMG, 2019), where a group of experts discussed and assessed interactions between SDGs in the context of global environmental issues. However, none of these tools has applicability for identifying interactions at the sub-national level.

In this paper, we make use of the methodology proposed by Weitz, Carlsen, Nillson, & Skanberg, (2018), which we will call the SDG Synergies approach from now. This method is a participative semi-quantitative method based on the Cross-Impact Balances Analysis (see Weimer-Jehle, 2006). The approach incorporates network analysis to account for second-order interactions and other emergent properties, which are often too complex for most human minds to grasp (Weimer-Jehle, 2006). For the application of the approach in Colombia, an accompanying online decision support tool, the SDG Synergies tool, was developed by SEI Latin America, which speeds-up the analysis process and allows for the simultaneous construction of a cross-impact matrix by various stakeholders. We applied the methodology and tool in two different workshops: a national analysis for Colombia and a study for the Colombian Department of Antioquia.

This paper will present the results from the exercises mentioned above. In doing so, we argue that using the SDG Synergies approach in combination with the tool can contribute to fostering policy coherence in reaching the 2030 Agenda by allowing the quick identification of context-specific synergies and trade-offs. The approach uses expert-based knowledge and policy review as the input and, thus, it does not depend on the development, or tracking, of indicators which can be constrained to the national level – this facilitates the study of interlinkages in regional and local scales. Additionally, the method contributes to fostering systemic thinking among stakeholders, as it allows the participants to observe how the SDGs interact between them and what emerging properties arise from these connections (Nilsson & Weitz, 2019) – the tool enhances this understanding through quick calculations and visualisations of the results.

The rest of the text is structured as follows. The second section explains the SDG Synergies approach and presents the SDG Synergies tool. In the third part, we discuss the context of the Colombian analyses, highlighting how the workshops created spaces for discussion that fostered systems thinking among participants. In the fourth section, we compare the results from the two case studies. Finally, in the last part, we present conclusions and provide some ideas for future tool development.

2. Approach

2.1 The SDG Synergies approach

As stated above, the studies carried out in this paper use the SDG Synergies approach, which can be described as a cross-impact methodology based on Cross-Impact Balance Analysis, (see Weimer-Jehle, 2006). Cross-impact methods are tools for scenario modelling that provide techniques to extract and structure expert judgements about possible future developments in systemic interactions (Weimer-Jehle, 2006), this allows for the use of theoretically heterogeneous approaches in the identification of the interactions within the system (Panula-Ontto et al., 2018). This is particularly important for the modelling of socio-environmental systems (such as the space of interaction of the SDGs) where relationships between environmental and social phenomena occur. The expert-sourced data is then inserted into a cross-impact matrix, where it can be used for further calculations using mathematical modelling.

Cross-impact approaches appeared in response to the limitations of the Delphi method (Weimer-Jehle, 2006), which emerged in the 1950s as a foresight tool for decision-making (Bañuls & Turoff, 2011). In its beginning, the Delphi method was used to ask experts about the future impact of different technologies; however, how different technologies influence each other was not considered (Weimer-Jehle, 2006). This shortcoming signifies that, when applied to policy analysis, the Delphi method cannot account for the emergent properties of policy outcomes interactions. Thus, it does not foster systemic thinking among decision-makers (Nilsson & Weitz, 2019). Cross-impact methods, on the other hand, explore how an event might influence the occurrence of another (Gordon & Hayward, 1968), these interactions can then be modelled to account for the systemic behaviour of the studied events. Along these lines, Nilsson and Weitz (2019) argue that cross-impact analysis can provide decision-makers with systemic thinking, which, in relation to the SDGs, means 1) to have a “holistic view” of how the targets intermingle and what emergent properties arise from these interactions, and 2) understanding what this means for the implementation of the agenda in different contexts. Fostering systemic thinking in the first stages of policymaking can help decision-makers in designing policies that better address synergies and trade-offs (Nilsson & Weitz, 2019).

In this way, the SDG Synergies approach (Weitz, Carlsen, Nillson, & Skanberg, 2018) is a cross-impact methodology tailored explicitly to model interactions among the SDGs. The approach draws from previous work on the conceptualisation of SDG interactions (Nilsson, Griggs, & Visbeck, 2016) that proposed a seven-point scale to distinguish the value of the interlinkages. From “indivisible” (+3), “reinforcing” (+2), and “enabling” (+1), characterising synergies, to “constraining” (-1), “counteracting” (-2), and “cancelling” (-3) on the trade-off side. “Consistent” values, where there is no interaction, are scored as 0. In the approach, this typology is used to answer the question *“If progress is made on target x, how does this influence progress on target y?”*. The resulting scores are then introduced in a cross-impact matrix – the row variables representing the influencing targets, and the column variables indicating the affected targets. Expert and stakeholder judgements are used for gathering the data. The advantage of using subjective-based knowledge as the input for the approach is that the method is not constrained by indicator databases, which are often bound to the national scale. In contrast, the SDG Synergies approach can be applied in any context and scale, provided that experts and stakeholders are willing to partake in the study.

The methodology could potentially be used to assess interactions among all the 169 SDGs. However, this would mean scoring 28,392 interactions, which would be time and resources consuming for the participants filling in the cross-impact matrix. In this regard, a target selection is necessary to make the method feasible. The inclusion of more targets would need to be evaluated regarding improved results vs additional time and resource requirements. In this selection, the SDGs have to be chosen in accordance with their relevance for the studied context. For instance, in the pilot study for the approach (Weitz, Carlsen, Nillson, & Skanberg, 2018), the authors picked 34 targets for the analysis of Sweden, scoring 1,122 interactions. The authors selected 2 SDGs per Goal, in consideration of what targets are more relevant in the Swedish context, and scored the interactions themselves.

The respondents then score each link, and the net influence of each target is calculated through the sum of its interactions using the 7-point typology. The impact that one target has on every other (its *weighted out-degree,* or *out-degree* from now on) is shown on the row sum, whereas the column sum shows the degree through which one target is influenced by all others (its *weighted in-degree,* or *in-degree* from now on). Therefore, a high out-degree value indicates that a target has a synergic effect on the agenda – meaning that it can make the achievement of other SDGs easier. On the other hand, a negative out-degree number, or a low value due to having many trade-offs, would suggest that the target impedes the achievement of others. On the receiving end, a high weighted in-degree number would indicate that the realisation of the whole agenda positively influences that particular target. In contrast, a negative or low value would mean that progress in the rest of the SDGs can hinder progress in that target.

According to the authors of the approach, these calculations, called *first-order interactions*, can be used as an overview of how SDGs work together. However, they hypothesise that an understanding of systemic interactions, i.e. beyond first-order connections, can provide better insight for SDGs prioritisation. Therefore, further calculations are suggested to assess how a target behaves in the whole system. For this, the approach applies techniques from *network theory* to observe the emergent properties of the SDGs.

When applying network theory to the analysis, the constructed cross-impact matrix can be interpreted as a *weighted directed network*, where each SDG is a *node*, and the interlinkages between them are *edges*. Additionally, using network theory has the advantage of providing visualisation tools to illustrate the behaviour of the network, enhancing systemic thinking among the users of the methodology.

The first emergent property that is calculated in the approach is the *second-order weighted out-degree* (*second-order degree* from now on) which estimates the systemic impact of one target beyond its adjacent targets in the cross-impact matrix. To estimate this value, the authors apply a second-order interaction formula (Eq. 1):

Equation 1. *Second-order degrees*

$$I_i^{Total} = I_i^{1st} + \frac{1}{2}\sum I^{2nd} = D_i^{Out} + \frac{1}{2}\sum_{j\neq i} I_{ij} D_j^{Out}$$

Where I^{1st}_i is the influence of target i on its closest neighbours, I^{2nd} is the influences from i's neighbour's on their neighbours weighted by a factor ½, D^{Out}_i is the weighted out-degree of target i, I_{ij} is the strengths of link from target i to target j, and D^{Out}_j is the weighted out-degree of target j (Weitz, Carlsen, Nillson, & Skanberg, 2018).

This formula calculates how one target influences other SDGs through its impact on its neighbours' neighbours. For instance, if target A has a strong positive connection with target B, which in turn has many synergies with other targets, the systemic impact of target A can be very significant. In contrast, if target C has a strong negative link with target B, which has many positive connections, the synergic impact of target B could be not as significant if target C progresses. And therefore, measures should be taken to mitigate the negative effect of target C. The second-order degree shows how the impact of one target ripples through the network, better illustrating the systemic impact of one target over the others. In this regard, according to the authors, second-order values should be favoured over first-order calculations for SDG prioritisation.

Another feature from network analysis that can guide SDG implementation is *clusterisation*, which is a process to detect groups of highly connected nodes or targets. There exist various algorithms for creating clusters, but (Weitz, Carlsen, Nillson, & Skanberg, 2018) do not define which one should be favoured in the methodology. However, they state that the idea behind creating clusters is detecting groups of highly connected targets, leaving negative connections outside the clusters. In this regard, clusterisation can guide cooperation between sectors that influence each other positively, building partnerships for governance.

In sum, the SDG Synergies approach is a participative system modelling method that can support decision-making by illustrating how the SDGs behave together as a complex system. The approach is semi-quantitative, allowing the input of subjective-based data and using network analysis for further processing. The analysis can create systemic thinking among the participants, as it identifies the emergent properties of the SDGs. Furthermore, the results from the study can guide prioritisation and cooperation in the implementation of the targets.

2.2 The SDG Synergies tool

In one of the conclusions of their paper, Weitz, Carlsen, Nillson, & Skanberg (2018) suggest that a user-friendly interactive tool would be useful to support the SDG Synergies Approach fully. To respond to this necessity, SEI Latin America has developed the *SDG Synergies* t*ool*, which is an online decision support tool that permits the remote scoring of SDG interactions among various participants simultaneously. The tool began its development in 2018, and it has been updated continuously since then to add features and upgrade its graphics. Currently, the SDGs Synergies tool is set on a private web server, and its access is restricted to individual processes accompanied by SEI scientists. However, SEI is working towards the release of the tool, which would allow wide-spread utilisation. A website explaining the tool (sdgsynergies.org) will also be launched in early July 2020.

The most important feature of the SDG Synergies tool is that it allows the creation of a cross-impact matrix using the SDG targets as the rows and column variables (Fig. 1). Participants are given a token to gain access to the cross-impact matrix, where they can score the interactions using the 7-point scale. The tool automatically aggregates all the scores, rounding the values to integer numbers, and displaying the row and column sums in real-time as the participants fill in the matrix. The tool also creates satellite graphs (Fig. 2) to inspect the connections, inwards and outwards, of any specific target. The results can also be displayed in a network graph, showing the weighted out-degree and in-degree values visually.

Finally, the platform can provide first and second-order values instantly in a spreadsheet table format. This allows for further processing of the results in spreadsheet and network analysis software. The matrix can be scored remotely, allowing for the design of remote workshops. Additionally, the scores are stored and saved in a web server, permitting the scoring of the matrix over several days as needed.

***Figure** 1. Example of Cross-impact matrix.* The tool enables the creation of customisable cross-impact matrices. The intensity of the colour represents the scored value, with blue circles showing synergies, and the red circles, trade-offs. The out-degree and in-degree of each target are on the row sum and column sum, respectively.

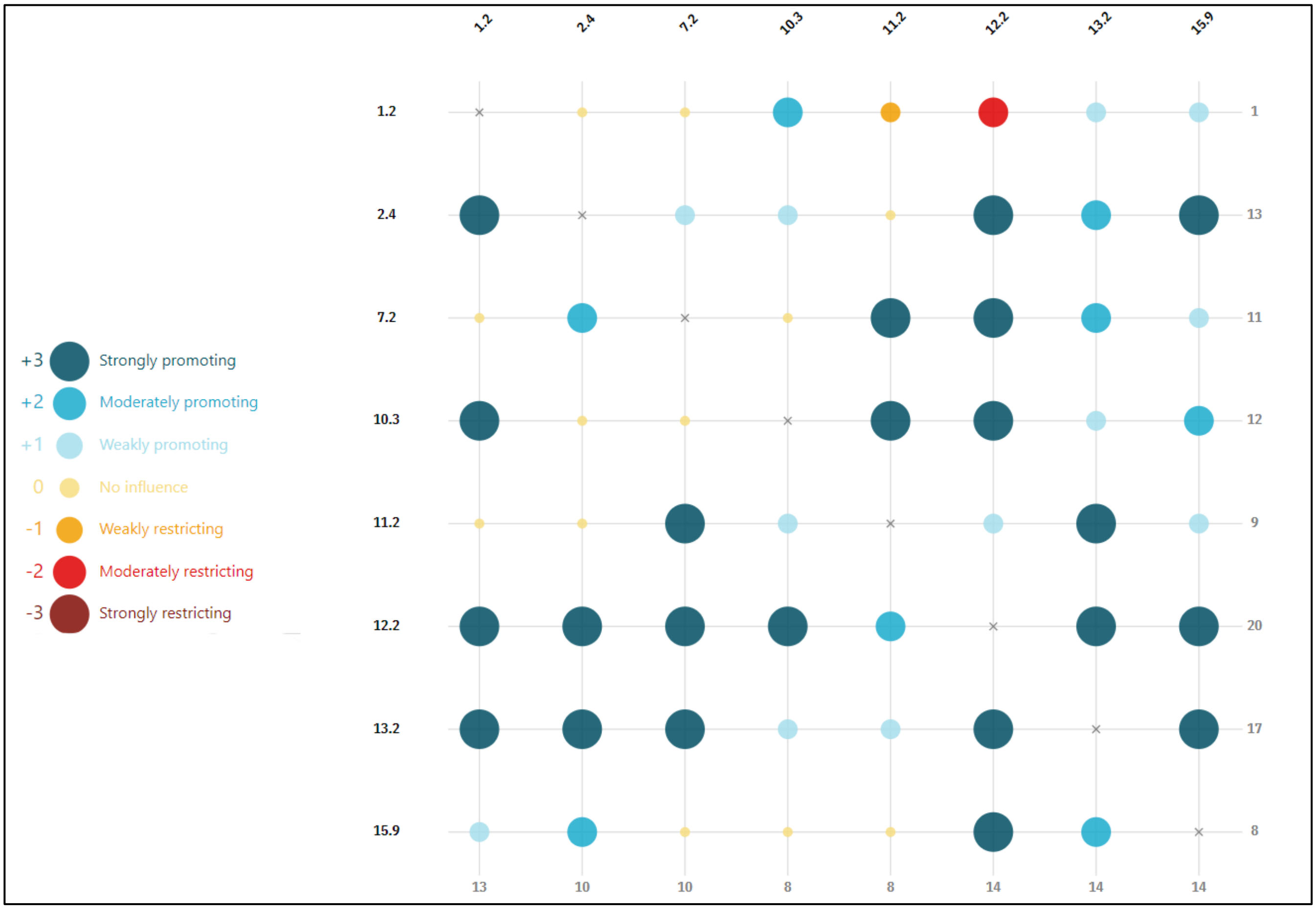
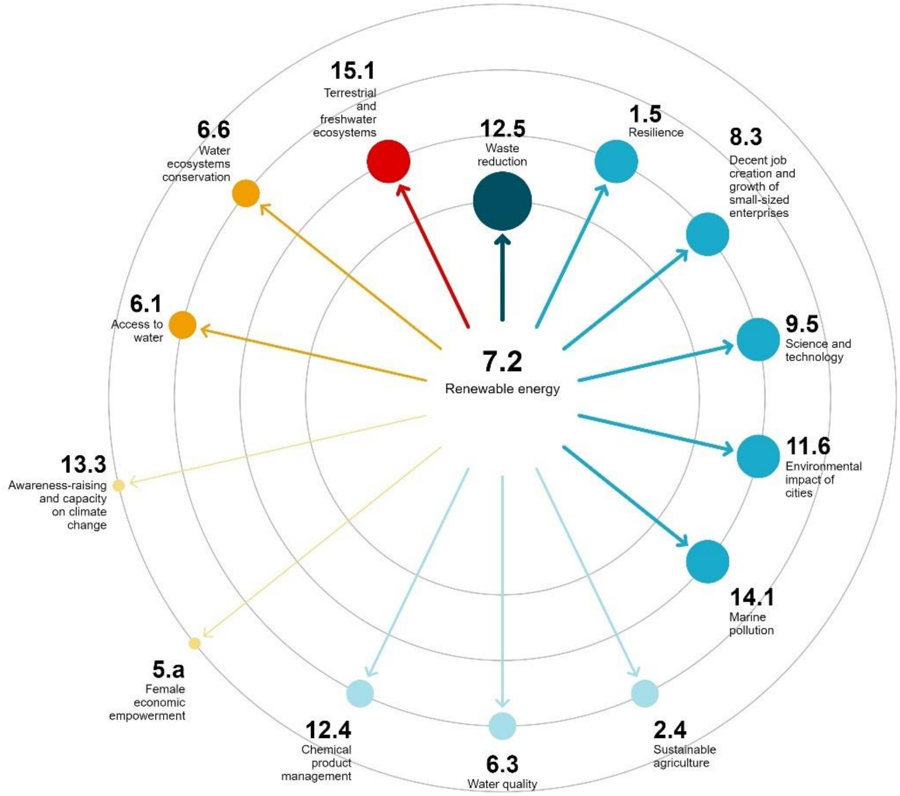
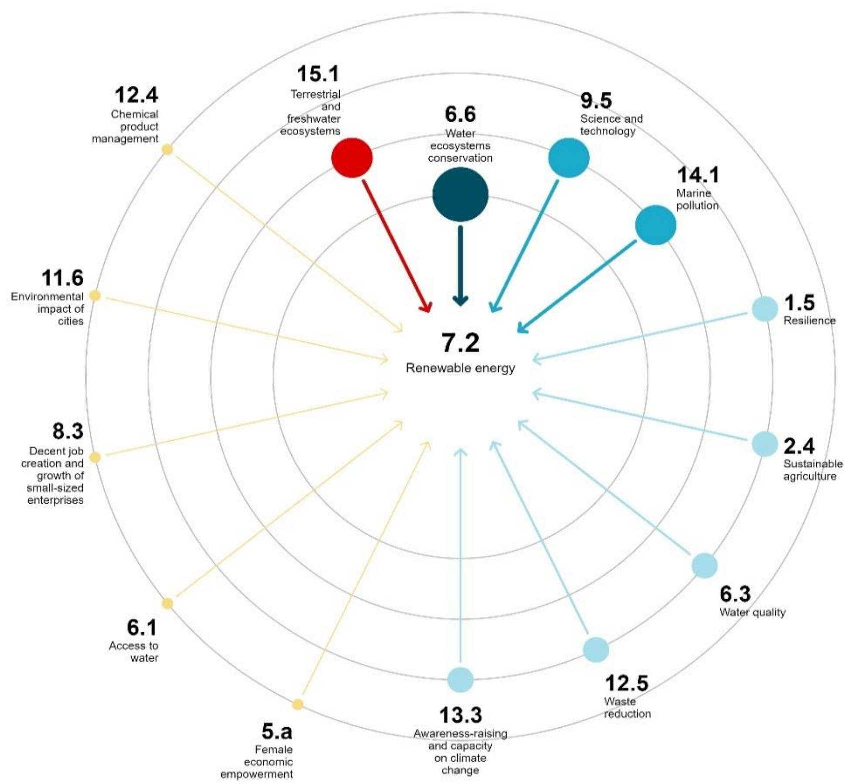


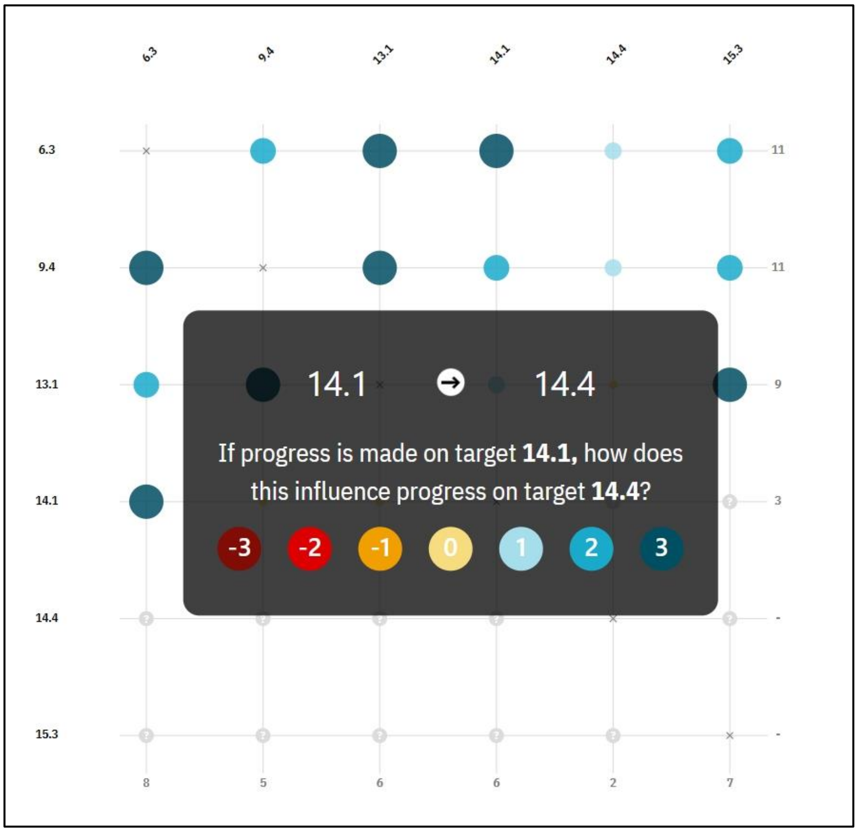
Figure 2. *Examples of satellite graphs*. The tool can produce satellite graphs that show the out-degree (top) and in-degree (bottom). The graphs use the same symbology as the matrix: the intensity of the colour represents the scored value, with blue circles showing synergies, and the red circles, trade-offs.





Respondents access the platform with personalised online access. Upon clicking an interaction on the matrix, a window appears with the question *"If progress is made on target x, how does this influence progress on target y?"* (Fig. 3), where the participants can choose a score from the 7-point typology. The respondents can indicate if they are uncertain about their score, and they can provide an explanation for the interaction. This information can be used for discussion in plenary, and by the researchers to infer mechanisms behind the identified synergies and trade-offs.

Figure 3. *Target scoring.* Upon clicking an interaction on the matrix, a window appears with the question "If progress is made on target x, how does this influence progress on target y?"



Apart from making the analysis easier for the researcher, the user-friendly interface gives the added capability of showing the participants quick calculations and visualisations of the results, facilitating dialogue among the stakeholders that partake in the methodology, and thus fostering systemic thinking. The tool can be used for global, national or sub-national studies, and it has the added feature of creating customisable policy agendas and targets, beyond the SDGs – expanding the usability of the platform to any sort of cross-impact analysis. The SDG Synergies tool, therefore, can support policymaking processes at any level.

Finally, clusterisation is a feature that is currently in development for the platform, and thus as the tool stands, this processing must be complemented with other software. However, the spreadsheets that the SDG Synergies tool generates can also be used in network analysis software for other calculations. In this regard, for the studies presented here, the clusterisation analysis was complemented with Gephi.

In the next section, we will describe the preparation of two case studies in Colombia, where the SDG Synergies tool was used to contribute to SDG implementation efforts.

3. Preparation of the Colombian SDG Synergies studies

Within the framework of the project *Towards coherent implementation of the environmental dimension of the SDGs*, SEI and the UN Environment Programme conducted two studies in Colombia: a national analysis, and a regional study for the department of Antioquia. At the national scale, the rationale behind this project was to produce considerations for the work of Colombia's National Commission on SDGs regarding inter-institutional coordination for the implementation of the agenda. At the departmental level, the study will be used to inform the new development plan of Antioquia.

The target selection process for the cross-impact matrices was made according to three specific criteria: alignment with relevant policies and plans; respect for the mainstreaming character of Agenda 2030 including environmental, social and economic aspects; and the feasibility of the analysis for the time available (in this case, it meant how many interactions could be scored in a 2-day workshop). Twenty targets were prioritised for the national study jointly with the National Planning Department and the Ministry of Environment and Sustainable Development. For the regional exercise, fifteen SDGs were selected together with the national and regional partners. Two two-day workshops were organised: 1) November 29-30, 2018 in Medellin, for the regional analysis, and 2) March 7-8, 2019 in Bogota for the national study. In both workshops, the attendees were provided with leaflets with the texts of the selected SDG targets for the matrices, as well as their alignment with relevant national or regional policies and indicators. This material is essential, as it helps the participants to characterise the SDGs in their particular context and scale.

The value of the analysis using the SDG Synergies approach depends on the quality of the scoring entered into the cross-impact matrix (Weitz, Carlsen, Nillson, & Skanberg, 2018). In this sense, it is accepted in participative modelling methodologies that a good representation of stakeholders is needed to account for different views and interests in the studied processes (Rowe & Frewer, 2000; Glicken, 2000; Reed, M., et al., 2009). Along these lines, the national level workshop was attended by 100 participants, and the regional level workshop by 60 – attendees consisted of SDG experts responsible for implementation, as well as actors from various sectors with knowledge in the topics covered by the different targets included in the studies.

Both workshops used the SDG Synergies tool for scoring. Groups of 5-6 participants filled in the matrices following group discussions. However, each respondent entered his or her score individually, and the tool rounded the values to integer numbers. Participants could indicate uncertainty in their score, which would allow discussion of those interactions in plenary. Respondents provided justifications for their scores, which were stored on the webserver.

In the end, the full matrix was displayed for debate in plenary. Additionally, to assist the discussion, satellite graphs were used to inspect the connections of the most synergic targets and the ones showing trade-offs – a closer look at these interlinkages encouraged debate about the processes behind these interactions. Thus, the approach gathered stakeholders from different sectors to analyse and discuss interactions between their areas of expertise and other SDG-related themes. This process can thus improve systemic thinking and provide a space of discussion where knowledge is shared, and the opinions and interests of others can be revised and agreed on. This learning experience during the first stages of policymaking is also an important aspect of reaching policy coherence for the 2030 Agenda, as this knowledge is what stakeholders ultimately utilise to make decisions (Nilsson & Weitz, 2019).

In the next section, we will revise the results from both workshops and discuss some of the findings.

4. Results

4.1 First-order interaction values

The main output from the SDG Synergies tool is a cross-impact matrix with all the first-order interactions between the selected targets displayed visually. From these calculations, it is possible to infer which SDGs can have an aggregated synergic or negative effect in the rest of the targets. In this regard, none of the matrices has targets with negative out-degree or in-degree values – meaning that most SDGs in the case studies are supportive of each other. Although the matrices have a different number of SDGs and there are some changes regarding the selected targets, thirteen SDGs are the same in both matrices. In this sense, the analysed themes in the two workshops are very similar, and thus the two matrices can be compared. Furthermore, interactions between the same pairs of targets in both matrices can be directly contrasted.

In the national analysis (Fig. 4), the most synergic SDGs are the targets 8.4 (Sustainable consumption and production) and 11.6 (Environmental impact of cities) – both with an out-degree score of 35 (displayed on the row sum). In contrast, in the Antioquia study (Fig. 5), the most influential are the targets 2.4 (Sustainable agriculture) and 12.5 (Waste reduction), with an out-degree score of 28 and 27, respectively. None of these targets produces trade-offs in their respective matrices, which suggests that they do not have restricting characteristics for other goals in the case studies. Such targets might be given priority in SDG implementation, as they have a high potential of contributing to the achievement of the agenda (Weitz, Carlsen, Nillson, & Skanberg, 2018).

On the other hand, the most influenced targets in the national study, ranked by their in-degree, are the SDGs 1.5 (Resilience) and 15.1 (Terrestrial and freshwater ecosystems), both with a score of 32. In the Antioquia analysis, the most influenced SDGs are the targets 1.5 (Resilience) and 2.4 (Sustainable agriculture), with scores of 32 and 29, respectively. These targets are the ones that are most benefited by progress on the agenda as a whole.

Regarding the SDGs showing trade-offs, in the national study, targets 2.3 and 5.a have negative links with other goals – with the target 2.3 (Agriculture and land) generating the most negative links (four in total). In the Antioquia matrix, the targets 7.2 (Renewable energy), 8.3 (Decent job creation and growth of small-sized enterprises) and 15.1 (Terrestrial and freshwater ecosystems) produce negative links – the target 8.3 is the one with the most trade-offs (five in total). Regarding these targets, it is necessary to implement them carefully and with their trade-offs in mind in order to mitigate them. Otherwise, other SDG efforts could become neutralised (Weitz, Carlsen, Nillson, & Skanberg, 2018).

Figure 4. National analysis cross-impact matrix. The symbology is of each score is displayed on the left.

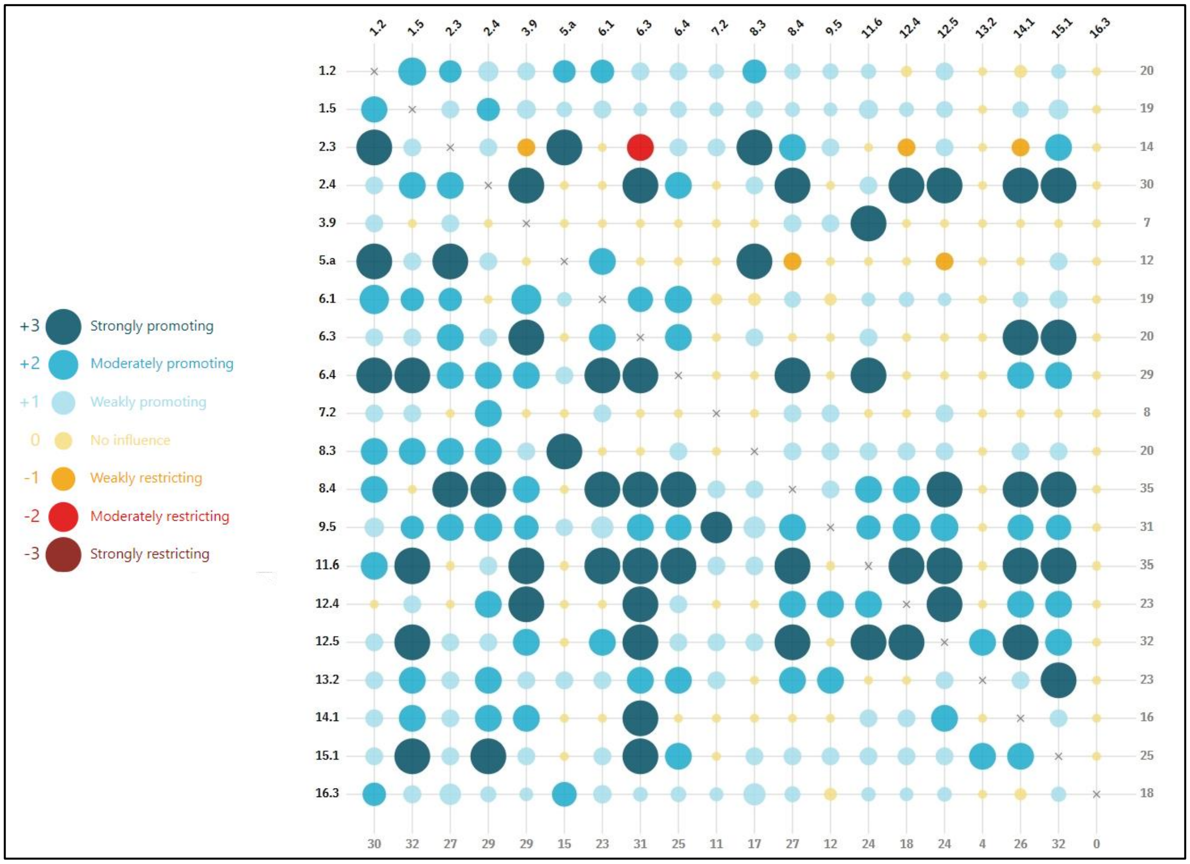
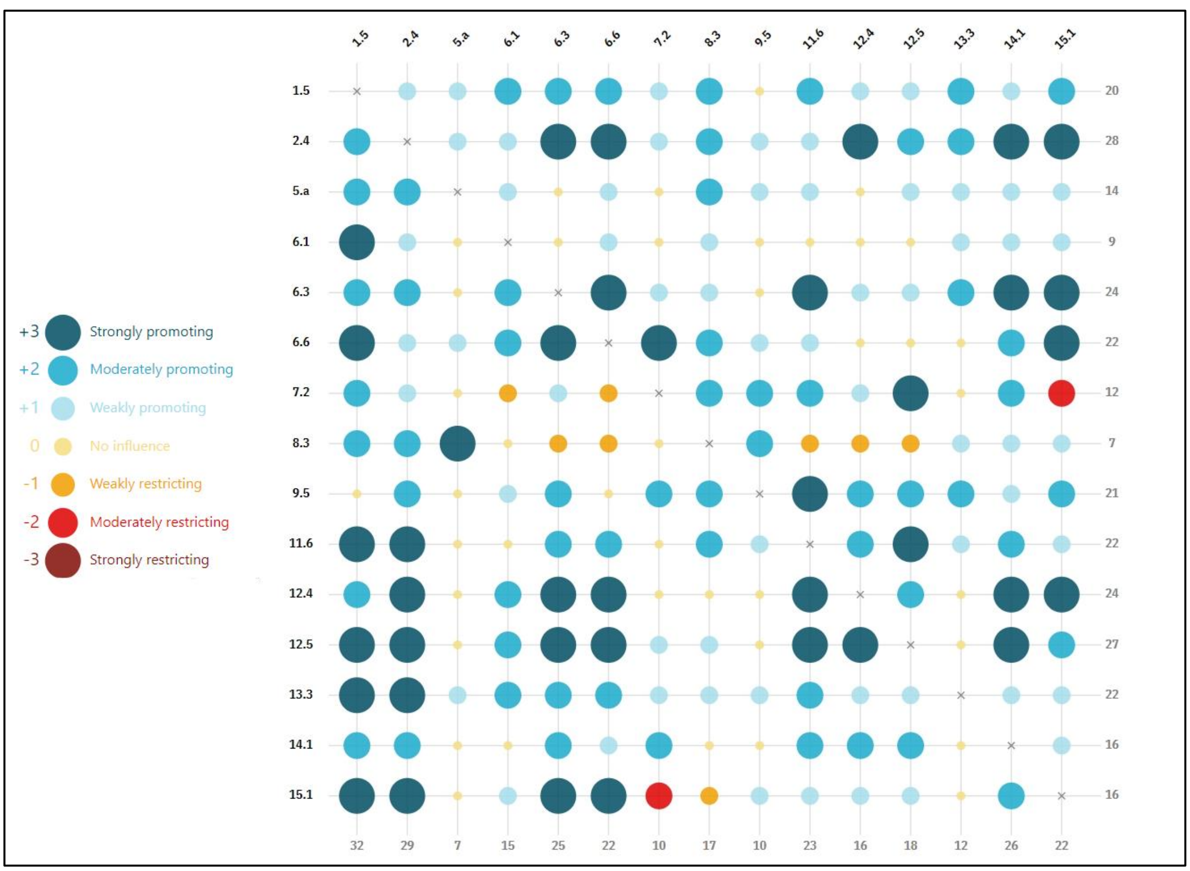
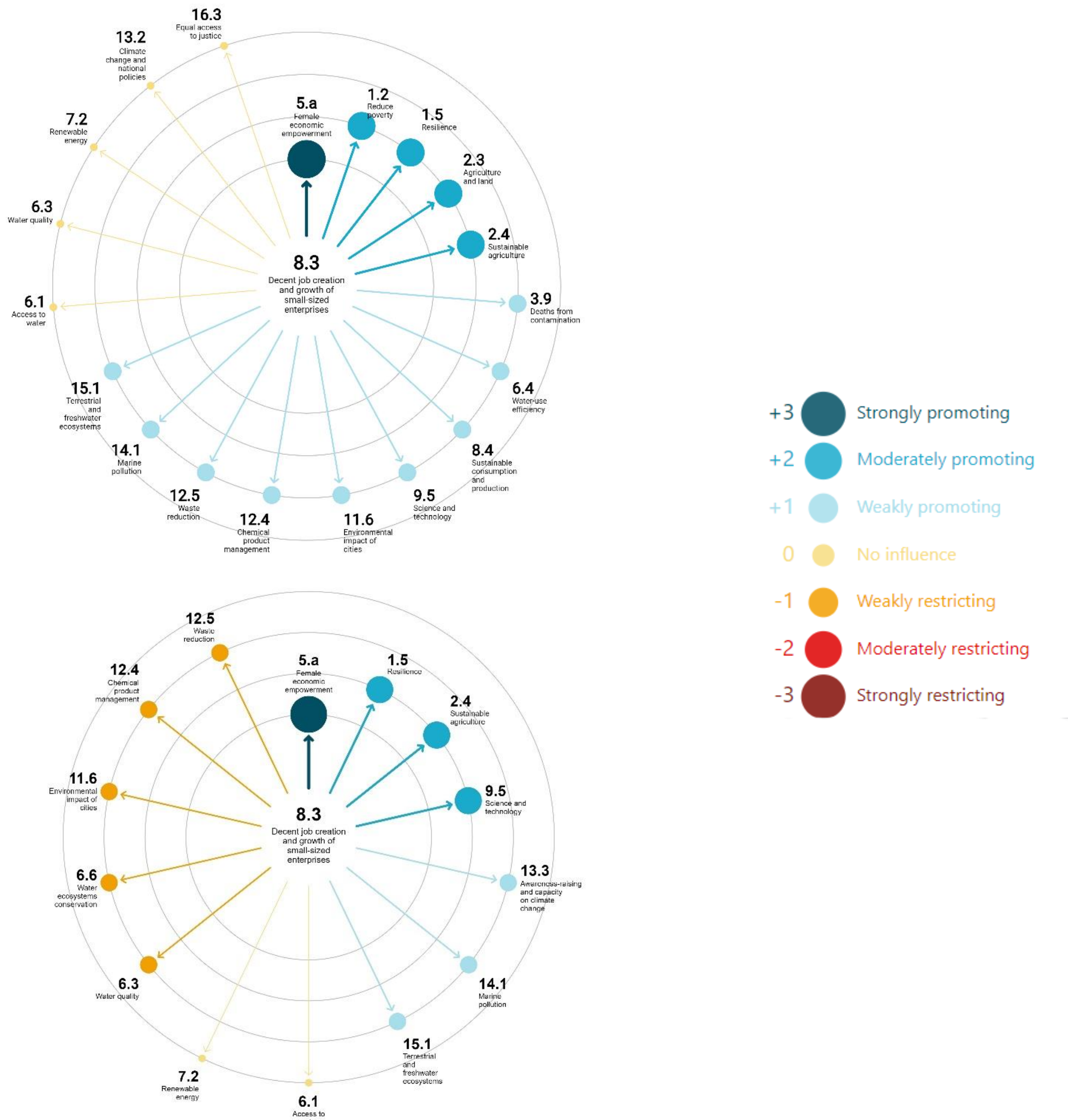


Figure 5. Antioquia analysis cross-impact matrix. The symbology is of each score is displayed on the left.



When comparing both matrices, it is also interesting to note how one same SDG target can behave differently depending on the case study. For instance, in the national analysis, the target 8.3 (Decent job creation and growth of small-sized enterprises) (Fig. 6) generates positive links (+1) with the targets 11.6 (Environmental impact of cities), 12.4 (Chemical product management), and 12.5 (Waste reduction). Whereas in the Antioquia study, the target 8.3 has negative links (-1) with those same three targets. This suggests that SDG policy coherence efforts also have to take into account the contextual differences between scales – even within the same country. A closer examination behind the mechanisms of these trade-offs would be necessary to align the Colombian national SDG strategy with Antioquia-level policies.

Figure 6. *Satellite graphs of the target 8.3 in both case studies***.** Comparison between the out-degree values of the target 8.3 in the Colombia national analysis (top), and Antioquia study (bottom). The symbology is of each score is displayed on the right.



4.2 Network analysis: second-order degrees and clusterisation

The tool calculates the second-order interaction values, which can be downloaded in a spreadsheet format. These scores should be favoured over the out-degrees for SDG prioritisation, as they better illustrate the systemic impact of one target (Weitz, Carlsen, Nillson, & Skanberg, 2018).

When comparing the first-order out-degrees *vis à vis* the second-order scores (Table 1), there are slight differences in the rankings. In the national study, targets do not rank too differently when comparing the first and second-order degree tables. However, in the first order ranking, some SDGs have the same score, such as the targets 8.4 (Sustainable consumption and production) and 11.6 (Environmental impact of cities), that share the first place with a score of 35. In this regard, the second-order values show more variance and thus can be used as tiebreakers. In the Antioquia study, the two most influential SDGs remain unchanged in both rankings (targets 2.4, Sustainable agriculture, and 12.5, Waste reduction), and positions start to switch until the third place. The Antioquia calculations show more changes in the rankings than the national analysis.

Table 1. Comparison between first-order and second-order degrees – first ten targets

	Colombia national analysis			
Rank	**First-order**	**Score**	**Second-order**	**Score**
1	**8.4** Sustainable consumption and production **11.6** Environmental impact of cities	35	**8.4** Sustainable consumption and production	425.5
2	**12.5** Waste reduction	32	**11.6** Environmental impact of cities	423
3	**9.5** Science and technology	31	**12.5** Waste reduction	388.5
4	**2.4** Sustainable agriculture	30	**2.4** Sustainable agriculture	364.5
5	**6.4** Water-use efficiency	30	**9.5** Science and technology	362
6	**15.1** Terrestrial and freshwater ecosystems	29	**6.4** Water-use efficiency	348.5
7	**12.4** Chemical product management **13.2** Climate change and national policies	23	**15.1** Terrestrial and freshwater ecosystems	314
8	**1.2** Reduce poverty **6.1** Access to water **6.3** Water quality **8.3** Decent job creation and growth of small-sized enterprises	20	**12.4** Chemical product management	307.5
9	**1.5** Resilience	19	**13.2** Climate change and national policies	288
10	**16.3** Equal access to justice	18	**8.3** Decent job creation and growth of small-sized enterprises	235.5
	Antioquia analysis			
Rank	**First-order**	**Score**	**Second-order**	**Score**
1	**2.4** Sustainable agriculture	28	**2.4** Sustainable agriculture	296
2	**12.5** Waste reduction	27	**12.5** Waste reduction	295.5
3	**6.3** Water quality **12.4** Chemical product management	24	**12.4** Chemical product management	272
4	**6.6** Water ecosystems **11.6** Environmental impact of cities **13.3** Awareness and capacity for climate change	22	**11.6** Environmental impact of cities	257

5	**9.5** Science and technology	21	**6.3** Water quality	252
6	**1.5** Resilience	20	**13.3** Awareness and capacity for climate change	239.5
7	**14.1** Marine pollution **15.1** Terrestrial and freshwater ecosystems	16	**9.5** Science and technology	226.5
8	**5.a** Women economic empowerment	14	**15.1** Terrestrial and freshwater ecosystems	209
9	**7.2** Renewable energy	12	**6.6** Water ecosystems	204.5
10	**6.1** Access to water	9	**1.5** Resilience	202.5

Finally, regarding the clusterisation, we used the spreadsheets created by the platform to build networks in Gephi and detect the clusters through its embedded algorithm (see Blondel, Guillaume, Lambiotte, & Lefebvre, 2008) (Table 2). In the national study, three clusters of synergic targets were identified and categorised according to the dominant themes of the SDGs that conform them: 1) social equity and poverty reduction, 2) science, innovation and technology, and 3) waste management and pollution reduction. In Antioquia, four thematic clusters were created: 1) resilience, 2) sustainable consumption and production, 3) social equity, science, and innovation, and 4) environment. These clusters can pinpoint which sectors need to cooperate to maximise the synergic effect of the targets (Weitz, Carlsen, Nillson, & Skanberg, 2018).

Table 2. Clusters

Colombia		Antioquia	
Cluster	Targets	Cluster	Targets
1. Social equity and poverty reduction	**1.2** Poverty reduction **2.3** Agriculture and land **5.a** Women economic empowerment **8.3** Decent job creation and growth of small-sized enterprises **16.3** Equal access to justice	1. Resilience	**5.a** Women economic empowerment **7.2** Renewable energy **8.3** Decent job creation and growth of small-sized **9.5** Science and technology
2. Science, innovation and technology	**1.5** Resilience **2.4** Sustainable agriculture **6.4** Water-use efficiency **7.2** Renewable energy **9.5** Science and technology **13.2** Climate change and national policies **15.1** Terrestrial and freshwater ecosystems	2. Sustainable consumption and production	**1.5** Resilience **6.1** Water access **13.3** Awareness and capacity for climate change
3. Waste management and pollution reduction	**3.9** Deaths by pollution reduction **6.1** Water access **6.3** Water quality **8.4** Sustainable consumption and production **11.6** Environmental impact of cities **12.4** Chemical product management **12.5** Waste reduction **14.1** Marine pollution	3. Social equity, science, and innovation	**2.4** Sustainable agriculture **11.6** Environmental impact of cities **12.4** Chemical product management **12.5** Waste reduction
		4. Environment	**6.3** Water quality **6.6** Water ecosystems **14.1** Marine pollution **15.1** Terrestrial and freshwater ecosystems

In brief, there exist evident differences in the results comparing both exercises. It could be hypothesised, however, that such differences exist due to the matrices having a few different targets in them. Nonetheless, as shown in the example of the target 8.3, one same SDG can have contrasting interlinkages with the same pairs of targets in one network compared to the other. This suggests that contextual and scale-related differences can determine the occurrence of synergies or trade-offs. We state that it is necessary to account for these scale-specific interlinkages to achieve policy coherence across scales in the SDGs – even within the same country. How to align SDG policies and efforts between scales considering their interlinkages can be a topic for further discussion.

5. Conclusions and ideas for future tool developments

The SDG Synergies approach is a participative cross-impact analysis methodology that allows for the identification of trade-offs, synergies, and clusters between SDGs targets in specific contexts – using subjective-based knowledge as the input for the policy system modelling. The advantage of utilising expert and stakeholder-sourced data as the input for the approach is that the method is not constrained by indicator databases, which are often bound to the national scale. In contrast, the SDG Synergies approach can be applied in any context and scale, provided that experts and stakeholders are willing to partake in the study. Moreover, this methodology generates systemic thinking among experts and stakeholders from different sectors, as it creates spaces of discussion where insights are made regarding the probability of occurrence of complex phenomena. Working with this knowledge in the first stages of policymaking can help decision-makers in designing policies that better address synergies and trade-offs (Nilsson & Weitz, 2019). The SDG Synergies online tool complements the methodology, speeding up the process by making easier the recoding of data into a cross-impact matrix, and by providing real-time calculations and visualisations of the results. This information can be used during workshops to promote discussion further and reinforce systems thinking among the participants – as was observed during the Colombia exercises.

In the preparation of the two analyses, we highlighted the need to have a wide range of stakeholders to score the cross-impact matrix. The quality of the input data will depend on the representation of actors and experts that partake in the study – stakeholder inclusion is thus important in both target selection and scoring. This process, as well as the list of participant stakeholders, should be fully accounted for and transparent. Regarding the target selection, as the method stands, it is necessary to choose a feasible number of targets for the cross-impact matrix – the inclusion of more or fewer targets needs to be evaluated between having improved results vs additional time and resource requirements. During the workshops, it is also necessary to provide the attendees with material clearly showing how the SDGs correspond to particular plans and indicators in the context of the study – this helps the participants to contextualise the SDGs in their specific settings and scales during the scoring.

The results from the Colombian analyses can be used in national policy-coherence efforts to reach the 2030 Agenda, as the identification of these connections can be used in national and regional implementation plans to prioritise policies in achieving the SDGs, while the clusterisation of targets can guide cooperation between different sectors. An examination of the results shows that there are different interlinkages between the same pairs of SDGs, as it is observed in the national results of Colombia *vis à vi*s the Antioquia department. We state that these particular interlinkages have to be accounted for in the implementation of the SDGs to achieve policy coherence across scales – even within the same country.

The SDG Synergies tool has great potential in assisting global, national and sub-national SDGs implementation. In this sense, an ambitious future development would be giving wide public remote access for the construction of custom cross-impact matrices. This would promote capacity building and systemic thinking for the achievement of the SDGs in any country and at any scale – fostering global policy coherence for the 2030 Agenda. Moreover, it would be an excellent opportunity for collecting crowd-sourced information regarding context-specific interlinkages. This database would provide an enormous contribution to the study of SDGs interactions and cross-impact analysis in general, and it could be utilised as a space of comparison and discussion among case studies for decision-makers. The wide-spread availability of the tool would require the setting up of the platform in more massive servers for online access and the storage or large datasets.

Acknowledgements:

SEI Latinamerica would like to acknowledge the technical and financial contributions for the development of earlier versions of the tool by UNDP Asia, UN Environment, Puntoaparte and Showntelldata.

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