



## **The contribution of the Brazilian research system to the Sustainable Development Goals**

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## Executive Summary

This report analyses the capabilities of the Brazilian research system to address the Sustainable Development Goals (SDGs). It does so from a transformative innovation perspective that suggests profound changes are required to create new developmental trajectories that are environmentally and socially sustainable. We begin from the premise that the SDGs are not a compilation of isolated targets and, therefore, we treat them as an interconnected system. We interpret our results using a systemic model developed by the Transformative Innovation Policy Consortium (TIPC) (<http://www.tipconsortium.net/>), and shown in figure 1 below, which groups the SDGs into three categories (SDGs related to socio-technical systems or application areas, SDGs related to transversal directions and SDGs related to framework conditions). We assume that successfully tackling the 2030 Agenda requires multi-disciplinary research and R&D capabilities associated with these three categories of SDGs.

The Brazilian SDG-related research capabilities were analysed through a bibliometric-based approach based on articles published by Brazilian researchers in the period 2006-2017 and indexed in Web of Science and SciELO databases. Using a set of SDG-related search terms, we were able to identify patterns of research in SDG areas. We then used Social Network Analysis tools (bibliographic coupling) to characterize knowledge networks that combine research capabilities associated with the three categories of SDGs (socio-technical systems, transversal directions and framework conditions).

Our results show that a very low proportion of the Brazilian scientific production addresses the SDGs (2.5% to 5%). SDG publications were mainly in the areas of health (SDG 3), water & sanitation (SDG 6), and education (SDG 4). SDGs related to environmental and social directionality, such as climate action (SDG 13), life on land (SDG 15), decent work (SDG 8), no poverty (SDG 1), were not as abundant but had an important role as connectors in knowledge networks. A very significant result is that after 2013, when a crisis in public R&D funding in Brazil began, the proportion of SDG papers in SciELO decreased substantially and SciELO knowledge networks collapsed. The system became less diverse and ended up dominated by a few SDG-combinations. Furthermore, SDGs related to transversal directions did not interact as often with SDGs related to sociotechnical systems. This is very concerning, since interactions between different categories of SDGs are fundamental to support transformations. Although the SciELO system as a whole was negatively affected by the crisis in public funding after 2013, at the research communities' level we still found positive examples of interactions between SDGs of different categories, such as water & sanitation (SDG 6), responsible production & consumption (SDG 12) and innovation (SDG 9).

In terms of recommendations for public policies in Brazil, our study reinforces the importance of prioritizing the funding of SDG associated research. Second, we underline the importance of developing policies that encourage actors to work across different thematic and transdisciplinary areas, combining sociotechnical systems with environmental and social directionality to open up new development trajectories. Third, it is important to deepen the understanding about knowledge communities identified in this study, which could support transformative niche activity.

## Introduction

In September 2015, the United Nations launched the Agenda 2030, a set of 17 global development targets, called UN Sustainable Development Goals (SDGs). In contrast to its predecessor, the UN Millennium Goals, the Agenda 2030 is about a broader societal and economic change. It is about implementing a new agenda, flagged in the strapline: *Transforming our World*.

Although Brazil made important progress in meeting the Millennium Development Goals (MDGs) (United Nations Department of Economic and Social Affairs, 2015), it might fail to meet a number of SDG targets by 2030, unless radical new policy visions are adopted (Scott et al., 2017). Some of the challenges faced by the country include an ageing population, low and declining growth in economic productivity, rising unemployment, dilapidated infrastructure, and political instability.

In fact, the SDGs demand radical and innovative policies because they are a complex system with deep systemic interconnected problems, influencing one another both in synergistic and negative ways (Nerini *et al*, 2018; Nilsson *et al*, 2018; Randers *et al*. 2018). Therefore, it is fundamental to approach the SDGs as an interconnected system rather than treat them as a compilation of isolated targets to be mainstreamed into current policies.

Building on studies of sustainability transitions of sociotechnical systems (Schot and Kanger, 2018; Grin et al., 2010), researchers at the Transformative Innovation Policy Consortium (TIPC) developed a new way of looking at the SDGs and their mutual relationships (Schot *et al.*, 2018). In the TIPC model, transformation is understood as the need to fundamentally change multiple sociotechnical systems (Schot and Kanger 2018). The SDGs are therefore, grouped in three categories (Figure 1).

The first category consists of a wider range of sociotechnical systems that comprise the material backbone of our economy and society: SDG2 on agriculture; SDG 3 on health; SDG 4 on education; SDG 6 on clean water and sanitation; SDG 7 on affordable and clean energy; SDG 9 on innovation, industry and infrastructure; SDG 11 on sustainable cities and communities; and SDG 14 on life below water.

The second category is about directionality towards social and environmental sustainability and comprises SDG1 (no poverty); SDG 5 (gender equality); SDG 8 (decent work and economic growth); SDG10 (reduced inequalities); SDG 12 (responsible production and consumption), SDG 13 (climate action) and SDG 15 (life on land).

The third category addresses framework conditions, that is, the mobilization of actors and improvement of governance conditions relevant to the implementation of the SDGs and includes SDG 16 (peace, justice and strong Institutions) and SDG 17 (inclusive partnerships).

The model considers that the fulfilment of the Agenda 2030 will happen through interactions between the three categories of SDGs, that is, within appropriate framework conditions, the sociotechnical systems must become more environmentally sustainable and socially inclusive. For example, promotion of affordable and clean energy (Goal 7) demands responsible

production and consumption (Goal 12) and can be achieved through inclusive partnerships (Goal 17).

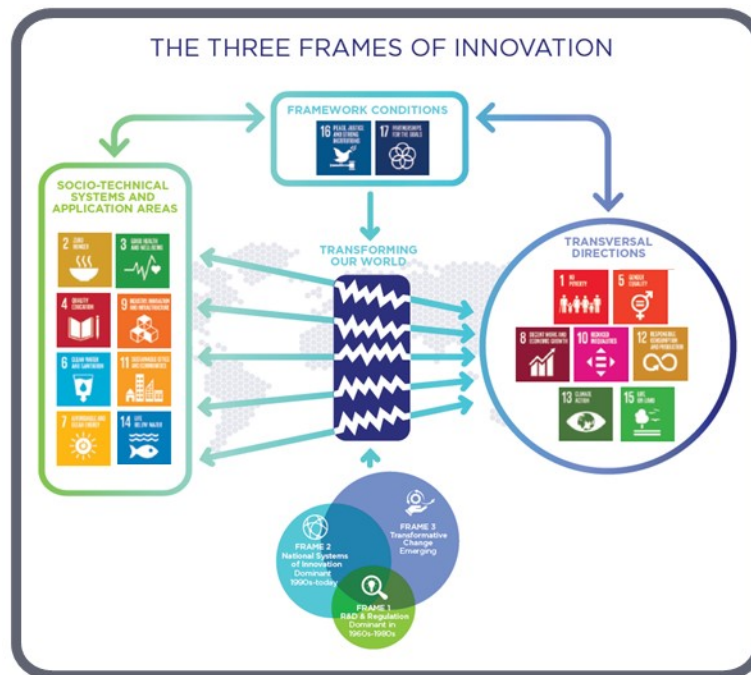


Figure 1: Addressing SDGs through Transformative Innovation Policy. Source: Schot *et al.*, 2018.

In the TIPC model, Science, Technology and Innovation (ST&I) plays an important role as an enabler and catalyst of the desired changes in the sociotechnical systems. However, the model assumes that the realization of the SDGs requires a new ST&I policy, termed Transformative Innovation (Schot and Steinmueller, 2018). TIPC, therefore, emphasizes the relevance of Transformative Innovation or frame 3 policies to achieve transformation, in comparison to more conventional ST&I policies, such as promotion of R&D and regulation (frame 1) and National Innovation Systems (frame 2).

Frame 3 policies place social and environmental sustainability at the core of ST&I policy. Another important element of frame 3 policies is the fostering of protected spaces, termed “transformative niches”, where sustainable development alternatives, which often compete with dominant ones, can emerge through experimentation (Schot and Geels, 2008).

A key element of niche formation are multidisciplinary knowledge networks. This could be a limitation for the Brazilian research system to become more transformative. There are indications that, although Brazil has an established scientific leadership in a few strategic SDG-related areas, such as health and agriculture (Barata et al, 2014), research is often restricted to a particular field of knowledge and does not include the economic and social dimensions of a given subject (Joly *et al.*, 2019).

Therefore, in the present report, therefore, we intend to map the main SDGs in Brazilian publications and understand to what degree they interact with one another in transdisciplinary “knowledge communities” with transformative potential. By doing this we aim to provide evidence of incipient transformative capabilities in the Brazilian research

system as well as suggest policy measures to foster the contribution of ST&I to the achievement of the SDGs in Brazil.

## Methodology

In order to assess the investments in the research system, we used a database of 74,274 research grants (APQ) funded by the Brazilian National Research Council (CNPq) in the period 2006-2017. The database contained the title of the projects, their authors, institutions, abstracts, thematic areas and funding. We then analysed the database in terms of amount of investments, number of projects, number of institutions and thematic areas in the period 2006-2007.

We used bibliometric analysis to examine the influence that the science system may be having on SDGs based on a systematic search of publications from databases Web of Science (WoS) and SciELO Citation Index (SciELO) (Shiffrin and Börner, 2004; Rafols and Meyer, 2010; Bornmann, 2013; Ciarli and Rafols, 2017). Knowledge maps are commonly used to understand the relationship between different disciplines (Rafols *et al.*, 2010; Grauwin and Jensen, 2011) that are analysed using social network analysis (SNA), which is commonly used to visualise and develop specific measures of knowledge integration (Shiffrin and Börner, 2004; Wagner and Leydesdorff, 2005; Leydesdorff, 2007; Rafols and Meyer, 2010). Our analysis relies on representing SDGs as shown in Figure 1, composed of different sociotechnical systems and directionalities that illustrate contrasting societal needs or demands (Ramirez *et al.*, 2019).

We produced co-bibliography networks composed of nodes (bibliometric data sources, e.g. articles or conference papers), ties (shared bibliography) and attributes (association with one or more SDGs). Bibliometric data for Brazil were gathered from WoS (507,251 sources) and SciELO (214,015 sources)<sup>1</sup>. In addition, we used a data set with 1,162 search terms related to SDGs developed by Ramirez *et al.* (2019, pp 11). Then, we searched these terms in the title, abstract and keywords of every bibliometric source, to detect which of them were related to SDGs. Finally, we identified articles that contained at least three search terms<sup>2</sup> and considered them to be related to SDGs (Figure 2).

Each bibliometric source was associated with one or more SDGs according to the frequency of search terms. We followed Ramirez *et al.* (2019, pp 11) approach to label bibliometric sources: “A bibliometric source was associated with one SDG when the frequency of search items related to that SDG was greater than 60% of the total search items found in it. When this was not the case, the bibliometric source was labelled with additional SDGs until the sum of the frequency of SDGs search items were equal to 75% of the search items in that bibliometric source. This cut-off point was implemented to avoid labelling articles with SDGs that were only mentioned peripherally”.

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<sup>1</sup> The query was CU=Brazil\* or brasil\* in WoS, and AD=Brazil\* or brasil\*. We took information from 2006 to 2017. It was only considered research sources that had complete information (title, abstract, key words and bibliography)

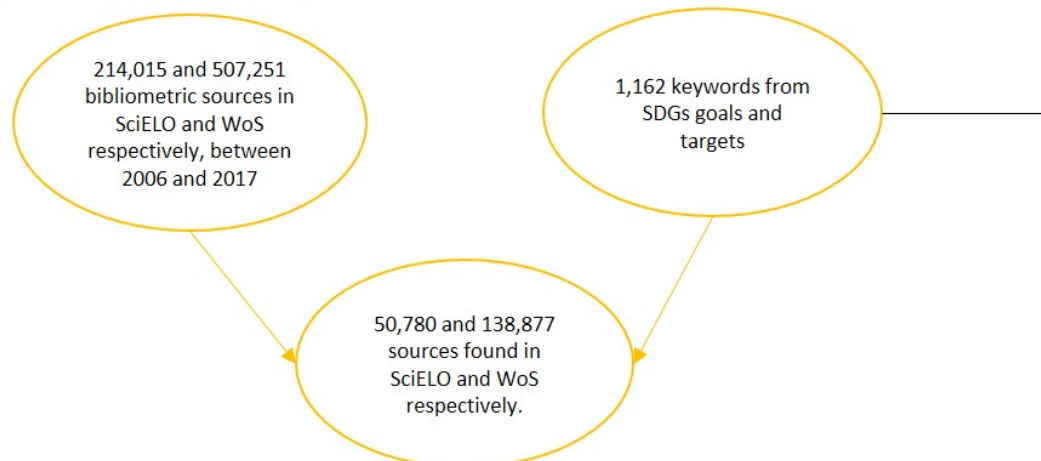
<sup>2</sup> The frequency of search items found in every bibliometric source was considered instead of the number of search items. For instance, a search item may be found three times or three different search items may be found one time. In our methodology, it is considered as a frequency of three in both cases.

Furthermore, research SDGs communities were detected following the method of Grauwin and Jensen (2011), that takes the weight of ties between nodes (deep bibliography)<sup>3</sup>. As a result, a co-bibliography network was selected with 20,227 bibliometric sources in WoS (modularity=0.9321, cut point=17.5%) and 6,878 in SciELO (modularity=0.7910, cut point=20%).

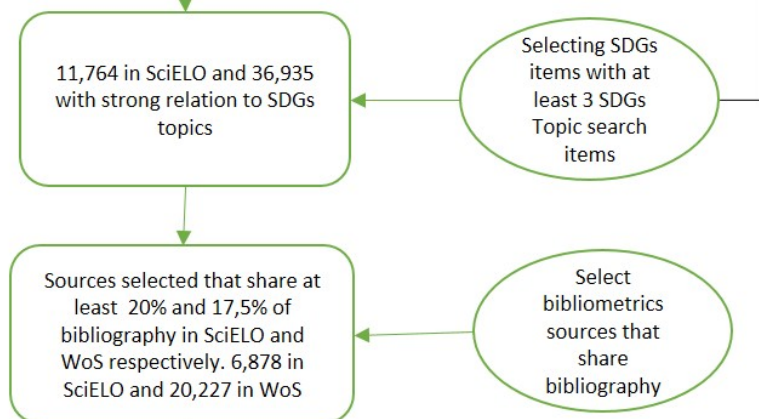
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<sup>3</sup> This methodology applies bibliographic coupling (BC) similarity between two bibliometric sources  $i$  and  $j$  to normalize the number of references that every bibliometric source has (Kessler, 1963), and Louvain modularity algorithm to find communities of bibliometric sources (knowledge communities) that share a large number of references (Grauwin and Jensen, 2011; Duncan and Pascucci, 2017). This approach also focusses on modularity maximization that allows one to detect well-defined communities (strong cognitive relationships).

### a) Detecting SDGs Bibliometric Sources



### b) Refining Data



### c) Analysing Data

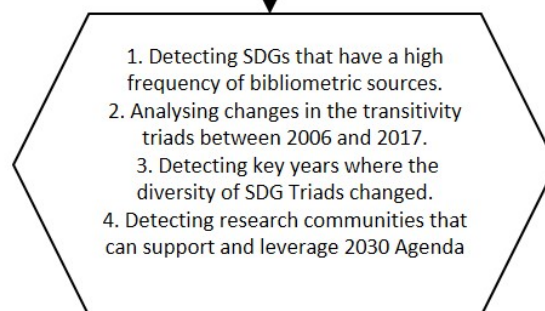


Figure 2: Steps taken to gather and analyse bibliometric data from WoS and SciELO.

In addition, we undertake a complementary method that evaluates interconnectivity between groups of three SDG articles in the co-bibliography network. These groups of three connected nodes are called triads in social network analysis jargon (Figure 3). We then find the most common triads in the network<sup>4</sup> (Burgin, 2018) and in every research community<sup>5</sup>. Then, using the Triad Census Distributions approach (TCDs) (Aarstad, 2013), it is possible to

<sup>4</sup> Because some article could have more than one attribute (SDGs), it was necessary to multiply one node so many times as the number of attributes (SDGs) for undertaking the Triad Census Distribution analysis.

<sup>5</sup> A community is a group of articles that share large numbers of connections in their bibliographies

determine the most common relationships between the three SDGs categories according to the classification introduced in Figure 1.

In summary, our methodological approach aims to detect the connectivity between knowledge related to SDGs, to detect communities that address sociotechnical systems and directionalities, and to evaluate the diversity of triads to reveal detail about the most frequent topics related to SDGs in the knowledge network.

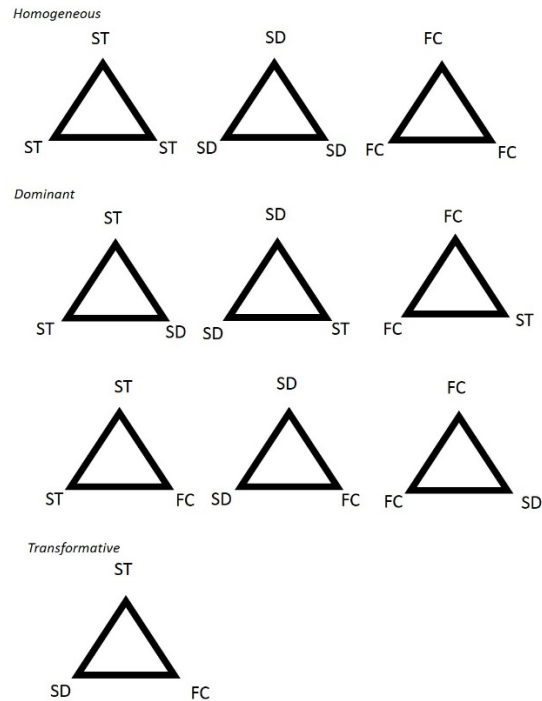


Figure 3: Based on the classification of SDGs in Figure 1, Ramirez *et al.* (2019) suggested three types of transitivity triads. Homogeneous triads are composed by just one category (that is, either sociotechnical systems, directionalities, or framework conditions); dominant SDG triads are made up of two categories of SDGs; and transformative triads are made up of all three SDG categories. Note. ST: Socio-technical System; SD: Social Directionality; FC: Framework Conditions.

## Results

### Analysis of research funding:

Figure 4 shows what happened to the research grants (APQs) funded by the Brazilian National Research Council (CNPq) in the period of this study (2007-2017). Between 2007 and 2013, there was an increase in funding. After 2013, however, there was a huge drop in investments. In 2017, the amount of funding corresponded only to 20% of the funding available in 2013. The drop in the investments caused a corresponding sharp drop in the number of projects and organizations supported by the agency. It is also important to note that the number of thematic areas decreased by half, indicating that in a context of funding reduction there might have been a prioritization of some areas over others.

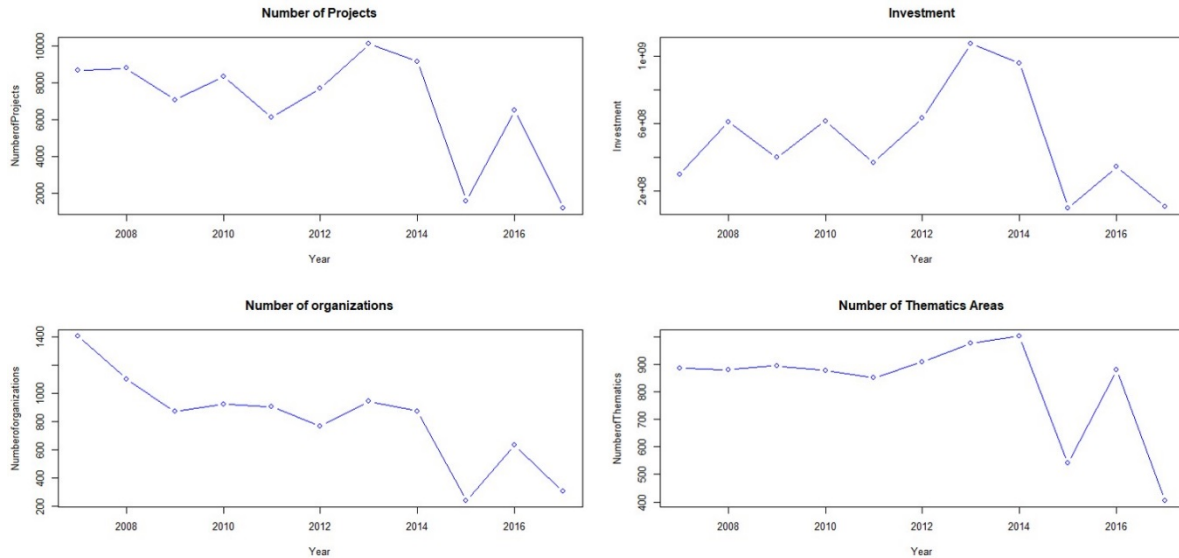


Figure 4: Funding of research projects by CNPq in the period 2006-2017.

### Analysis of SDG-related publications:

Figure 5 shows how many articles by Brazilian researchers were indexed in Web of Science (WoS) and SciELO databases in the period 2006-2017, as well as the number and percentage of SDG-related publications in this period. A different behaviour stands out in the two databases. In WoS there is steady increase in the number of articles published each year, from about 20,000 articles in 2006 to about 60,000 articles in 2017. In SciELO the number of articles per year also increased from about 12,000 articles in 2006 to 20,000 articles in 2013. After 2013, however, the number of citations in SciELO database remains stable.

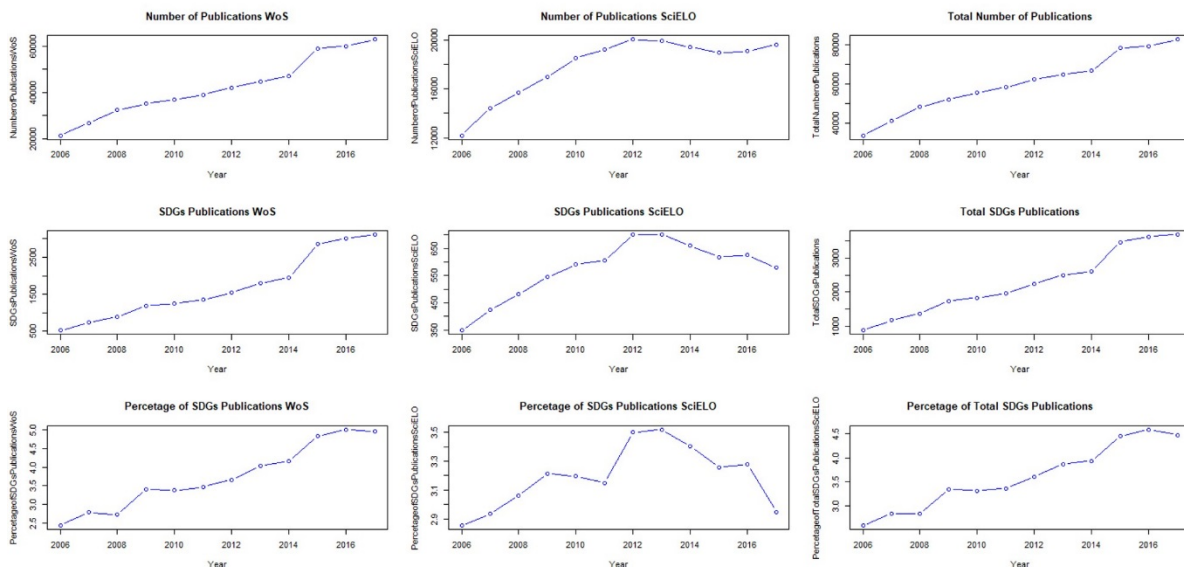


Figure 5: Total number of publications, number and percentage of SDG-publications in WoS and SciELO in the period 2006-2017.

With regard to SDG-related publications, its percentage increases in WoS from 2.5% in 2006 to 5% in 2016, when it stabilized. In SciELO, however, there is a steady increase in

preponderance of SDG related research up to 3.5% in 2013, followed by a sharp decrease back to initial levels in 2017.

Figure 6 shows the main areas of SDG-related publications in WoS and SciELO databases. In WoS health care (Goal 3), water and sanitation (Goal 6), responsible production and consumption (Goal 12), industry and innovation (Goal 9), education (Goal 4) and climate change (Goal 13) appear in this order as the top five SDGs. In SciELO, the most relevant SDGs are also health care (Goal 3), water and sanitation (Goal 6), education (Goal 4) and responsible production and consumption (Goal 12), although health care detaches itself more clearly from the other areas at the top, whereas innovation (Goal 9) and climate change (Goal 13) become less important. In both databases, there is a low number of publications related to social issues, such as poverty (SDG1) and inequality (SDG 10). SDGs related to the environment, such as life below water (SDG 14) and life on land (SDG 15), are not abundant in both databases either.

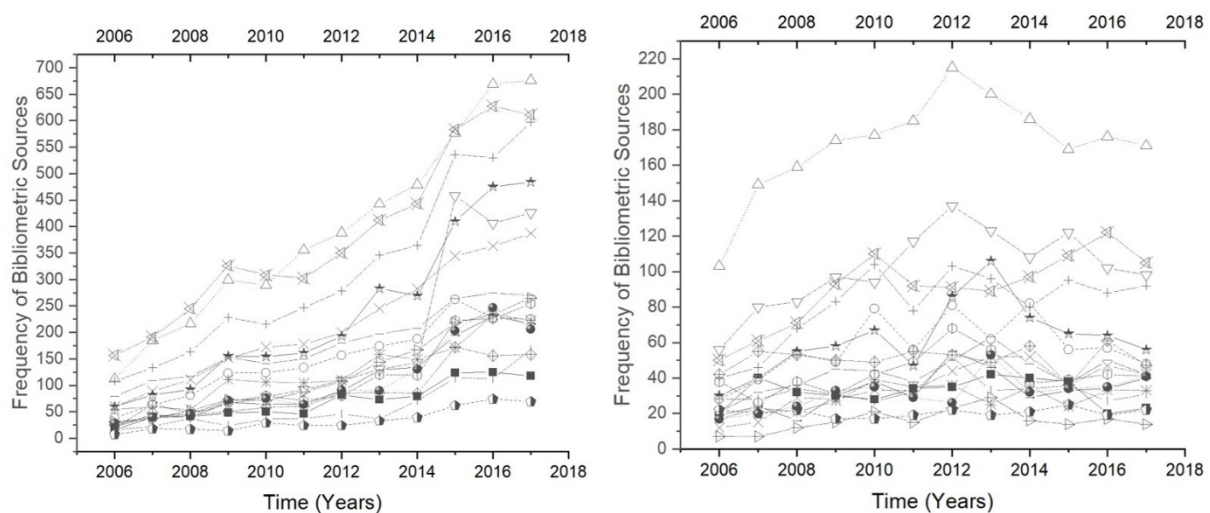


Figure 6: Number of SDG-related publications in WoS (left) and SciELO (right) databases.

In summary, until 2013 there was an increase in research funding, an increase in total Brazilian publications, as well as in SDG-related publications. After 2013, in a context of crises in funding, SciELO and WoS show different behaviours. Whereas in WoS the total number of articles kept rising, there was no further increase in SciELO. Furthermore, after 2013 the percentage of SDG-related publications in SciELO drastically drops. In terms of composition, SDGs related to important public sociotechnical systems, like health care (SDG 3), education (SDG 4) and water & sanitation (SDG 6), are very relevant. On the other hand, SDGs related to environmental and social directionality, such as poverty (SDG1), inequality (SDG 10), life below water (SDG 14) and life on land (SDG 15), are less frequent. SDGs associated with global issues, such as climate change (SDG 13) and industry & innovation (SDG 9), are more frequent in WoS. We assume that differences in the composition of both databases derive from their nature. SciELO mainly contains local and regional publications, which might preferentially address local challenges as well as be more sensitive to constraints in Brazilian funding. WoS publications, on the other hand, are more international and likely to be more specialized;

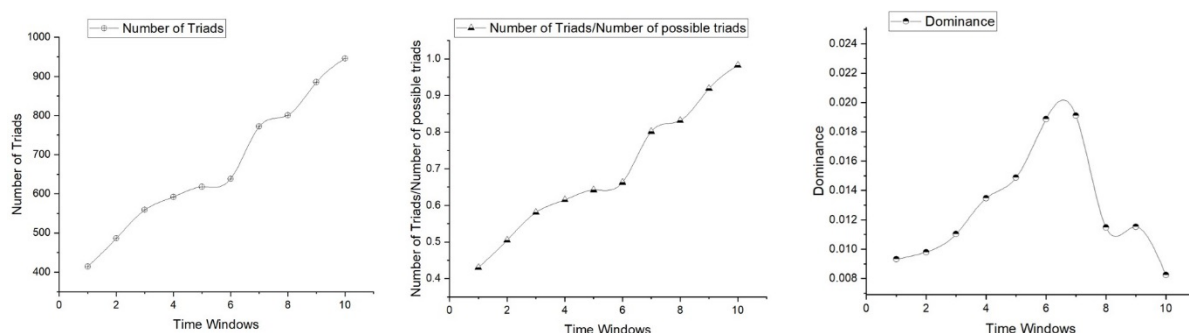
therefore, they deal preferentially with global issues and show greater resilience to crises in the national research system.

### Analysis of knowledge networks:

Knowledge networks are important to detect groups of articles that express a high degree of thematic similarity between them (Grauwin and Jensen, 2011). Through this thematic proximity, it is possible to understand whether a publication that focuses on one SDG is related to other SDGs. For example, if an article about health (SDG 3) shares bibliography with articles dealing with issues of poverty (SDG 1) and nutrition (SDG 2) it means they belong to the same knowledge network.

Based on number and composition of triads (combination of 3 articles sharing bibliography) and transitivity (number of triads/number of possible triads) we were able to estimate: 1) the size and diversity of the knowledge networks formed in WoS and SciELO; 2) the degree of interaction between different categories of SDGs; 3) the most frequent SDG combinations.

In order to understand the size and diversity of the knowledge networks formed in WoS and SciELO, we calculated the total number of triads, their transitivity and dominance. Figure 7 shows that in WoS the total number of triads (combination of three articles that share references) increases over time and so does the transitivity (number of triads/number of possible triads). There is, therefore, an increasing amount of new article combinations, bringing more thematic diversity into the system. In SciELO, on the other hand, the opposite happened. After 2013, SciELO knowledge network collapsed with a fall in the total number of triads and a corresponding increase in the dominance of a few triads. In other words, many triads that had lower frequencies disappeared, causing a reduction in the network thematic diversity or interdisciplinarity. This probably happened because of the decline in SDG related publications, which followed the crises in research funding after 2013.



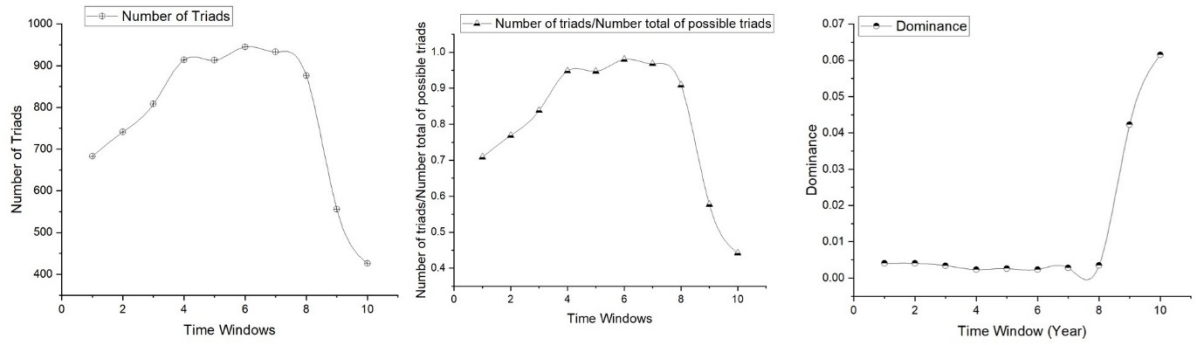


Figure 7: Triads dynamics in WoS (upper) and SciELO (lower) databases.

In order to assess the degree of interaction between different categories of SDGs according to the TIPC SDG-model shown on Figure 1, we calculate the percentage of triads in WoS and SciELO databases with interactions between SDGs related to sociotechnical systems (ST), transversal directions (SD) and framework conditions (FC).

According to the scheme in Figure 3, transformative triads should include the three categories of SDGs. Figure 8 shows that in both databases about 20% of the triads are homogeneous and formed only by SDGs of sociotechnical type (ST-ST-ST). 50% to 60% of the triads are of the dominant type, combining SDGs of sociotechnical type with those dealing with transversal directions (ST-ST-SD or SD-SD-ST). On the other hand, 10% to 20% of triads are highly transdisciplinary in nature (FC-SD-ST). However, it is relevant to note that, after 2013, there is a decrease in the percentage of the latter in SciELO, whereas the sociotechnical, homogeneous type of triads increase. This result complements the findings on Figure 7, showing that in a context of crises, there is a decrease in diversity of knowledge networks in SciELO and that, in such a context, interactions between different SDG categories are negatively affected.

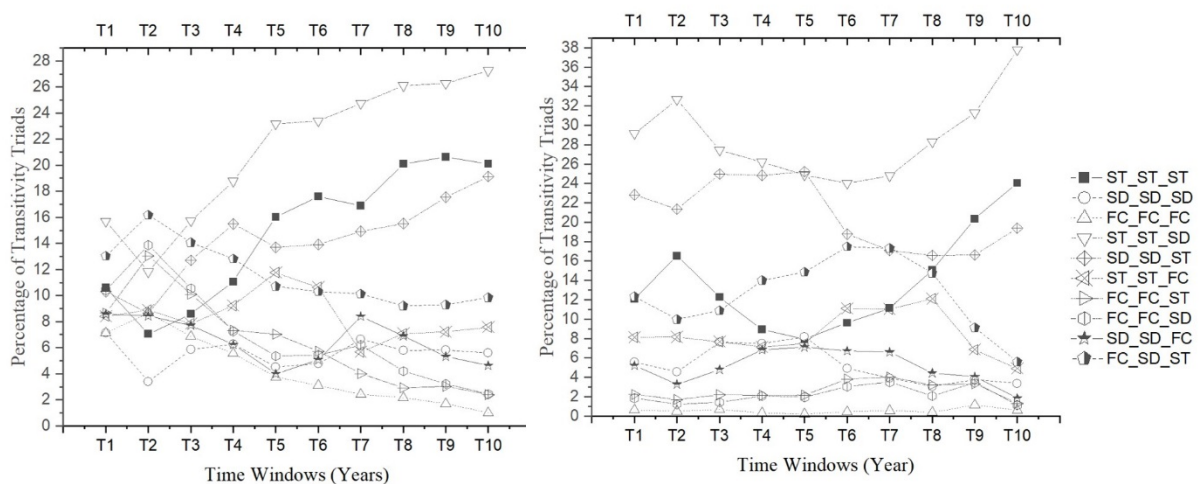


Figure 8: Percentage of transitivity triads in WoS (left) and SciELO (right) databases (ST= sociotechnical systems, SD= transversal directions, FC= framework conditions).

In Figure 9 (WoS) and Figure 10 (SciELO), we display the most frequent SDG combinations in the triads within the period of the study. In WoS, clean water and sanitation (SDG 6) is the most important SDG in terms of interactions with other SDGs. It shares a common knowledge base with publications on responsible production and consumption (SDG 12), with industry and innovation (SDG 9) and with health (SDG 3). Although they were not abundant in terms of number of publications (Figure 6), SDGs related to ecological systems, such as SDG 14 (life under water) and SDG 15 (life on land), played an important role in building many interactions with other SDGs, especially with SDG 2 (zero hunger). After 2013, SDG 4 (education) started to build important relationships with SDG 12 (production and consumption) and health (SDG 3).

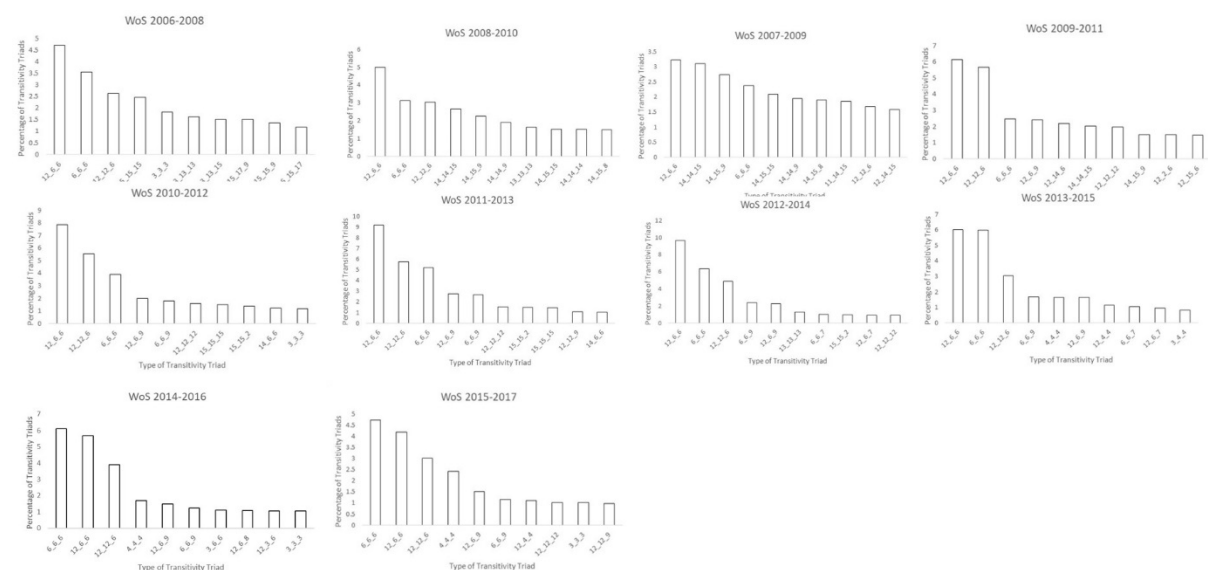


Figure 9: Triads (relationships between three SDGs) in WoS in different times.

In SciELO (Figure 10) from 2006 to 2013, education (SDG 4) was the most relevant SDG in terms of interactions, often combining with gender equality (SDG 5), employment (SDG 8) and health (SDG 3). In 2013, clean water & sanitation (SDG 6) and production & consumption (SDG12) started to play an important role in the system, combining with health (SDG 3). From 2014 onwards, however, the diversity of the system brakes down, with triads containing SDG 6 (water and sanitation) accounting for more than 50% of the triads, acquiring a fairly dominance in the system. This result is consistent with the increase in dominance and decrease in transitivity shown in Figure 7.

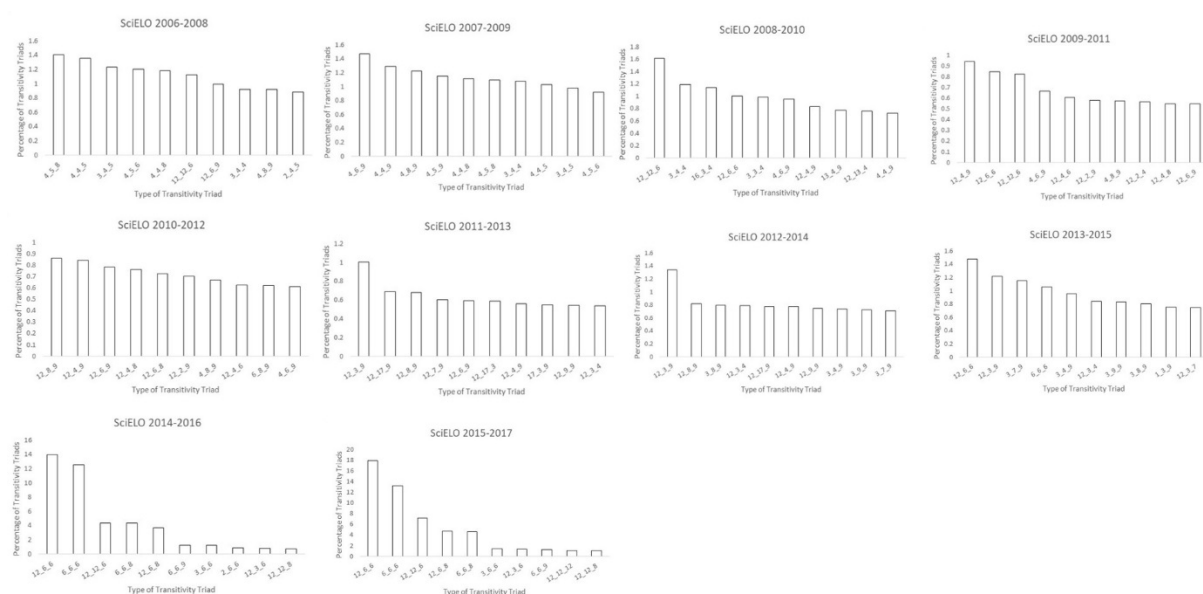


Figure 10: Triads (relationships between three SDGs) in SciELO in different times.

In summary, our results reveal that the pattern of SciELO knowledge network dramatically changed after 2013, when the crises in R&D funding in Brazil began. The system became less diverse and dominated by a few triads. Homogeneous triads became more abundant than transdisciplinary triads, meaning that SDGs related to transversal directions did not interact as often with SDGs related to sociotechnical systems. SDG 6 (water and sanitation) became dominant, whereas other important sociotechnical systems, such as health and education lost importance. The WoS knowledge network, on the other hand, was more stable throughout the whole period of study. As previously explained, SciELO might be less resilient to reductions in funding because it is mainly composed by local and regional journals, in contrast to WoS, integrated mainly by international publications.

### Analysis of knowledge communities:

Co-bibliography networks allow knowledge communities or groups of articles that express a high degree of thematic similarity between them to be identified (Grauwin and Jensen, 2011). In this work, we assessed the emergence of communities closely related to the SDGs and highlighted those which combined sociotechnical systems with transversal directions, as depicted in Figure 1.

In WoS we found a network of 20,227 articles associated with the SDGs. These articles formed 173 knowledge communities. In general, these communities have a high tendency to address SDGs of sociotechnical type. However, some communities combine both socio-technical with social and environmental SDGs. For example, in Figure 11 there is a community on “water quality”, which combines SDG 6 (water & sanitation), SDG 12 (responsible production & consumption) and SDG 15 (life below water). Other important examples of interdisciplinary communities combine education and sustainability; health, gender equality and justice; life on earth, life under water and zero hunger; climate change, life on earth and water & sanitation.

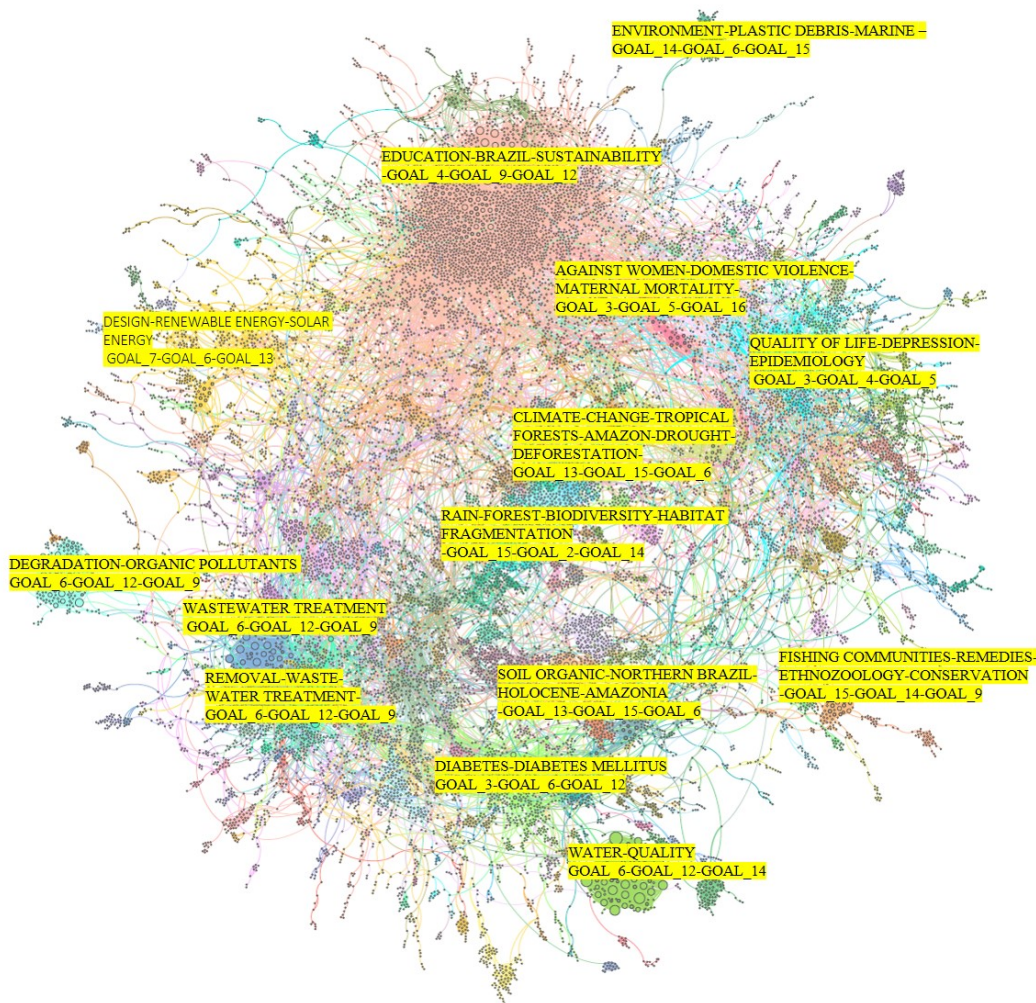


Figure 11: Formation of knowledge communities in WoS.

In SciELO we found a network of 6,878 articles associated with the SDGs. These articles were grouped in 75 communities. In Figure 12 we show the most relevant communities combining sociotechnical and directionality SDGs. There are examples of sociotechnical systems closely related to local challenges such as education (SDG 4), employment (SDG 8), health (SDG 3) and water & sanitation (SDG 6) interacting with ecological and social issues, such as gender” and “sustainability”.

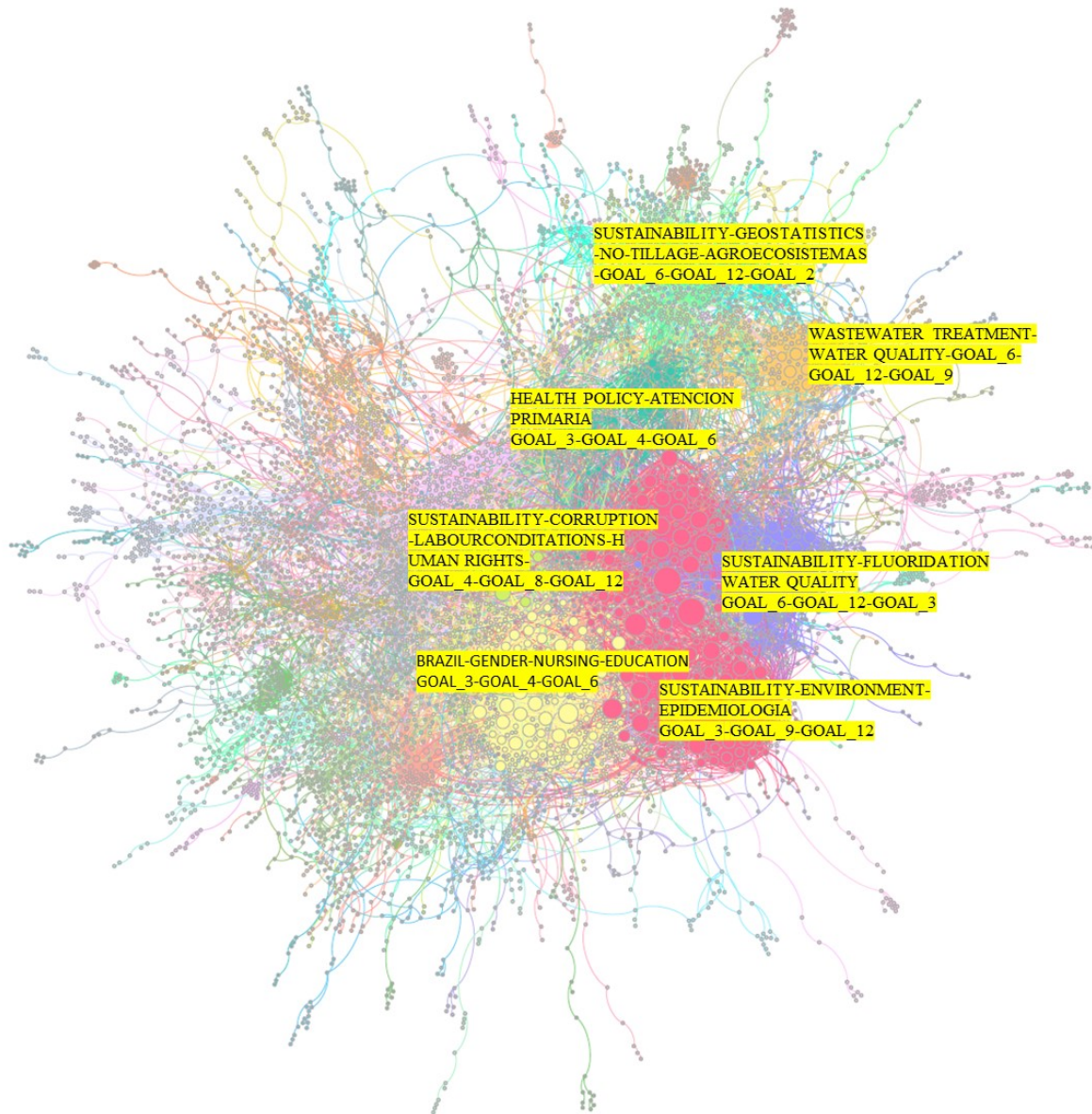


Figure 12: Formation of knowledge communities in SciELO.

### Conclusions and policy recommendations:

The transformative innovation approach considers research, especially in science, technology and innovation as a potential key enabler of the transformations that will lead to the fulfilment of the SDGs. In this study, we used bibliometric data and tools from Social Network Analysis to analyse the characteristics of the SDG-related research in Brazil over the last 10 years. Our main conclusions are:

- 1) A very low proportion of the Brazilian research production addresses the SDGs (2.5% to 5%). Actually, after 2013, in a context of crises in R&D funding, this proportion further decreased in SciELO, a database mainly formed by local and regional publications. Topics related to environmental sustainability and social inclusion, such as life on land, poverty and inequality, have been especially neglected. Therefore, it

is important to increase investments in research associated with the SDGs. A positive step in this direction might be the implementation of the Brazilian National Strategy for Science, Technology and Innovation 2016-2022 (ENCTI), which actually includes many SDG-related topics amongst its main challenges.

- 2) In a scenario of reduction of funding, there is a breakdown of the SDG-knowledge network in SciELO, with a decrease in the diversity of the system and the percentage of transformative triads. This is very concerning, since interactions between different categories of SDGs are fundamental to support transformation. Our results show, for example, that, although not as important in terms of amount of publications, SDGs related to environmental and social issues, such as climate action, life on land, decent work, no poverty, etc., build important connections with sociotechnical SDGs, like sanitation, health and education. These connections are necessary to give directionality to sociotechnical systems. Therefore, it is important to implement policies that support transdisciplinary SDG-related research. The calls for projects Nexus I e Nexus II, launched in 2018 by the Brazilian Ministry of Science and Technology and the National Research Council (CNPq), which integrate water, energy and food security, are good examples of such policies already in place.
- 3) We found positive examples of knowledge communities combining sociotechnical and directionality associated SDGs. These knowledge communities represent potential thematic compositions that could be relevant to create, strengthen or promote transformative niches. It would be important to assess their degree of maturation and actual collaboration between their members in future studies. Building a knowledge base around the communities would allow to focus interventions more effectively and to implement policies to support these initiatives.

In conclusion, investment in the research system, especially in science, technology and innovation could be the driver of transformation for Brazil to meet the SDG targets by 2030. However, to support transformation the research system has to transform itself. ST&I policies should become more transformative and give more priority to environmental and social issues. Second, research and civil society actors should be encouraged to work together across transdisciplinary fields, combining sociotechnical with environmental and social issues (directionality).

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