

Addressing the Sustainable Development Goals at Utrecht University

Commissioned by Utrecht University
Centre for Global Challenges and
Utrecht University Executive Board

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1. Extended Summary

1.1. Introduction

The UN Sustainable Development Goals (SDGs) present a global agenda addressing social, economic, and environmental challenges in a holistic approach. The development of new knowledge is central to this agenda. Universities thus have a major responsibility to contribute to achieving these goals.

To support this type of change a systemic view of knowledge production is needed, operationalized by us by using a transformative lens. Drawing on sustainability transitions work (Grin J., Rotmans J., & Schot J., 2010; Ramirez, Romero, Schot, & Arroyave, 2019; Roberts & Geels, 2019; Schot & Kanger, 2018), we analyse whether and how knowledge trajectories that integrate new social and environmental directionalities are intertwined with knowledge trajectories focused on single or multiple sociotechnical systems, and incorporate knowledge trajectories addressing framework conditions such as peace, justice, and partnership (Ramirez et al., 2019; Schot, Boni, Ramirez, & Steward, 2018). Below we elaborate upon the transformative lens employed in the project.

Here we stress that knowledge production addressing the SDGs is fundamentally different from knowledge production in other areas in a number of ways. Firstly, addressing the SDGs introduces an element of directionality in research (Cornell et al., 2013; Ramirez et al., 2019; Sachs et al., 2019). Furthermore, research requires a variety of approaches related to the complexity associated with the SDGs (Arroyave et al., 2021; Frost et al., 2019; Stirling, 2009). Moreover, pursuing integrated research and decision-making related to the SDGs fundamentally depends on understanding interactions between them, both negative ("trade-offs") and positive ("co-benefits") (McCollum et al., 2018; Nilsson, 2015; Nilsson et al., 2018; Weitz, Carlsen, Nilsson, & Skånberg, 2018), and how these interactions contribute to transformative change (Ramirez et al., 2019; Schot et al., 2018).

In this report we will contribute to a more systematic understanding of the growth and development of SDG research at Utrecht University for the period 2000-2019. We map the emergence of the SDGs research, including single SDGs analysis and interactions across the SDGs (and non-SDG) research communities using our transformative lens. Additionally, we have interviewed researchers working in knowledge communities that study multiple SDGs and their interactions. The findings from these interviews are assisting us in making preliminary propositions related to mechanisms for triggering knowledge production associated with the SDGs.

We anticipate that the results will support Utrecht University (UU) in identifying and profiling the thematic orientation of its research in the framework of the SDGs. Thus, our result will help to increase the transformative potential of Utrecht University (UU) research through adding a reflexive layer which researchers can employ for 'bottom-up' navigation. Our results do not only aim to enhance the development of common visions by characterizing current capabilities, but also permitting the analysis of the actual potential of the Utrecht University (UU) research system as a key enabler for achieving the SDGs. The transformative potential is uncovered by mapping the SDG interactions occurring within Utrecht University's research system.

1.2. Knowledge trajectories and knowledge system transformation.

To fully appreciate the multifaceted nature of SDG research and to understand knowledge production with Utrecht University (UU), studying how knowledge trajectories have emerged around and connect to multiple SDGs is critical (Ramirez et al., 2019; Schot et al., 2018). The generation, consolidation and growth of such trajectories depends upon existing knowledge blocks from multiple knowledge domains (Boschma, Heimeriks, & Balland, 2014; Heimeriks & Leydesdorff, 2012) such as energy, water, politics, history, sustainable food, and environmental health. However, the integration of such diverse knowledge domains implies a major challenge,

since each knowledge domain has its own specificities, and the integration of knowledge bodies usually encounters high institutional barriers (Grauwin & Jensen, 2011; Shiffrin & Börner, 2004).

In addition, integrating multiple bodies of knowledge associated with the 17 SDGs is essential to deploy diverse solutions to social and environmental challenges, as well as visualising disagreements and a diversity of various knowledge claims (Arroyave et al., 2021; Rafols & Meyer, 2010; Stirling, 2007). This brings significant implementation uncertainty and fuzzy conceptual translation issues across the goals (Heimeriks & Balland, 2016) that only can be dealt with in a process of trust building and embracing multiple opinions within the implementation process.

The emergence of knowledge trajectories has been studied through analysing the development of knowledge clusters and the interactions across multiple knowledge domains (Boschma et al., 2014; Heimeriks & Leydesdorff, 2012). Those studies posit the relatedness between knowledge topics and fields as a main mechanism of trajectory development (Arroyave et al., 2021; Boschma, Coenen, Frenken, & Truffer, 2017; Boschma et al., 2014). In this report, cognitive interactions between SDGs topics are studied in a similar manner, as well as the entry and exit of knowledge building-blocks accumulated in the Utrecht University (UU) knowledge system. We have added a new element, the idea of a transformative lens, explained in further detail below.

The analysis of cognitive trajectories involves the use of network analysis and synthetic indices which give details of the structure and dynamics of research systems (Arroyave et al., 2021; Boschma et al., 2014; Rafols & Meyer, 2010; Shiffrin & Börner, 2004). Building on this notion, a diversity model based on triads census distribution (using the transformative lens of counting of cognitive interactions between groups of three SDGs) is used (Ramirez et al., 2019; Schot et al., 2018). We also identify existing knowledge structures by identifying knowledge clusters as a proxy of cognitive cohesion in the Utrecht University (UU) research system (Arroyave et al., 2021; Grauwin & Jensen, 2011; Ramirez et al., 2019). We further elaborate on the transformative lens used in the project before presenting the results.

1.3. The transformative lens

Following the Transforming our World strapline of the UN Agenda 2030, we use the transformation lens framework (Ramirez et al., 2019) to study the cognitive and social integration of multiple SDGs. This framework suggests that the transformative potential of knowledge system increase when SDGs integration happen between three types of SDGs (see figure 1), described as follows:

- Socio-technical systems and application areas: SDGs that address areas of basic needs that need to be transformed, such as Zero Hunger (SDG 2), Good Health and Wellbeing (SDG 3), Quality Education (SDG 4), Clean Water and Sanitation (SDG 6), Affordable and Clean Energy (SDG 7), Industry, Innovation and Infrastructure (SDG 9), and Life Below Water focusing on fishing (SDG 14). These areas are defined as socio-technical systems and niches provisioning for these basic needs. These SDGs represent alternatives to the current dominant practices that have exacerbated environmental and social problems.
- Transversal directions: SDGs that address directions of change, such as No Poverty (SDG 1), Gender Equality (SDG 5), Decent Work and Economic Growth (SDG 8), Reduced Inequalities (SDG 10), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13); and Life on Land with its focus on biodiversity (SDG 15).
- Framework conditions: SDGs addressing framework conditions for a change in process: Peace, Justice, and strong Institutions (SDG 16) and Partnerships for the Goals (SDG 17).

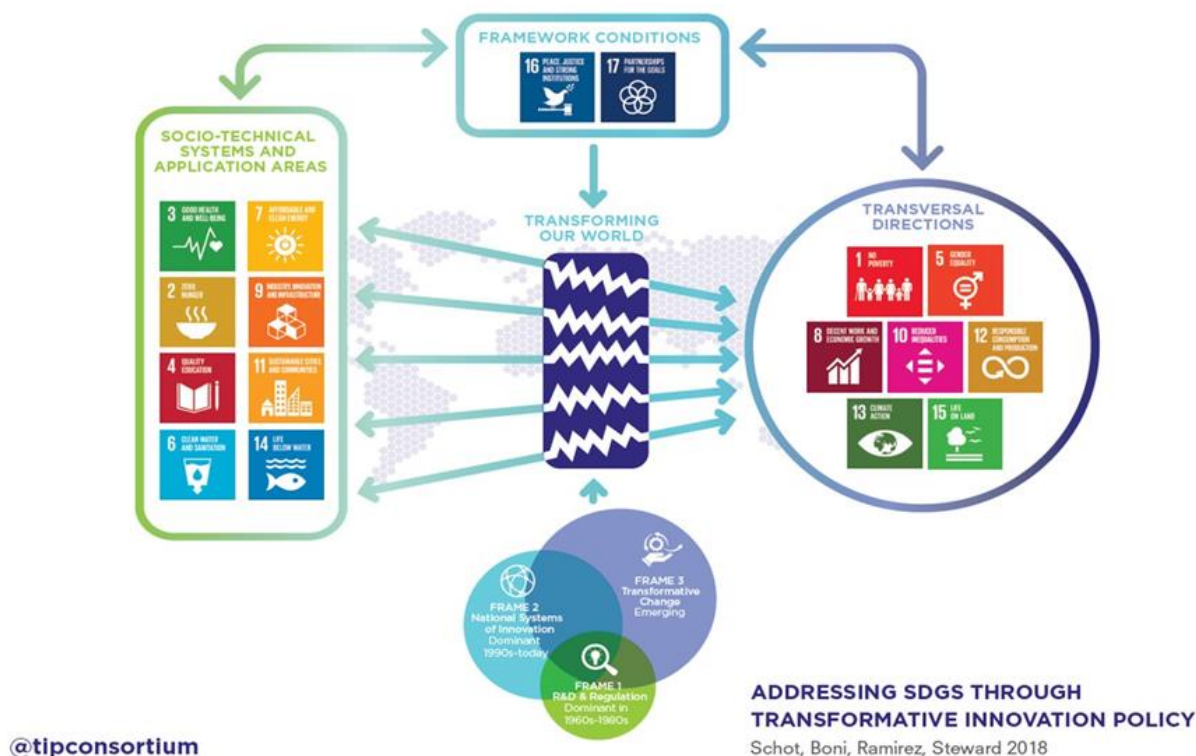


Figure 1. Transformative lens. Addressing the SDGs requires a focus on transformation. The UN Agenda 2030 refers to 17 SDGs for transforming our world. Therefore, the transformation idea is positioned in the centre of the graph. Through this transformation lens drawing on sustainability transitions theory, SDGs are classified within three categories: sociotechnical systems (ST); framework conditions (FC); and transversal directionalities (TD) as shown in the graph. This categorization assumes a need for a specific type of interactions across these categories. Finally, it visualizes how this transformation necessitates an original type of research policy not simply relying on investment (frame 1); on network formation (frame 2) but on an explicit focus on transformative change (frame 3). see Ramirez et al., 2019; Schot & Steinmueller, 2018.

The transformative lens underlines the necessity of developing knowledge trajectories that integrate two and ultimately three types of SDGs. An example would be research that includes a focus on one or more areas that have to be transformed (e.g., sustainable agriculture, SDG 2) into a specific direction (e.g., reduction of inequalities, SDG 10), thereby considering framework conditions (e.g., partnerships necessary for implementing sustainable practices in a social justice way, SDG 16 & 17). Such research can to a larger extent and more effectively catalyse research from multiple knowledge domains, thereby triggering synergies and increasing the transformative potential.

1.4. Methodological approach

To map and analyse the transformative potential, this research employs a mixed methods approach, combining a quantitative with a qualitative approach (figure 2). The quantitative approach consists of a number of steps: firstly, the development of the knowledge trajectories and knowledge clusters between 2000 and 2019 are examined by analysing Utrecht University's bibliometric dataset using publication data from Web of Science (WoS). The cognitive interactions between SDGs are then characterised by describing the most frequent triads formed by SDG publications in a co-bibliographic network (where academic publications are connected by a high percentage of common bibliography, for more detail see the extended report).

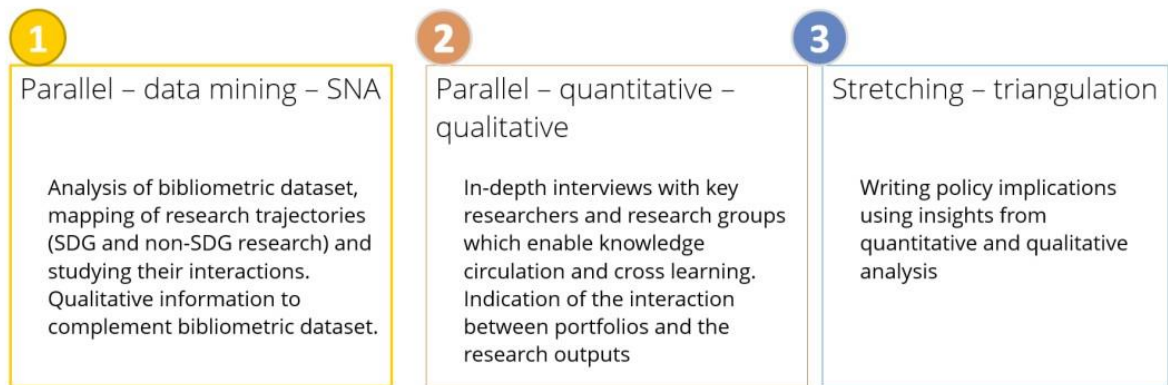


Figure 2. A sequential mixed method approach is undertaken. The first phase focuses on mapping scientific publications related to the SDGs; during the second phase we use semi-structured interviews to provide detail of how researchers undertake research which catalyses multiple SDGs. Lastly, in the third phase we combine the insights gained from phase 1 and 2 to provide a policy recommendation.

Thirdly, both knowledge clusters that integrate various SDGs and the knowledge clusters that support work on SDGs in an indirect way are identified. This research does not assume that all research should be directly related to specific SDGs but instead makes visible how non-SDG-related research provides a supporting knowledge basis for SDG related work. The qualitative part is based on 13 interviews (around 3 for each selected clusters) and a workshop with 27 participants in which the findings of the interviews was corroborated. This qualitative part of the methodology allows for an identification of enabling conditions and a characterisation of the bottom-up strategies that help to integrate and enable SDG research at Utrecht University (see extended report for a detailed explanation of the methods).

1.5. Key Findings of quantitative research.

Generally speaking, the quantitative results show that the most frequent SDG trajectories emerge around Health and Wellbeing (SDG 3), Climate Action (SDG 13) and Clean Water and Sanitation (SDG 6) (figure 3).

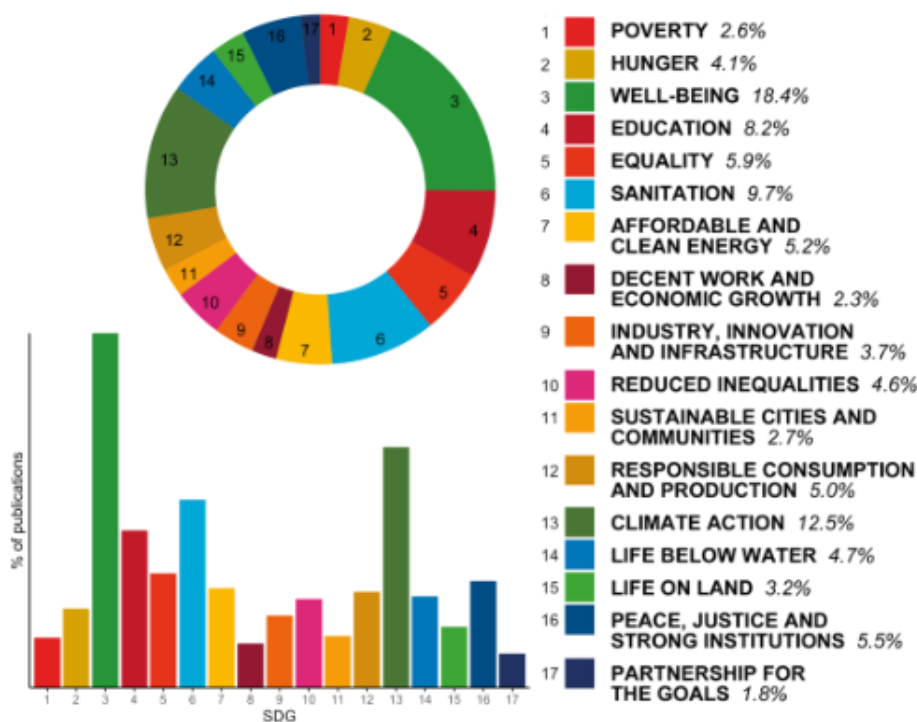


Figure 3. Multiple representations of the SDG publications. Percentage of SDGs publications at Utrecht University from 2000 to 2020.

Figure 3 & 4 illustrate that both Utrecht University and the non-UU Dutch papers (NL) have the highest amount of publication located in Good Health and Wellbeing (SDG 3), both show a steep increase over the past 20 years (figure 4). One noticeable difference is that Utrecht University has a relatively large number of publications on Climate Actions (SDG 13), as compared to the non-UU Dutch(NL) research.

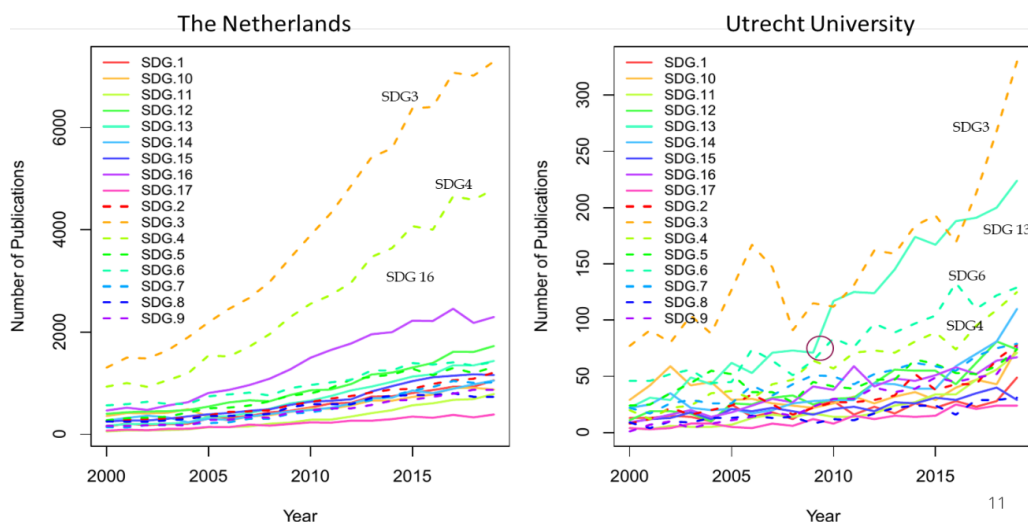


Figure 4. Annual number of publications per SDG for the non-UU Dutch papers (NL) and Utrecht University. The total amount of publications in the Netherlands is 726,477 between 2000 and 2020; 48,994 of these publications are associated with Utrecht University. 273,903 publications are related to the SDGs in the Netherlands, meanwhile 17,896 are from Utrecht University.

To analyse the interaction between the SDGs and how SDGs are simultaneously addressed at the Utrecht University the transformative lens has been employed with a triad census analysis (see table 1). The most frequent triad (three SDG papers cognitively connected) is 13-13-13 (Climate Action), which is a combination of the categories TD-TD-TD (transversal directionality). This is in line with the analysis of the individual SDGs, illustrating that Utrecht University has many publications relating to SDG 13 (see the extended report).

	Triad	Category	Frequency	Share
1	13-13-13	TD-TD-TD	4578	10.0%
2	13-6-6	ST-ST-TD	3417	7.5%
3	13-13-6	ST-TD-TD	3214	7.0%
4	3-3-3	ST-ST-ST	2012	4.4%
5	6-6-6	ST-ST-ST	1987	4.3%
6	13-13-14	ST-TD-TD	1793	3.9%
7	7-7-7	ST-ST-ST	1050	2.3%
8	11-3-3	ST-ST-ST	987	2.1%

Table 1. Triad senses analysis. Total number of SDG triad combinations in the network: 682 Total number of triads in network: 45 824. The most frequent FC-ST-TD triad combination is: 13-17-6 (frequency = 87 (0.19%))

The most frequent triad is 13-13-13. This triad is a combination of three transversal directionalities. The 10 most frequent triads (number of papers making specific combinations) at Utrecht University are found to focus on sociotechnical systems or transversal directionalities, or a combination thereof (for example 13-6-6, a combination of ST-ST-TD). None of the 10 most frequent triads combine all three categories (FC-ST-TD). The most frequent triad which combines the three SDG categories is the triad between Climate Action (SDG 13), Clean Water and Sanitation (SDG 6), and partnership for the Goals (SDG 17), which represents only 0.19% of the triads in the whole network. The most frequent interactions that combine two SDGs are: Climate Action and Clean Water and Sanitation (SDG 13 and 6); Climate Action and Life Below Water (SDG 13 and 14) and Good Health and Wellbeing and Sustainable Cities and Communities (SDG 3 and 11). These represent interconnectivity between sociotechnical systems and transversal directionalities (table 1).

1.6. Knowledge cluster dynamics & knowledge circulation

Next to mapping publications about individual SDGs and interactions across SDG, we have identified specific knowledge clusters consisting of a group of similar publications using similar references. In Figure 5 the SDG related knowledge clusters are coloured by their main SDG. Within a cluster there can be – and in most instances are – multiple SDGs, but for the simplification of this graph the most prominent SDG in the publications within the cluster is used. Analysing figure 5 we see that there are two prominent knowledge clusters, one related to Health Care and wellbeing (SDG 3) and one related to Climate Action (SDG 13). The SDG 13 group is located at the (top) edge of the network, which indicates that the research concerned with climate change shows less interaction with other research areas and clusters in the network. The SDG 3 group is located at the bottom, towards the centre, of the graph. This knowledge group is connected to many other clusters and plays an important role in the circulation of knowledge, due to its location in the network. There is one cluster, slightly above centre in the network, concerned with Clean Energy (SDG 7) (number 176). This cluster can catalyse knowledge related to the health and medication cluster (mostly SDG 3, to the right), the urban development and energy development clusters (SDG 9, 11, to its left), as well as with the climate action group (SDG 13, above it). See the extended report for further detail on the circled knowledge clusters.

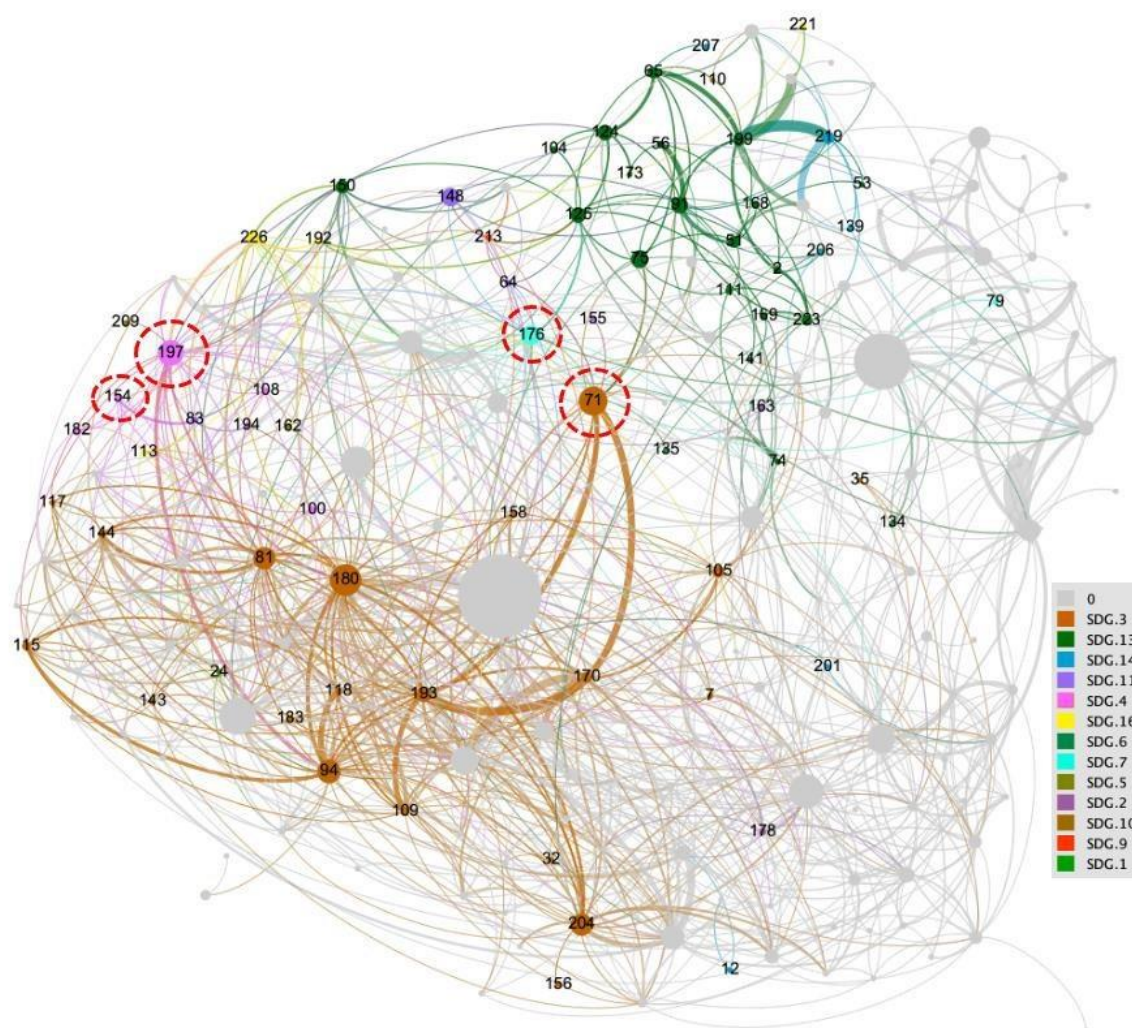


Figure 5. Utrecht University network of knowledge clusters. Nodes in the network represent a cluster consisting of a group of similar publications in terms of their bibliography. Clusters are coloured by their main SDG and labelled by their cluster number (ID), while grey nodes are clusters composed of less than 30% of SDG publications. Node size is the betweenness centrality of the cluster. The network shows that the SDG clusters are located throughout the network and interact with many other SDG clusters and other non-SDG clusters, indicating that SDG research at Utrecht University is well embedded in the scientific landscape and is found in different research areas and disciplines. Circled nodes are clusters that are analysed in depth

1.7. Triads in knowledge clusters

In this section the cluster analysis and the triads census distribution are integrated. The relative frequency of triad categories in each SDG cluster is plotted (figure 6). Most knowledge clusters have a relative high frequency of triads in the transversal directions (TD) or sociotechnical systems (ST) categories, or a combination thereof. However, there are a few knowledge clusters showing a relative high frequency of triads that combine SDGs in all three categories (FC-ST-TD). These clusters are circled in red.

These knowledge clusters have a high transformative potential since their SDG research occurs in all three categories. The fact that only four clusters have a relatively high(er) frequency of triads in the FC-SD-TD group is indicative of the difficulty of combining the three different types of SDGs. To increase the transformative potential of SDG research, this type of interactions is desirable. The knowledge clusters that have a high frequency of triads in the FC-ST-TD group can offer insights in how to combine research on SDGs in all categories. In this regard, cluster 154 is analysed in more depth in the following qualitative part of the research together with the cluster with 71, 176 and

197 which also are in a central position within the network, permitting them to connect multiple clusters.

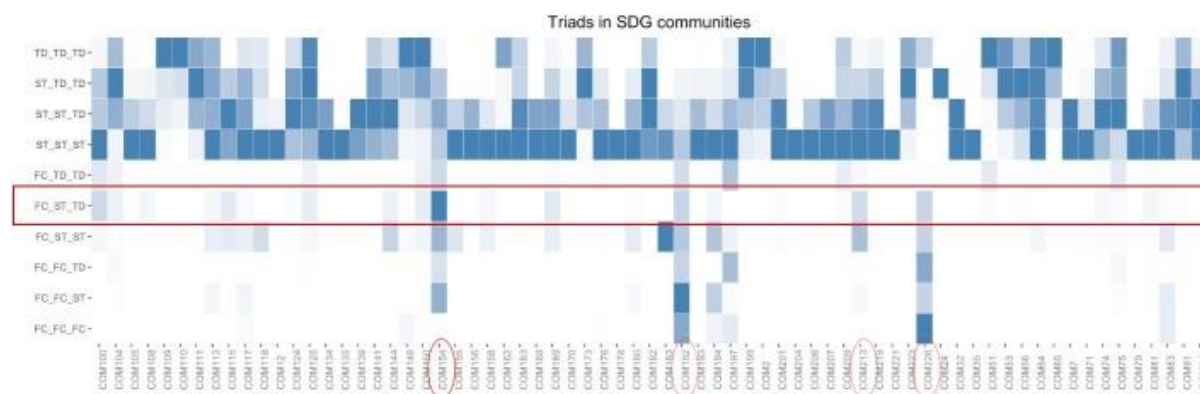


Figure 6. Heatmap of the triad categories per knowledge cluster. The heatmap is scaled column-wise, i.e., per SDG cluster. The darker blue a box is, the higher the frequency of that triad category within that cluster. TD: transversal directionalities; ST: sociotechnical systems; FC: framework conditions.

1.8. Qualitative results

In the qualitative part of our research, we explore the conditions and drivers that have enabled the emergence and development of clusters that catalyse multiple SDGs. Using the results of our quantitative work, four clusters were selected for further analysis, to identify in what ways they integrate or enable the integration of multiple SDG topics (figure 5, circled in red). Knowledge clusters are selected based on their location in- between several SDGs clusters and their centrality in the network. In figure 7 we present the main topics researched in the selected four clusters.

Within each of these knowledge clusters, we interviewed three leading researchers to gain a preliminary understanding of knowledge production that combine multiple SDGs. In Table 2 we summarise the analysis of the interviews specifically evaluating how and why researchers use the SDGs to develop their research agenda, the influence of the SDGs in their research motivation and collaboration strategies for undertaking research at Utrecht University (see extended report for a detailed analysis of the interviews).

Regarding the influence of the SDG on developing research agendas, we identify that most of the researchers interviewed acknowledge the importance of the SDGs (table 2) but do not experience a strong link between the SDG agenda and their own research agenda or activities, even though their work is closely related to SDG topics. They work on themes associated with social and environmental goals, but they do not link them to the SDG agenda. Moreover, they do not identify incentives to work on the SDGs. Other political agendas have better links with their research interests such as the Human rights International Law, the Environmental Risk Assessment (ERA), The Convention on Biological Diversity (CBD) or the Paris Agreement on Climate Change. Researchers have built their collaboration network and funding strategies around these other agendas.

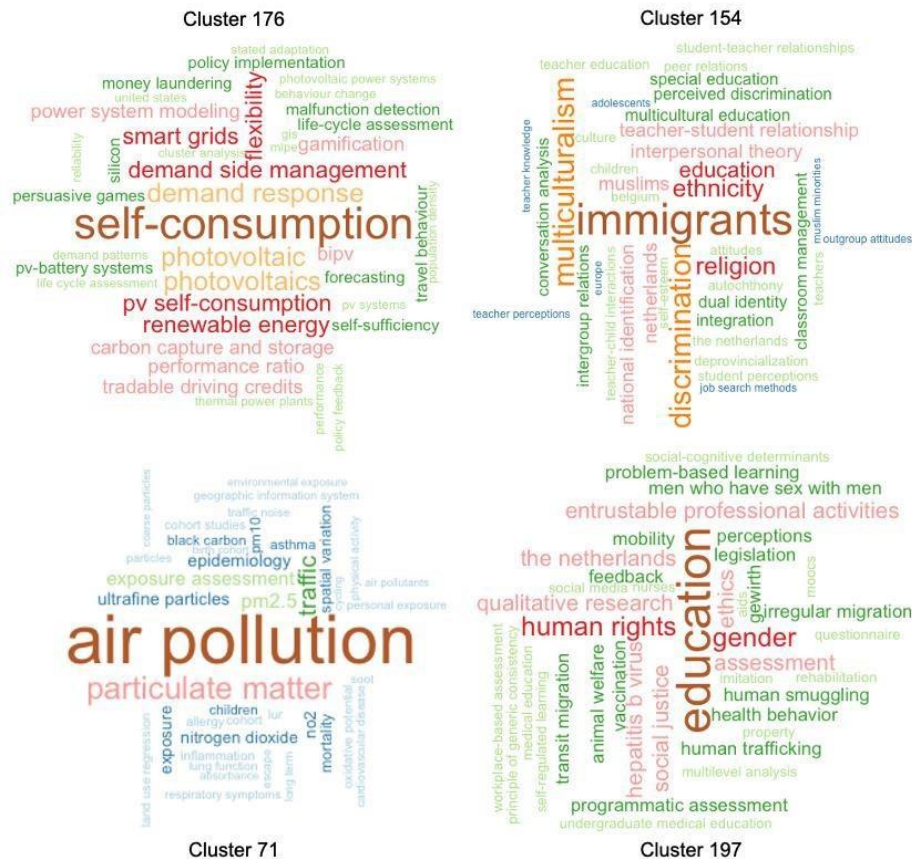


Figure 7. Word clouds of the selected SDG clusters. The word clouds are based on the author-keywords of all the publications in the cluster, with a maximum of 40 words. The larger a word, the higher the frequency of the keyword in the cluster. Cluster 176 mainly focuses on SDG 7 (clean energy), SDG 13 (climate action) and SDG 4 (quality education). The word cloud shows that the research topics are related to generating one's own (sustainable) energy (figure 7). Cluster 154 mostly contains research on SDG 4 (quality education) and SDG 10 (inequalities). Its word cloud shows that the research topics are associated with immigrants in relation to education. Cluster 71 relates to SDG 3 (healthcare) and SDG 11 (sustainable cities). Its word cloud shows that the research topics are related to air pollution caused by traffic. Cluster 197 relates to research on SDG 4 (quality education), SDG 16 (peace, justice, and institutions) and SDG 3 (healthcare). Its word cloud shows the research topics are on education on human rights and ethics.

As a continuation of this, we study the motivation of the researchers (Table 2). Our interviews show that research motivations depend on researcher personal interests and values associated with social and environmental goals. New areas of interest also emerge from interactions with colleagues. The researchers interviewed are part of a close-knit research community and thus research motivations draw on normative values and collaborations dynamics, but not so much on the SDGs. Therefore, the relation between researchers' agendas and the SDGs is more incidental than by design.

	SDG agenda	Research motivation	Collaboration
<i>Description</i>	Awareness of SDGs and the relation between the SDG agenda and personal research agenda	Motivation for research topic which addresses SDG(s)	Barriers and opportunities for interdisciplinary and international collaboration
<i>Key insights</i>	No good fits between an SDG agenda and personal research agenda	Most significant motivation is personal interests and personal values; research should be socially relevant. Relating to the SDGs seems more incidental as opposed to by design for most researchers	Reasons for collaboration are to improve research and include different views. Collaborating is difficult, but the benefits outweigh the difficulties. Lack of global funding opportunities is a challenge
<i>Opportunities</i>	Most researchers acknowledge the importance of SDGs and of creating awareness of how research relates to SDGs	Researchers see the importance of developments and the opportunities for their own research	Research questions on these topics require an interdisciplinary approach; Grant requirements for collaboration Networks & networking events are important to interact with (new) researchers
<i>Barriers</i>	Research already been undertaken on societal relevant topics: no impetus to link research to SDGs; (Extra) benefit of linking research to SDGs unclear; Lack of knowledge about SDGs	Knowledge trajectories around these topics have been accumulating over a long period and researchers build upon their own research and that of colleagues	Epistemological, methodological and philosophical differences between disciplines; Disciplinary-oriented funding agencies; Not all research is, or should be, interdisciplinary
<i>Funding</i>	Smaller grants could offer opportunities to experiment with research in relation to SDGs	Funding opportunities limit the options, but researchers would unlikely do research simply because there is funding available for it	Funding can stimulate collaboration but can become trivial. Lack of global funding opportunities is problematic
<i>Proposition</i>	Utrecht University can play a more active role in disseminating knowledge about the SDGs and creating an incentive to link research to the SDGs	Research is mostly motivated by societal relevance of the research and intrinsic motivation (personal interest). This is more important than the availability of funding	The Utrecht University Strategic Research Themes and Focus Areas are well placed for addressing SDG research that combines diverse concepts, methods, and countries

Table 2. Summary of qualitative results per categories

Funding opportunities can also influence researchers' motivations; almost all researchers acknowledge the influence of funding on developing research agendas. Nonetheless, researchers interviewed feel that they can also shape calls and generate new expectations about research topics. Ultimately interviewees argue that personal interest and societal relevance play a more relevant role in research motivation and starting a new research project than funding opportunities.

Results related to collaboration show the interest in building global networks with diverse partners (table 2). Researchers interviewed indicate that collaborating with researchers from other fields enables them to work on a topic in a broader sense. In this regard, the Strategic Themes and Focus Areas at Utrecht University have stimulated collaboration across faculties. For the selected knowledge communities, it is clear that Utrecht University Strategic Themes and Focus areas have played a role in generating interfaculty and interdisciplinary research.

International collaboration helps researchers to consider multiple contexts and have a more grounded understanding of their research topic. Although Utrecht University (UU) contributes to stimulating interdisciplinarity within the University, international collaboration emerges mainly through researchers' networks and networking events outside the university. Strategic themes and Focus areas do not play a large role here.

Interviewees also related barriers to collaboration (Table 5). These barriers are mainly epistemological and methodological differences in disciplines, but none of these barriers are significant enough to impede collaboration, meaning the benefits outweigh the costs. Researchers discussed that they found several ways to overcome these barriers, finding a common language and establishing a common goal for example.

Funding can also influence collaboration as some funding opportunities (grants) stipulate interdisciplinary or international partnership as a requirement (Table 2). The influence of funding in collaboration strategies depends on the characteristics of each knowledge community. For example, companies can become interested in research produced within community 176 on energy resources, often at a later stage to develop or improve a product. In contrast, corporations are less interested in research topics associated with education – in community 197, and public funding is limited for this type of research. Funding can also be a significant barrier for collaboration, whereas funding agencies are more disciplinary oriented, meaning there is a lack of funding for interdisciplinary projects (table 5). There are almost no funding schemes for research related to global challenges, including Global South countries and very few funding opportunities for worldwide research, whereas the SDGs are concerned with global problems.

Our qualitative findings allow us to make preliminary propositions related to the development of knowledge trajectories that integrate multiple SDGs (table 2). The following paragraphs present three propositions and provide further elaboration:

Utrecht University can play a more active role in creating awareness about the SDGs and motivating researchers to link their research to the SDGs. The majority of researchers interviewed acknowledge the importance of the SDGs. However, they do not identify a strong link between the SDG agenda and their own research agenda or activities, even though their work is closely related to SDG topics. Generating awareness around the role of researchers in the SDGs provides researchers with the opportunity to make strategic choices. There are two researchers interviewed that use the SDGs in their research. Their research is more closely related to agendas which are ingrained with the SDG agenda, as compared to other research which might be based on agendas with a more tenuous relation to the SDG agenda.

Researchers have an intrinsic interest in topics related to societal and worldwide relevance of topics, which does not necessary fit succinctly within the parameters of research funding. Even though most researchers interviewed do not identify a strong link between the SDG agenda and their own research agenda, their work is closely related to SDG topics. Their research is mostly motivated by societal relevance of the research and inherent motivation for the topic. The availability of funding restricts research possibilities but does not play a role in motivation for researching particular topics.

The Utrecht University Strategic Research Themes and Focus Areas are well placed for addressing SDGs research that implies the combination of diverse concepts and methods. The Utrecht University Strategic Themes and Focus Areas enable interaction across faculties and disciplines and offer small grants which researchers can use to experiment or initiate new research ideas with researchers from other faculties. Using this seed money, researchers are stimulated to do interdisciplinary research which combines multiple SDGs.

1.9. Conclusions

This summary report presents an overview of the analysis of the Scientific Knowledge Trajectories related to the Sustainable Development Goals (SDGs) at Utrecht University (UU). A principal conclusion is that research efforts related to the SDGs have grown rapidly in the period since 2000, covering all SDGs, but to a differing degree. This reflects the strategic direction which posits the SDGs as major guiding principles and places them at the heart of the operations and ambitions of the University. The quantitative results show that the most frequent SDG trajectories emerge around Health and Wellbeing (SDG 3), Climate Action (SDG 13) and Clean Water and Sanitation (SDG 6). Compared to the national trend, Utrecht University (UU) is particularly strong in research related to Climate Actions (SDG 13).

Our analyses show that there are many interactions across SDGs (and non-SDG) research communities. The interactions of Sociotechnical Systems with Transversal Directionalities (such as SDG 13 and SDG 6) are particularly strong, thus providing indications for an ongoing transformation of the research system. However, we identify that less than 2% of the research at Utrecht University combines SDGs from the three categories (socio-technical systems, transversal directionalities, and framework conditions). It is therefore a key area of research to be developed since the implementation of the SDGs implies that their complex interactions (synergies and trade-offs) are considered.

The results presented here can support Utrecht University (UU) in identifying the thematic orientation of its current research in the framework of the SDGs and will help to increase the transformative potential of Utrecht University research by adding a reflexive layer to be used for navigation by researchers and decision-makers at the University. The results can also be used for university profiling. Our qualitative results demonstrate that researchers at Utrecht University (UU) are interested in undertaking research which enhances interactions across the SDGs. The intrinsic interest of researchers in integrating diverse SDGs topics and the current facilities to collaborate at Utrecht University are already having a positive impact. However, Utrecht University may further increase its impact by increasing awareness about the SDGs within the University, generating reflections on SDG research, and employing seed money along with additional mechanisms to nurture and develop knowledge trajectories that integrate diverse SDGs.

We have identified the following opportunities for potential follow-up activities:

- Distribute results of this work more widely within the University and facilitate further discussions about how to navigate the results, in which directions the research could and should develop, setting of priorities (if any) and generating more interactions for example;
- Develop more insights on how Utrecht University (UU) compares with other institutions, and how its research is complemented and strengthened by its strategic collaborators;

- Develop further insights into the nature of national and international scientific collaborations of SDG communities, societal networks and partners of Utrecht University (UU) within these SDG communities;
- Applying the methodology to other universities or groups of universities;
- Deepen the qualitative work by studying a larger sample of research communities;
- Developing the methodologies used in this study, in particular how to measure the transformative potential.

2. Introduction

The UN Sustainable Development Goals (SDGs) present a global agenda addressing social, economic and environmental challenges in a holistic approach. The development of new knowledge is central to this agenda to enable transformation in our world. Universities thus have a major responsibility to contribute to achieving these goals.

To support societal change a systemic view of the scientific developments is needed. Furthermore, contributing to societal challenges requires transformation of existing institutions governing the development of science and technology. In this context, knowledge production should be understood as a participative process, transforming science from 'research that informs' towards 'research that transforms' (Tilbury, 2011)

Knowledge production addressing the SDGs is fundamentally different from knowledge production in other areas in a number of ways. Firstly, addressing the SDGs introduces an element of directionality in research. Starting from very different local contexts, SDG research aims at contributing to a global transformation. The manner in which research is conducted requires different approaches related to the complexity and wickedness associated with SDGs. Moreover, pursuing integrated research and decision-making related to the SDGs fundamentally depends on understanding interactions between the SDGs, both negative ones ("trade-offs") and positive ones ("co-benefits") (McCollum et al., 2018; Nilsson et al., 2018; Weitz, Carlsen, Nilsson, & Skånberg, 2018)

In this report we will contribute to a more systematic understanding of the growth and development of SDG research at Utrecht University in the period 2000-2020. We map and explain the emergence of SDG research, including analysis of single SDGs and interactions across SDGs (and non-SDG) research communities. Central to the analysis is the idea that the SDGs agenda is a transformative agenda, it indicates that there is a need to go beyond business as usual and the current attempts to optimize the current economy and society. Transformation is thus about changing the underlying systems for health, food, energy, water and mobility provision in a more sustainable direction considering that the process of system change needs to be a Just Transition.

To support this type of change a systemic view of knowledge production is needed, operationalized by us by using a transformative lens. Drawing on sustainability transitions work (Grin J., Rotmans J., & Schot J., 2010; Ramirez, Romero, Schot, & Arroyave, 2019; Roberts & Geels, 2019; Schot & Kanger, 2018), we analyse how knowledge trajectories that integrate new social and environmental directionalities are intertwined with multiple sociotechnical systems in a context of peace, justice and partnership.

Workshops engage researchers and other stakeholders in a dialogue to articulate the evolution of research trajectory over time, inviting new perspectives on what research goals and priorities will contribute to transformative change. These dialogues play an essential role in bridging aligning strategies and will increase the reflexivity of the research system. We anticipate that the results will thus support universities in identifying the thematic orientation of their research in the framework of the SDGs, as well as helping to increase the transformative potential of UU research through adding a reflexive layer to be used for navigation and profiling. Our results aim not only at favouring the development of common visions by characterizing current capabilities, but also permitting the analysis of the untapped potential of the Utrecht University research *system* as a key enabler to achieving the SDGs. The transformative potential is uncovered by mapping the SDG interactions being carried out in Utrecht University's research system.

3. Background

Knowledge is the fundamental engine driving new inventions, economic growth and the ability to address grand societal challenges that are central to achieving the UN Sustainable Development Goals (SDGs). Universities thus have a major role in achieving these goals. However, new insights and relevant ideas do not emerge automatically. Knowledge developments are constrained by path- and place dependency. Knowledge production is path dependent in the sense that existing scientific knowledge provides the building blocks for new knowledge production (Arthur, 2007). Knowledge production is also place dependent; it is differentiated among locations (Boschma, Heimeriks, & Balland, 2014). The existing scientific portfolio of a locally embedded research university influences the capacity to develop new ideas. New knowledge developments are dependent on place-specific circumstances that reflect conditions inherited from the previous knowledge production at a location (Martin & Sunley, 2007). In order to understand the opportunities for development of SDG research at Utrecht University, we first need to understand the emergence of knowledge communities involved in SDG research.

3.1. Knowledge trajectories and knowledge system transformation

It is critical to understand how knowledge trajectories emerge around and connect to multiple SDGs to fully appreciate the multifaceted nature of SDG research (Ramirez et al., 2019; Schot, Boni, Ramirez, & Steward, 2018). The generation, consolidation and growth of such trajectories depends upon existing knowledge blocks from multiple knowledge domains (Boschma et al., 2014; Heimeriks & Balland, 2016; Heimeriks & Leydesdorff, 2012), such as energy, politics, sustainable food and environmental health. However, the integration of such diverse knowledge domains implies a major challenge, since each knowledge domain has its own specificities, and the integration of knowledge bodies usually deals with high institutional barriers (Grauwin & Jensen, 2011; Shiffrin & Börner, 2004).

Integrating multiple bodies of knowledge associated with the 17 SDGs is essential to deploying diverse solutions to social and environmental challenges. We argue here that SDG research deals with high levels of implementation uncertainty and fuzzy conceptual definitions of the required transformations across the goals (Heimeriks & Balland, 2016). Therefore the integration of multiple cognitive domains is needed to trigger common solutions and manifest disagreements as well as convergences and shared visions (Arroyave et al., 2021; Rafols & Meyer, 2010; Stirling, 2007). This integration is consequently essential to build trust and integrate multiple voices within implementation strategies.

The emergence of knowledge trajectories has been studied through analysing the development of knowledge clusters and the interactions across multiple knowledge domains (Boschma et al., 2014; Heimeriks & Balland, 2016; Heimeriks & Leydesdorff, 2012). Those studies posit the relatedness between knowledge topics and fields as a main mechanism of trajectory development (Arroyave et al., 2021; Boschma et al., 2014). In this report the cognitive interconnectivity between SDGs topics is studied in a similar manner, as well as the entry and exit of knowledge building-blocks accumulated in the Utrecht University knowledge system.

The analysis of cognitive trajectories involves the use of network analysis and keywords which provide detail of the structure and dynamics of research systems (Arroyave et al., 2021; Boschma et al., 2014; Rafols & Meyer, 2010; Shiffrin & Börner, 2004). Building on this notion a diversity model based on triad census distribution (counting the cognitive interactions between groups of three SDGs) is used (Ramirez et al., 2019). We also identify existing knowledge structures by identifying knowledge clusters as a proxy of cognitive cohesion in the Utrecht University research system (Arroyave et al., 2021; Ramirez et al., 2019). We use sustainability transitions to interpret these results and analyse how knowledge trajectories that integrate new social and environmental directionalities are intertwined with multiple sociotechnical systems in a context of peace, justice

and partnership. The following section elaborates upon the transformative lens employed in the project.

3.2. The transformative lens

Based on the 'Transforming our World' strapline of the UN Agenda 2030 we have used the transformation lens framework (Ramirez et al., 2019). The transformative potential relies on the cognitive and social integration of multiple SDGs, that is to say that it relies on the capability of knowledge systems to build common visions of the challenges and possible avenues for SDG implementation. Using this lens allows us to identify three types of SDGs (see Figure 1), which are described as follows:

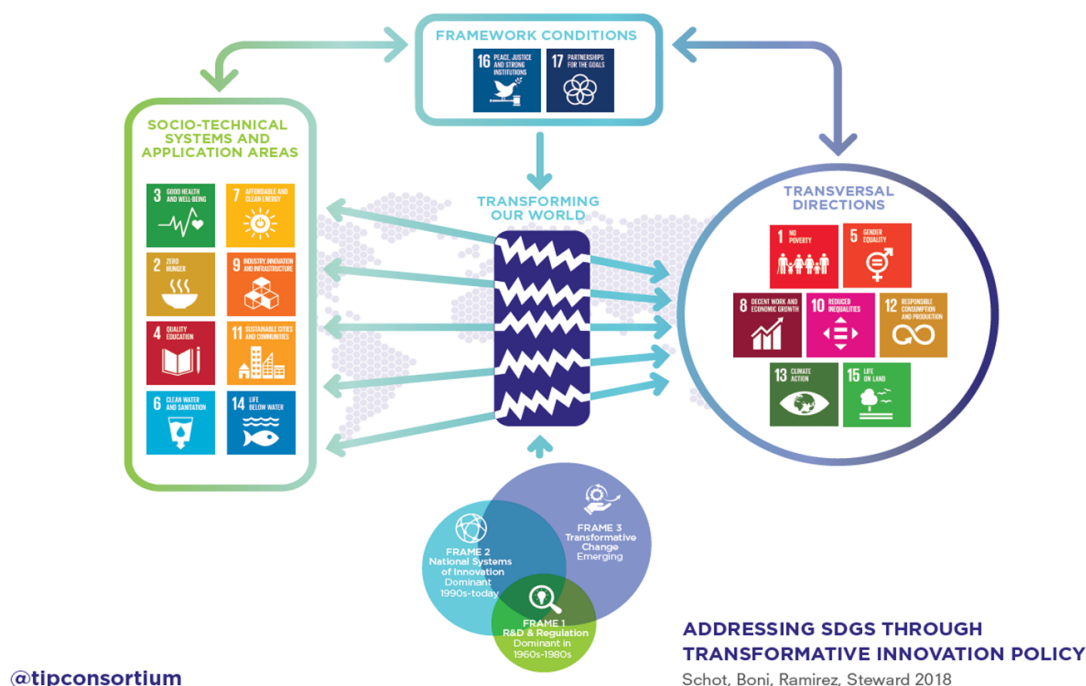


Figure 1: The transformative lens. The SDGs are classified within three categories: sociotechnical systems (ST); framework conditions (FC); and transversal directionalities (TD). The Transformation of our world relies on the simultaneous transformation of the 17 SDGs. This transformation depends on the independent transformation of each SDG and their complex interactions. In doing so the three frames of science technology and innovation can contribute by providing solutions in each SDG. For more detail of the frames for science technology and innovation see Schot Steinnmueller 2019; Ramirez et al., 2019.

- **Socio-technical systems and application areas:** SDGs that address areas of basic needs requiring transformation, such as Zero Hunger (SDG 2), Good Health and Wellbeing (SDG 3), Quality Education (SDG 4), Clean Water and Sanitation (SDG 6), Affordable and Clean Energy (SDG 7), Industry, Innovation and Infrastructure (SDG 9), and Life Below Water with its focus on fishing (SDG 14). These areas are defined as socio-technical systems and niches provisioning for these basic needs. These SDGs represent alternatives to the current dominant practices that have exacerbated environmental and social problems.
- **Transversal directions:** SDGs that address directions of change, such as No Poverty (SDG 1), Gender Equality (SDG 5), Decent Work and Economic Growth (SDG 8), Reduced Inequalities (SDG 10), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13); and Life on Land with its focus on biodiversity (SDG 15).
- **Framework conditions:** SDGs that address framework conditions for a change in the process: Peace, Justice, and strong Institutions (SDG 16) and Partnerships for the Goals (SDG 17).

The transformative lens underlines the necessity of developing knowledge trajectories that integrate two and ultimately three types of SDG. An example would be research that includes a focus on one or more areas to be transformed (such as sustainable agriculture in Zero Hunger,

SDG 2) into a specific direction (reduction of inequalities, SDG 10), thereby considering framework conditions (for example partnerships necessary for implementing sustainable practices in a social justice way, SDG 16 & 17). Such research can to a larger extent and more effectively catalyse upon research from multiple knowledge domains, thereby triggering synergies and increasing the transformative potential.

4. Method

This section explains the method employed in the research. A mixed methods approach was applied, we began with a quantitative data analysis to which qualitative data was added, allowing for a bottom-up characterisation. The steps of the quantitative part of the methodology are illustrated in the flow diagram in Figure 2, and are explained accordingly in the following paragraphs. The methodology of the qualitative phase is explained proceeding this.

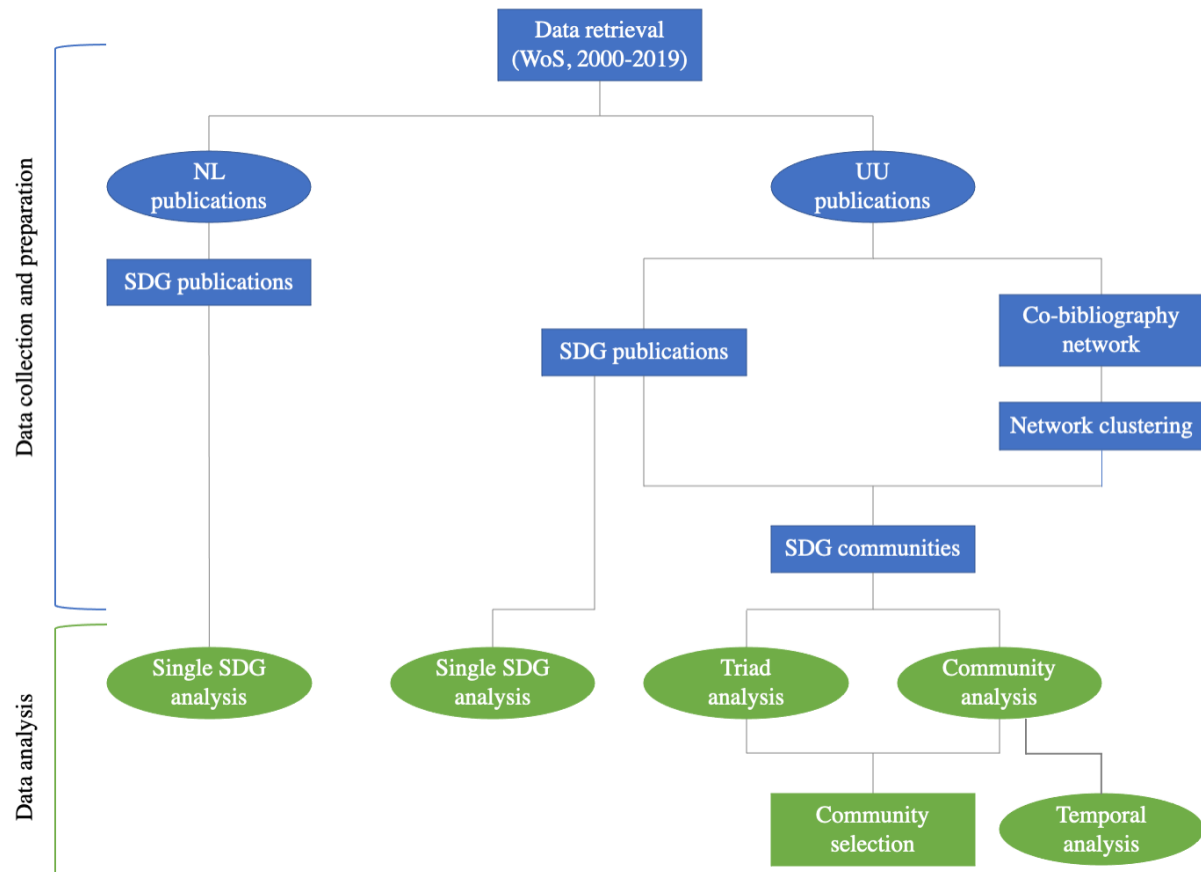


Figure 2: Flow diagram of the method for the quantitative phase

4.1. Quantitative data collection

4.1.1. Data retrieval

Scientific publications from the Netherlands were downloaded from Web of Science, within a time span of 2000 to 2020. Web of Science may introduce a bias favouring the Natural Sciences, Engineering and Biomedical Research¹, but it is one of the most used databases for peer-reviewed publication data. The bias can be reduced by including multiple data sources, for example a university-specific database. Publications that include at least one author affiliated with Utrecht University ('univ utrecht' in WoS field C1) were selected and represent the sample for Utrecht University. The database is summarised in Table 3. There is a difference in the number of publications for Utrecht University and the number of publications within the Utrecht University network; this difference follows from the clustering of the network, where only the publications with a strong cognitive relationship are included (see further under *Co-bibliography network*).

¹ <https://arxiv.org/abs/1511.08096>

	Journal	Series	Books	Total
NL publications	647 983	48 902	26 212	723 097
NL SDG publications	220 314	14 973	13 286	248 573
UU publications	60 692	2 542	1 043	64 277
UU SDG publications	17 248	428	220	17 896
UU network publications	46 134	2 085	775	48 994
UU network SDG publications	12 294	322	142	12 758

Table 3: The database

4.1.2. SDG publications

The SDG publications were collected using an automated text search. Multiple efforts have been made to develop a thesaurus in order to identify research related to the SDGs (Vanderfeesten & Otten, 2017)(Aurora Network); (Armitage, Lorenz, & Mikki, 2020) (Bergen University); (Duran-Silva, Fuster, Massucci, & Quinquillà, 2019) (SIRIS), (SPRU, 2019). Collecting SDG publications using an automated text search is a substantial undertaking, which depends to a large extent on both the search terms in the thesaurus and the rational through which the thesaurus was developed, as well as the stipulated search terms.

For this research a thesaurus, developed by Ramirez et al., containing 2172 search terms related to the 17 SDGs was used, and was chosen as it has been constructed considering the sustainability transition lens as explained in the introduction. The results generated by employing the Ramirez et al. thesaurus were compared in depth with a thesaurus developed for the STRINGS² project (Steering Research and Innovation for Global Goals), a project conducted by seven leading universities, research centres and the UNDP. The search terms in the STRINGS thesaurus are based on policy agendas and have, as compared to the Ramirez et al. thesaurus, a focus on individual SDGs. Both thesauruses were used to find and label SDG publications in the dataset. A publication is matched when at least one of the search terms from the thesaurus is found in the title, abstract or keywords. The results of both thesauruses were compared and a results-based choice for one thesaurus made.

The analysis shows that the Ramirez thesaurus retrieves more publications than the STRINGS thesaurus (1.7 times as many), but that 75% of the publications retrieved by STRINGS are also retrieved by Ramirez. This means that largely they find similar publications. The keywords found by the STRINGS thesaurus seem more bounded as compared to the Ramirez et al. thesaurus, whereas search terms from the STRINGS thesaurus consist more often of multiple words that have to be found together, resulting in less publications matched. On examining the amount of publications per SDG, we see that the STRINGS thesaurus finds a substantial number of publications in SDG 3: nearly 40% of all publications. With the Ramirez thesaurus, we observe that many publications labelled as SDG 3 by STRINGS are more equally distributed over SDG 1, 2 and 3. Overall it seems that the publications found with the Ramirez et al. thesaurus are more evenly distributed over all 17 SDGs and less biased towards particular SDGs (such as SDG 3). The full in-depth comparison can be found in Appendix A. Focusing on the reasoning behind the thesauruses, we will continue with the Ramirez thesaurus. This project concentrates on the transformative potential, and the Ramirez thesaurus has been developed using a transformative lens. The Ramirez thesaurus also includes SDG 17. The similarity with the STRINGS thesaurus validates the results of the Ramirez thesaurus and shows possible biases to be considered (such as the differences in classification for SDG 3, 8 and 9).

4.1.2.1. Labelling of the publications

A publication can relate to several SDGs; to determine the relevant SDG for each publication a set of rules was applied. Firstly, if the frequency of search terms found in one SDG was greater than

² For more information see: <http://strings.org.uk>

75% of the total search terms found in the publication, one SDG was attributed to the publication. If the first rule is not met the frequency of search terms found in the two most prominent SDGs are considered, and if the sum of the frequency is larger than 60%, the two SDGs are attributed to the publication (where the first SDG is the most prominent). If the second rule was also not met, the frequency of search terms found in the three most prominent SDGs were attributed to the publication.

4.1.3. Co-bibliography network

A co-bibliography network is constructed to analyse the emergence and existence of scientific knowledge communities at Utrecht University. Each node in the network represents a publication and publications are linked by shared bibliography items (Grauwin & Jensen, 2011; Ramírez, Romero, Arroyave, & Schot, 2019). Publications that share more bibliometric sources have a stronger connection to each other and are more closely located to one another in the network. In order to move from links between two publications to communities, we identify groups of publications that share a large number of references. Two well-known clustering algorithms were implemented to analyse the differences and suitability for this project: the Leiden clustering algorithm and Louvain clustering algorithm. The analysis can be found in Appendix B. The Louvain algorithm results in a higher modularity and has a faster and easier implementation in the software R Project 6.6 (R Core Team, 2019). Using the Louvain algorithm 229 well-defined communities are localised in the Utrecht University network (see Appendix C for technical details).

4.1.4. SDG communities

The communities in the Utrecht University bibliographic network are divided into SDG communities and non-SDG communities. SDG research is deeply embedded within the former, whereas the latter focuses on topics either unrelated to the SDGs or are less directly related to the SDGs. This distinction of communities is important whereby SDG communities represent consolidated structures of knowledge related to the SDGs. Non-SDG communities can still facilitate SDG research by conducting research that is foundational for SDG research, such as mathematics, physics or psychology.

To define whether the main research focus of a community is related to the SDGs, two characteristics of the community are considered; the first criterium is the share of SDG publications in the community. The SDG publication share is defined as the number of SDG publications divided by the total number of publications in the community. The second criterium is the growth or decline of the share of SDG publications in the community. The SDG publication share is determined for each five-year timeframe: 2000-2004, 2005-2009, 2010-2014 and 2015-2020 (T1-T4), as well as for each single year. A simple linear regression is fitted on the SDG publication share for each year, resulting in a trendline for each community. The slope of the trendline indicates whether the SDG publication share of a community grew (positive slope) or declined (negative slope). Applying both criteria, as shown in Appendix D, results in 93 SDG communities in the Utrecht University network.

In the following step the SDG communities are clustered into seven high-level SDG-clusters, using Hierarchical Clustering on Principal Components (HCPC clustering). This clustering method is based on the frequency of the search terms for each SDG in the communities, and communities which are more alike in terms of SDGs are clustered together. These seven main clusters allow a more general overview of SDG research conducted at Utrecht University as well as the overall image. The non-SDG communities are clustered into seven main non-SDG clusters in a similar manner, where the similarity of the communities in the research areas (as defined by Web of Science) is used. This allows for a general overview of research areas in the Utrecht University scientific landscape. Moreover, it enables analysis of non-SDG areas in the network and their location, and the overarching research areas of the non-SDG clusters.

4.2. Quantitative data analysis

After labelling the publications and grouping them, we introduced the three levels of the SDG publications analysis focused upon in this report (see also Figure 1):

1. *Characteristics of SDG research*

Firstly, the results are analysed in terms of the individual SDGs. Comparing the annual number of SDG publications at Utrecht University with the rest of the Netherlands shows in which SDGs Utrecht University has substantial research and in which SDGs Utrecht University has limited research, relative to research carried out in the Netherlands. This characterisation permits us to access the dynamics of publications of each SDG and identify in which SDGs Utrecht University has developed a significant trajectory.

2. *Relational dynamics of the SDGs (triad analysis)*

Triad census analysis is employed to analyse the interrelated dynamics (and thus the transformative potential) across the SDGs. A triad consists of a group of three connected publications (nodes) in the co-bibliography network. We focus the triad analysis on SDG publications: where a publication relates to multiple SDGs each SDG is considered for a triad: i.e., publications on multiple SDGs are included twice or three times. The analysis enables us to analyse the most frequent SDG interactions within the entire co-bibliography network in triads. Moreover, the analysis makes it possible to identify the emergence of knowledge building blocks that address various SDGs simultaneously, and which SDGs are researched in conjunction with one another. This analysis provides the possibility to operationalise the idea of relatedness and transformative potential as referred to in the introduction section. This means we focus particularly on analysing combinations of three specific SDGs: one related to sociotechnical systems, transversal directionalities and framework conditions. In addition to analysing the triads in the full UU network, we also analyse the triads in each SDG community in the network.

3. *Community dynamics and knowledge circulation*

In the last step the entire scientific landscape of Utrecht University is analysed and the interaction between the SDG and non-SDG communities, demonstrating how SDG and non-SDG research is connected in the Utrecht University research network. Based on the co-bibliographic network where each node represents a publication, a network map of all communities is created. In this network each node represents a community from the Utrecht University network (both SDG and non-SDG communities), and each link represents the sum of links between the publications in one community to publications in another community. Nodes in the graph that have a high betweenness centrality (many incoming and outgoing links to other communities) are communities with a significant influence over the flow of information and bridge different knowledge areas in the network.

4.3. Temporal analysis

A temporal analysis of the network allows for an understanding of how and where SDG communities emerge and how they develop over time. It permits us to study the knowledge trajectories of communities, as well as how communities interact and generate new knowledge. Knowing where and how the communities are formed and how they evolve to become an SDG community could assist in forming new SDG communities, but also allows for analysing how non-SDG communities interact with and assist SDG research.

Instead of analysing the static graph including all publications from 2000-2020, the time component of the network is taken into account: the publication year of a publication (Badlani,

Shah, Elizalde, Kumar, & Raj, 2018)³ describe a method for comparing communities between different time slices, using incremental subsets of the graph based on time, and the following methodology is based on their method. Using a timeframe of three years⁴, static graph snapshots were created for each timeframe. The first graph snapshot is composed of all publications with publication year up to 2002; the second graph snapshot will in this way contain all publications with publication year up to 2005. The last snapshot is composed of all publications. The community membership is determined for each snapshot of the graph. A similarity matrix is created between communities for each timeframe, where the similarity is based on the number of publications in the communities (for technical details see Appendix E). The similarity matrix allows us to analyse where publications went (from community A to community B). We can trace back the selected communities and analyse from where these communities originated, whether they already existed in the first years and from which communities they formed (merged or split of), as well as how they have altered over the years. This also allows for an analysis of how the research focus of the community varied over the years.

4.4. Qualitative data collection

The aim of the interviews was to characterise the bottom-up strategies to integrate and enable SDG research at UU. Four diverse SDG communities were selected and three to four key SDG authors in these communities were interviewed. These authors were selected based on the number of publications in the community, where the authors with the most SDG publications were invited to participate in an interview in the first instance. In some cases these authors were unavailable and suggested other researchers to us, who were only approached if they were part of the relevant community. The list of interviewees (anonymised), their community and faculty can be found in Appendix F.

The interview questions focused on the emergence and enabling conditions of SDG research at Utrecht University, as well as in what ways knowledge circulation occurs and which mechanisms of knowledge circulation within Utrecht University that enable SDG research. The interviews were semi-structured and of an exploratory nature; the aim of the project was presented as well as the results of the quantitative analysis and the characteristics of the community in which the interviewee is located. By explaining the nature and the background of the research the interviewee was invited to reflect further on this project and explore possible directions together with us. The interview guide can be found in Appendix F.

Interviewees were invited to participate in a workshop alongside other participants (other researchers interested in or affiliated with the SDGs, leaders of UU platforms and members from different departmental central offices), where the results of the interviews were discussed. Several statements and questions were formulated based upon an initial analysis of the interviews, see **Error! Reference source not found.** for the list of statements and questions. Mechanisms that came forward in the interviews were reflected upon and discussed among the interviewees and other workshop participants. The results were recorded and used in the analysis.

4.5. Qualitative data analysis

Based on an initial analysis of the interviews, first results in the form of statements and questions were formulated and used in the workshop. Using these as basis, two researchers from the project independently read the interview transcripts and formulated the coding categories for the interviews. All the interviews were coded independently by these two researchers according to the coding categories using NVivo, and discussed afterwards. The coding categories that are applied

³ <http://snap.stanford.edu/class/cs224w-2018/reports/CS224W-2018-50.pdf>

⁴ The timeframes are as follows: T1 = 2000-2002, T2 = 2003-2005, T4 = 2006-2008, T5 = 2009-2011, T6 = 2012-2014, T7 = 2015-2017, T8 = 2018-2020

can be found in Table 4. Based on the coding in NVivo the results are grouped and summarised per coding category.

Using this iterative method enabled us to obtain the principal results of the interviews, whilst ensuring no information or insight was lost in the process. Moreover, the first propositions in the workshop helped in confirming or rejecting initial interview findings by discussing them with the researchers and other participants. Because the interviews were explorative insights from the interviewees and workshop participants helped in each iteration to find the most interesting insights. For the final results in this report the categories 'UU resources' and 'Funding' are integrated into the other categories, because it became evident in the analysis that 'UU resources' referred to collaboration and that 'Funding' is important within each category. The two separate 'Collaboration' categories – catalysers and barriers, are also combined, allowing for a more comprehensive analysis and results section.

Coding category	Explanation	Coding
<i>SDG agenda</i>	All researchers selected for interview carry out research on topics closely related to the SDGs. Are they aware that their research is closely related to the SDGs, and do they use the SDGs in formulating new research ideas or projects? What is the relationship between the SDG agenda and the research agenda of the interviewees?	All answers related to the SDGs and SDG agenda
<i>Research motivation</i>	Despite most researchers not identifying a strong link between the SDG agenda and their own research agenda, their work is closely related to SDG topics. What motivates researchers to work on these topics and indirectly address the SDGs?	All answers related to how a new research idea is formulated and the motivation for it provided
<i>Catalysers for collaboration</i>	Researchers built up interdisciplinary and international networks to undertake research related to global challenges as outlined in the SDGs. What is the motivation for collaboration and what enables this collaboration?	All answers related to elements that facilitate or motivate (new) collaborations
<i>Barriers for collaboration</i>	In relation to interdisciplinary and international collaboration, researchers acknowledge multiple barriers. What are the most important barriers and how do researchers overcome such barriers, if possible?	All answers related to elements that impede or hinder (new) collaborations
<i>UU resources</i>	Utrecht University offers different possibilities to stimulate interdisciplinary research and to connect to other researchers. How is SDG research stimulated by Utrecht University?	All answers related to support from Utrecht University in relation to its research, and in particular in relation to collaboration
<i>Funding</i>	Funding is required to carry research out, and therefore the availability and type of funding influences research. How is SDG related research influenced by funding and how does this steer the research?	All answers related to the influence of funding on research

Table 4: Categories for the qualitative results interview coding

5. Results

The presentation of the results of the first phase, the quantitative data analysis, uses the three levels introduced in the method sections: 1) characteristics of SDG research, 2) triad analysis, expressing the relational dynamics of the SDGs and 3) the community analysis showing its dynamics and knowledge circulation. This is followed by the results of the qualitative phase, which is divided into three sections: a general overview of the results is presented, followed by a more in-dept description for the three categories: SDG agenda, research motivation and collaboration. Lastly, the qualitative results are summarised and a proposition is formulated for each category.

5.1. Quantitative data analysis

5.1.1. Characteristics of SDG research

Employing the Ramirez et al. thesaurus a total of 17248 SDG related publications were found for Utrecht University. The most frequent SDG trajectories emerge around Good Health and Wellbeing (SDG 3), Climate Action (SDG 13) and Clean Water and Sanitation (SDG 6), see Figure 3.

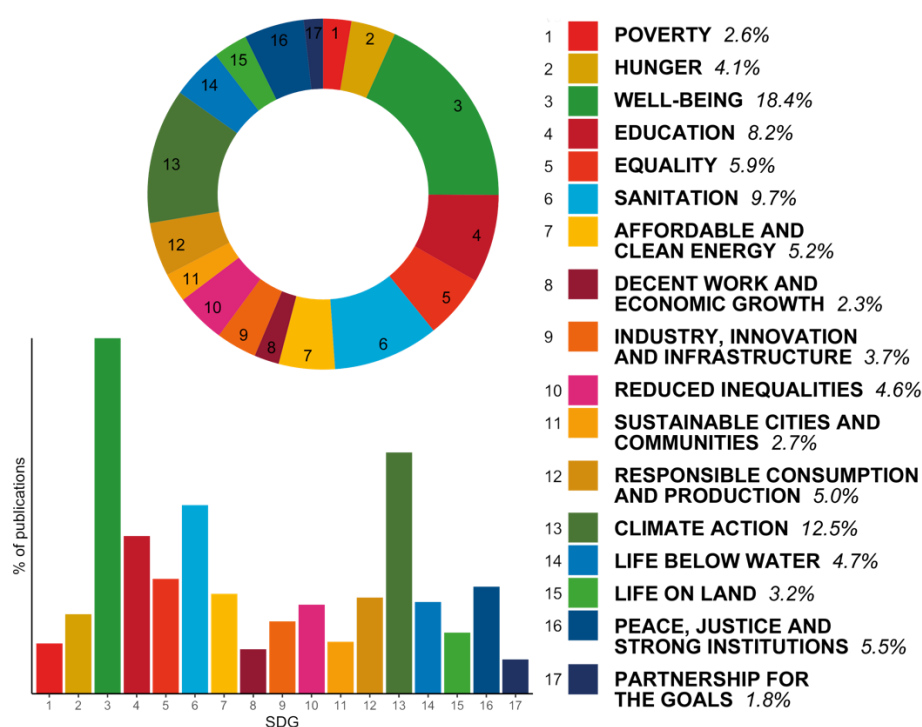


Figure 3: Multiple representations of the SDG publications. Percentage of SDG publications at Utrecht University from 2000 to 2020

Figure 4 illustrates that the number of SDG related publications grew steadily over the past 20 years for each of the SDGs for both the Netherlands and Utrecht University. The annual number of publications for individual SDGs shows that Good Health and Wellbeing (SDG 3) was the most researched SDG in both the Netherlands as a whole and Utrecht University (Figure 4). Both show a steep increase over the past 20 years. Quality Education (SDG 4) is also referred to in a substantial number of publications in both the Netherlands and Utrecht University. The graph illustrates that Utrecht University has a relatively high number of publications on Climate Action (SDG 13), as compared to the Netherlands. From 2009 onwards there is a steep increase in publications relating to SDG 13 at Utrecht University; it is clear that researchers here have been building a knowledge trajectory related to climate action over the past 11 years. Further research is needed to explain why Utrecht differs in this respect.

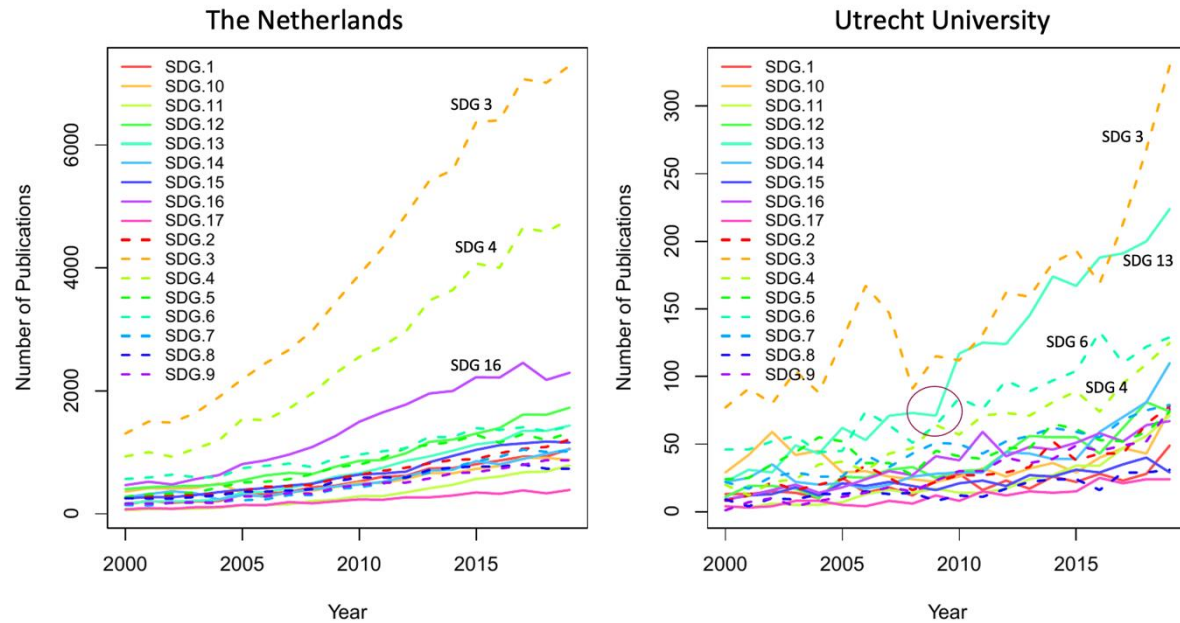


Figure 4: Annual number of publications for each SDG for the Netherlands (left) and Utrecht University (right)

5.1.2. Relational dynamics of the SDGs

To analyse the interactions between the SDGs we use triad census analysis. As previously explained, we make a distinction between three types of SDGs: 1) socio-technical systems or areas (ST), 2) transversal directions (TD), and 3) framework conditions (FC). Table 5 shows the distribution of the triad categories for Utrecht University, we see that most triads fall in the category ST-ST-ST (sociotechnical systems). The first four rows with triad categories, which only refer to the sociotechnical systems (ST) and the transversal directions (TD), account for 94.8% of all the SDG triads in the Utrecht University network.

	Category	Frequency	Share
1	ST-ST-ST	13,700	29.9%
2	ST-ST-TD	12,545	27.4%
3	ST-TD-TD	10,166	22.2%
4	TD-TD-TD	7013	15.3%
5	FC-ST-ST	891	1.9%
6	FC-ST-TD	657	1.4%
7	FC-TD-TD	463	1.0%
8	FC-FC-ST	158	0.3%
9	FC-FC-TD	119	0.3%
10	FC-FC-FC	112	0.2%

Table 5: Triad categories distribution of the Utrecht University triads

The ten most frequent SDG triads at Utrecht University are listed in Table 6. The most frequent triad is 13-13-13 (Climate Action), which is in category TD-TD-TD (transversal directionality). This is in line with the analysis of the individual SDGs, which showed that Utrecht University has many publications on Climate Action (SDG 13). It is note-worthy that Quality Education (SDG 4) does not appear in the most frequent triads, while Utrecht has many publications on this particular SDG. A possible explanation is that publications related to these SDGs are connected to many publications referring to many different SDGs. In that case they are in several triad categories and

widely distributed over the network, and therefore do not appear in the top 10 of most frequent triads. The most frequent triads at Utrecht University are all in the sociotechnical systems or transversal directionalities or a combination thereof. None of the most frequent triads are in all three categories (FC-ST-TD). There are some interesting interactions between Climate Action and Clean Water and Sanitation (SDG 13 and 6, number 2 and 3 in Table 6), Climate Action and Life Below Water (SDG 13 and 14, number 6) and Climate Action, Life Below Water and Clean Water and Sanitation (SDG 13, 14 and 6, number 9). These represent interconnectivity between systems and directionalities.

	Triad	Category	Frequency	Share
1	13-13-13	TD-TD-TD	4578	10.0%
2	13-6-6	ST-ST-TD	3417	7.5%
3	13-13-6	ST-TD-TD	3214	7.0%
4	3-3-3	ST-ST-ST	2012	4.4%
5	6-6-6	ST-ST-ST	1987	4.3%
6	13-13-14	ST-TD-TD	1793	3.9%
7	7-7-7	ST-ST-ST	1050	2.3%
8	11-3-3	ST-ST-ST	987	2.1%
9	13-14-6	ST-ST-TD	932	2.0%
10	14-6-6	ST-ST-ST	853	1.9%

Table 6: The 10 most frequent triads at Utrecht University

5.1.3. Triads in communities

The triad census analysis was also applied at community level, where the most frequent triad categories were analysed in each SDG community, shown in the heatmap Figure 5. The heatmap is scaled per community, meaning that the darker blue a box is, the higher the frequency that triad category is within that community. The heatmap shows that most communities have a high frequency of triads in the transversal directions (TD) or sociotechnical systems (SD) categories or a combination thereof. However, there are a few communities showing a high frequency of triads which combine SDGs in all three categories (FC-ST-TD). These are community 154, 192, 213 and 226, circled in red in the heatmap. These communities have a higher transformative potential because their SDG research covers all three categories. Community 154 refers to Quality Education (SDG 4) and Reduced Inequalities (SDG 10); Community 192 is about Peace, Justice and Strong Institutions (SDG 16), Life Below Water (SDG 14), and Clean Energy (SDG 7); Community 213 is about Industry, Innovation and Infrastructure (SDG 9), Clean Energy (SDG 7) and Partnerships for the Goals (SDG 17) and community 226 about Peace, Justice and Strong Institutions (SDG 16), Gender Equality (SDG 5) and Quality Education (SDG 4). Community 154 is analysed in more depth later in the report. The fact that only a couple of communities have a high frequency of triads in the FC-SD-TD group implies that this is a rare combination, and possible explanations for this are further explored in our qualitative research.

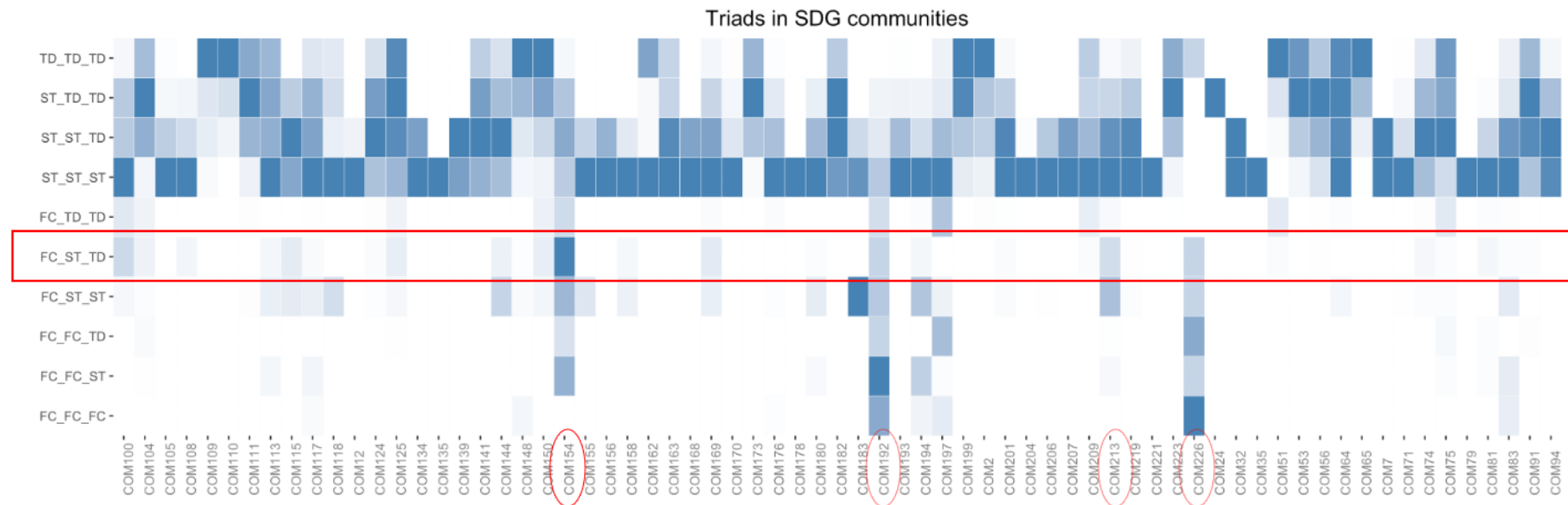


Figure 5: Heatmap of the triad categories per community. The heatmap is scaled column-wise, i.e., per community.

5.1.4. Community dynamics & knowledge circulation

In this section we analyse the scientific landscape of Utrecht University including the communities that work on common themes and their interactions. There are 229 communities in the Utrecht University network, of which 70 carry out research linked significantly to the SDGs with many publications related to them (i.e., SDG communities). Some communities are highlighted in this section to further investigate the meaning of the results.

5.1.5. Overview of the Utrecht University network

The community network of Utrecht University is visualised in Figure 6. Each node represents a community or research group consisting of a group of similar publications with regards their bibliography. The communities in green are defined as SDG communities, whereas the grey nodes are other communities. The network shows that the SDG communities are located throughout the network and interact with many other SDG communities and other communities. This means that SDG research at Utrecht University is well embedded in the scientific landscape and can be found in different research areas and disciplines.



Figure 6: The Utrecht University network, with the SDG communities in green. Each node is a community and each line represents a connection between two communities (based on the shared bibliography of publications within the community). Node size is the betweenness centrality score.

5.1.6. Overview of the main clusters and research areas

The seven main clusters of SDG communities are represented in Figure 7. Most communities are in cluster 6, medicine and public health which is mostly concerned with Good Health and Wellbeing (SDG 3), Gender Equality (SDG 5) and Quality Education (SDG 4). In the network we see that this

cluster is mostly located at the lower half and left of the network, stretching out to the centre. This means that research on medicine and public health, and SDG 3, 5 and 4, is also important for other communities, and interacts with communities through a large part of the network. There are two clusters related to climate change, both ecological and physical, which can be seen at the top of the network. These are mostly concerned with Climate Action (SDG 13), Life Below Water (SDG 14) and Clean Water and Sanitation (SDG 6). They are located at the edge of the network, indicating that the research concerned with climate change has less interaction with other research areas and communities in the network. This is a niche of communities related to climate action. There is some interaction with non-SDG communities, geophysics and geography (see Figure 8, N3 – the orange cluster).

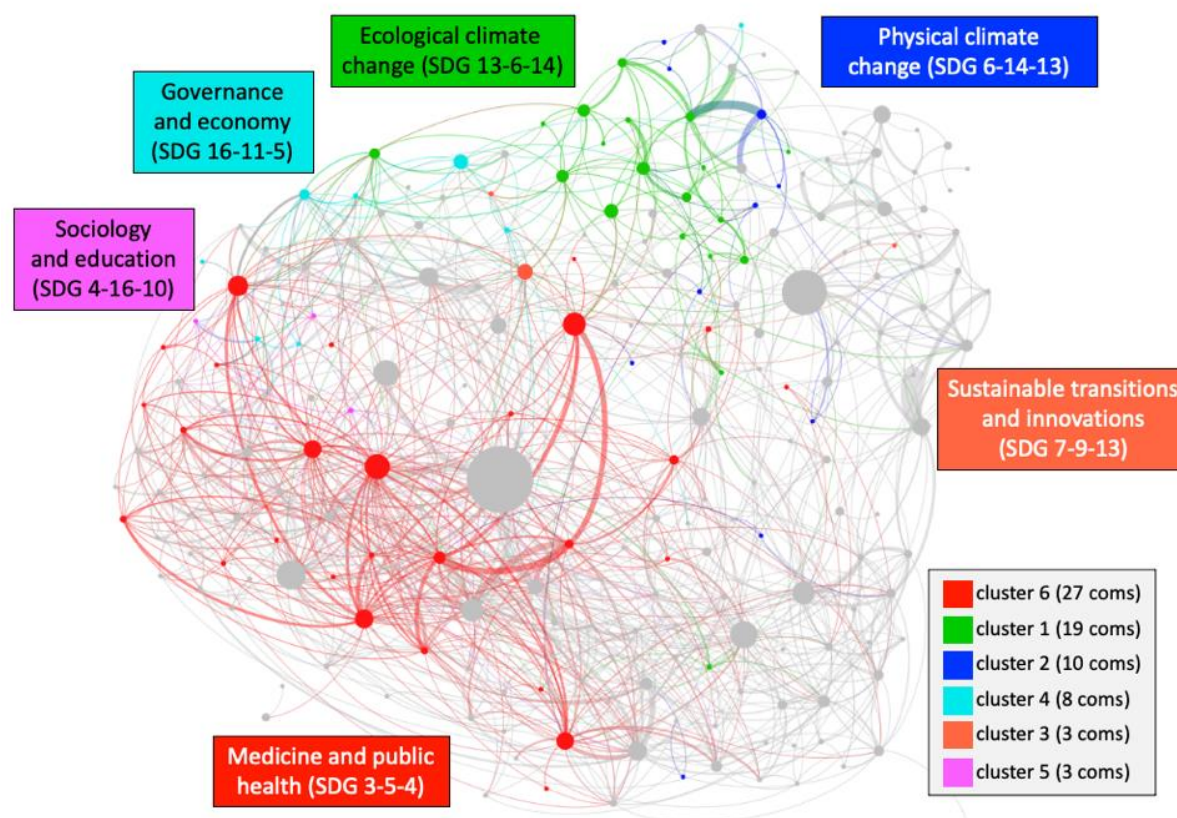


Figure 7: Network with the seven main clusters of the SDG communities, their main research area(s) and most common SDGs. Node size is the betweenness centrality score.

The seven main clusters of the other communities are represented in Figure 8. Cluster N4, biochemistry, medicine and veterinary, is the largest, consisting of 68 communities and is located in the bottom right-hand corner of the map, stretching up to the centre of the graph. Comparing the location of cluster N4 with Figure 7 an overlap with cluster 6 (medicine and public health) is apparent. We also see that cluster N6, psychology and neurosciences, shows overlap with cluster 6. This overlapping means that these SDG communities and non-SDG communities interact with one another and knowledge circulates between these communities. We see the same for cluster N5 and cluster 4.

In Figure 7 there is a notable grey area at the right side of the network, where no SDG communities are located. In Figure 8 we see that there are two clusters located in this grey area, cluster N1, astronomy and astrophysics, and cluster N2, physics, chemistry and material sciences. The research topics of these two clusters already indicate why there is scarce SDG research in this area of the network: the SDGs are not directly concerned with these topics. The SDGs are more concerned with applied research, whereas these clusters conduct more fundamental research which forms the basis of other research, including other SDG research. What is interesting

however, is how this fundamental research contributes to the SDGs, and how this knowledge circulates through the network to be used in SDG related research: i.e., how these communities support and enable SDG research.

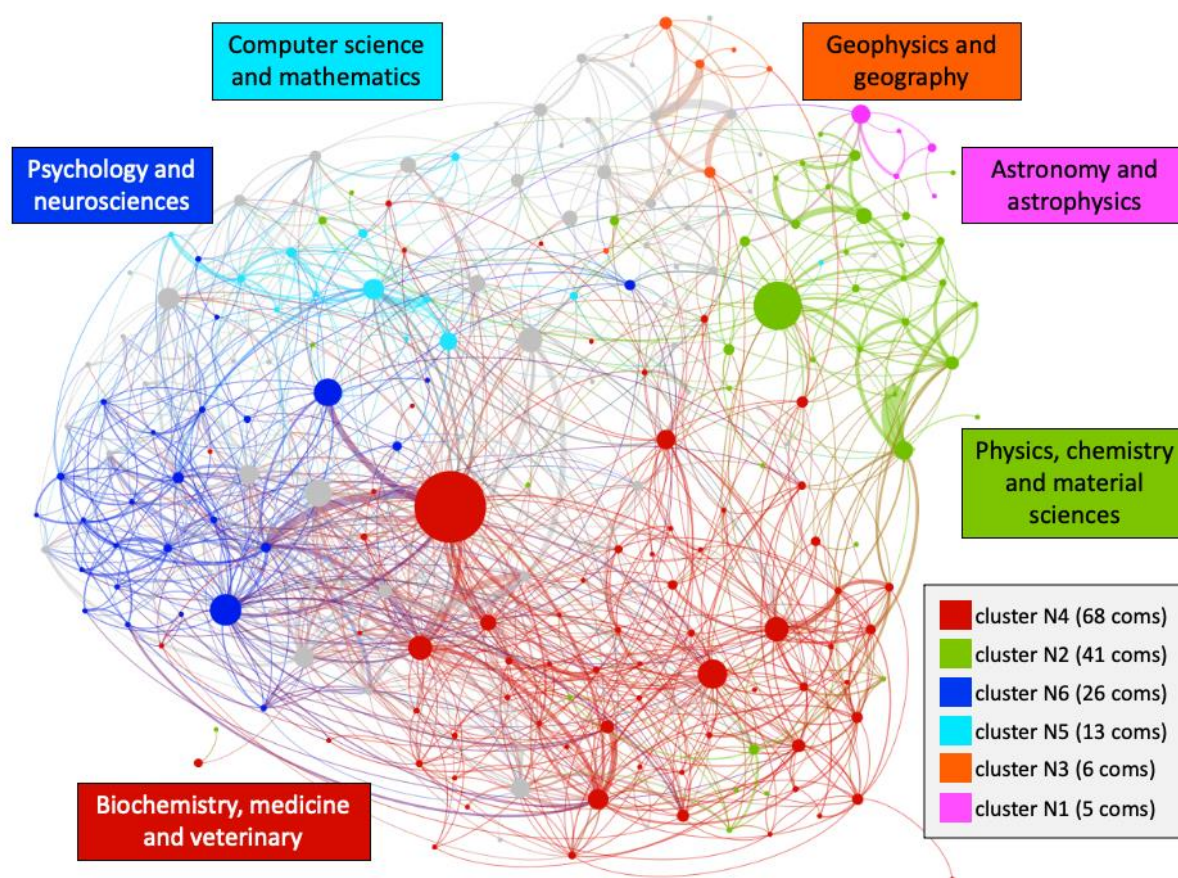


Figure 8: Network with the seven main clusters of the other communities and their main research area(s). Node size is the betweenness centrality score.

5.1.7. The SDG communities

We now focus on individual SDG communities. These communities are highlighted and labelled with their main SDG in Figure 9. A community can – and mostly does – consist of multiple SDGs, but to facilitate the explainability of this graph, the most prominent SDG in all publications within a community is used as a ‘main SDG’ of the community. We can see that there is a cluster of communities related to Climate Action (SDG 13) at the top of the network – the green cluster, with some communities on Life Below Water (SDG 14) to the right. This is consistent with what we previously identified in the main cluster network (Figure 7). There is a small cluster of communities with main SDG 4 to the left, the purple communities. There is one large node: this community has a large betweenness centrality score meaning it is connected to many other communities and plays an important role in the circulation of knowledge. There is one community, slightly above centre in the network, for which the main SDG is SDG 7 (Affordable and Clean Energy – light blue); this community has a relatively high betweenness centrality. It bridges knowledge between the health and medication cluster (mostly SDG 3, below), and the urban development and energy development cluster (SDG 9, 11, above). In the next section we consider some of these communities and their characteristics further.

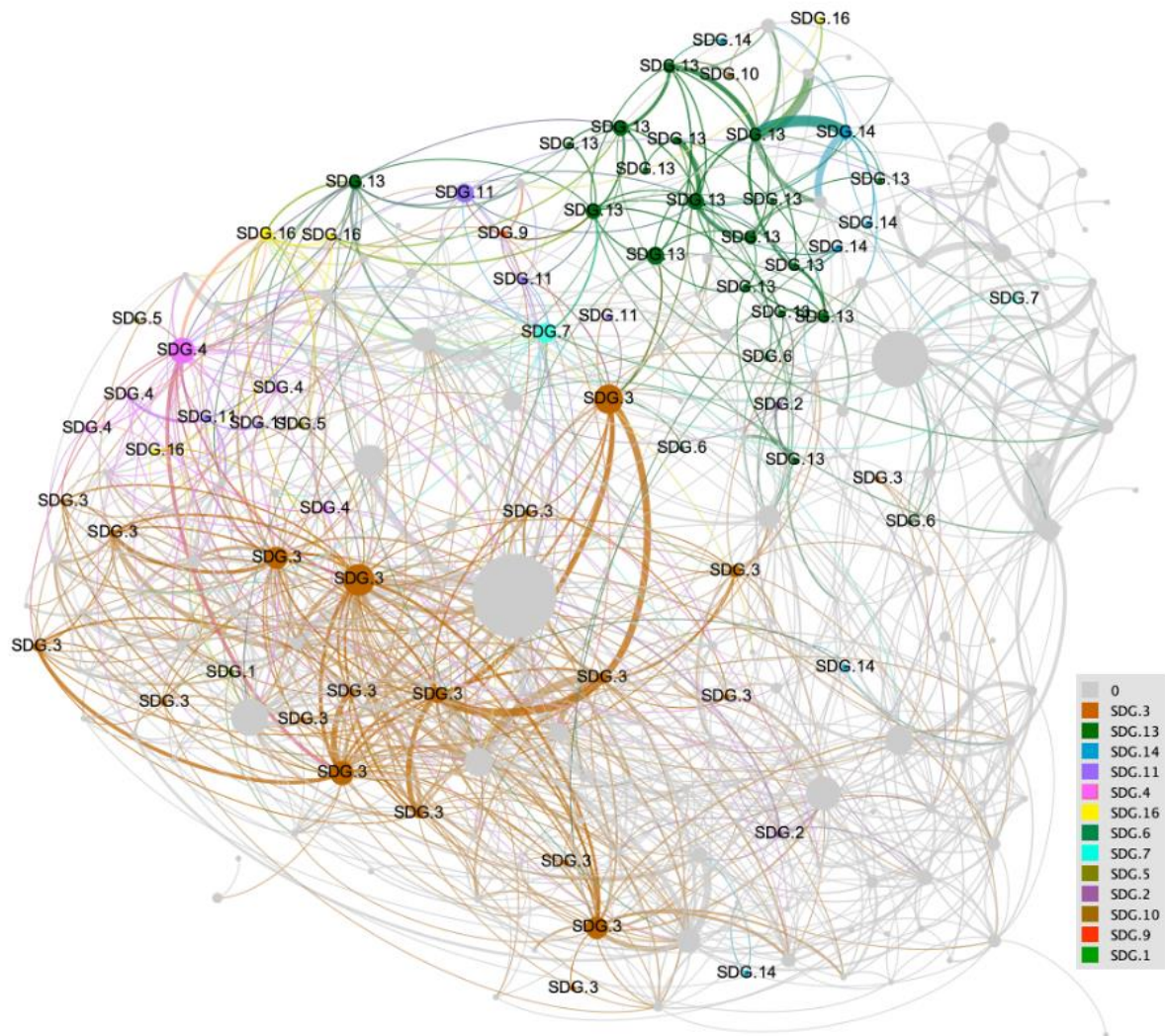


Figure 9: The SDG communities and their main SDGs. Node size is the betweenness centrality of the community.

5.1.8. Community characteristics

Four communities of the Utrecht University network are selected for further research in the qualitative phase. These communities are circled in Figure 10; community 176, 154, 71 and 197. Community 154 is selected because it has a relative high frequency of triads in the FC-ST-TD category (see *Triad analysis*). The other three communities were selected as they have a central location in the network and a key position connecting other communities. They are connected to many other communities, both SDG and non-SDG communities (i.e., they have a high betweenness centrality score) and therefore they play an important role in the knowledge circulation in the network. Moreover, they connect a diverse set of communities and combine research from different fields and topics. We conduct an individual analysis of these four communities in this section prior to the qualitative phase, examining them in terms of their research topics and triads, as well as how the community has emerged and developed (temporal analysis). The full in-depth community analysis, including the temporal analysis, can be found in Appendix H. In this section the communities are summarised, and the similarities and differences are highlighted.

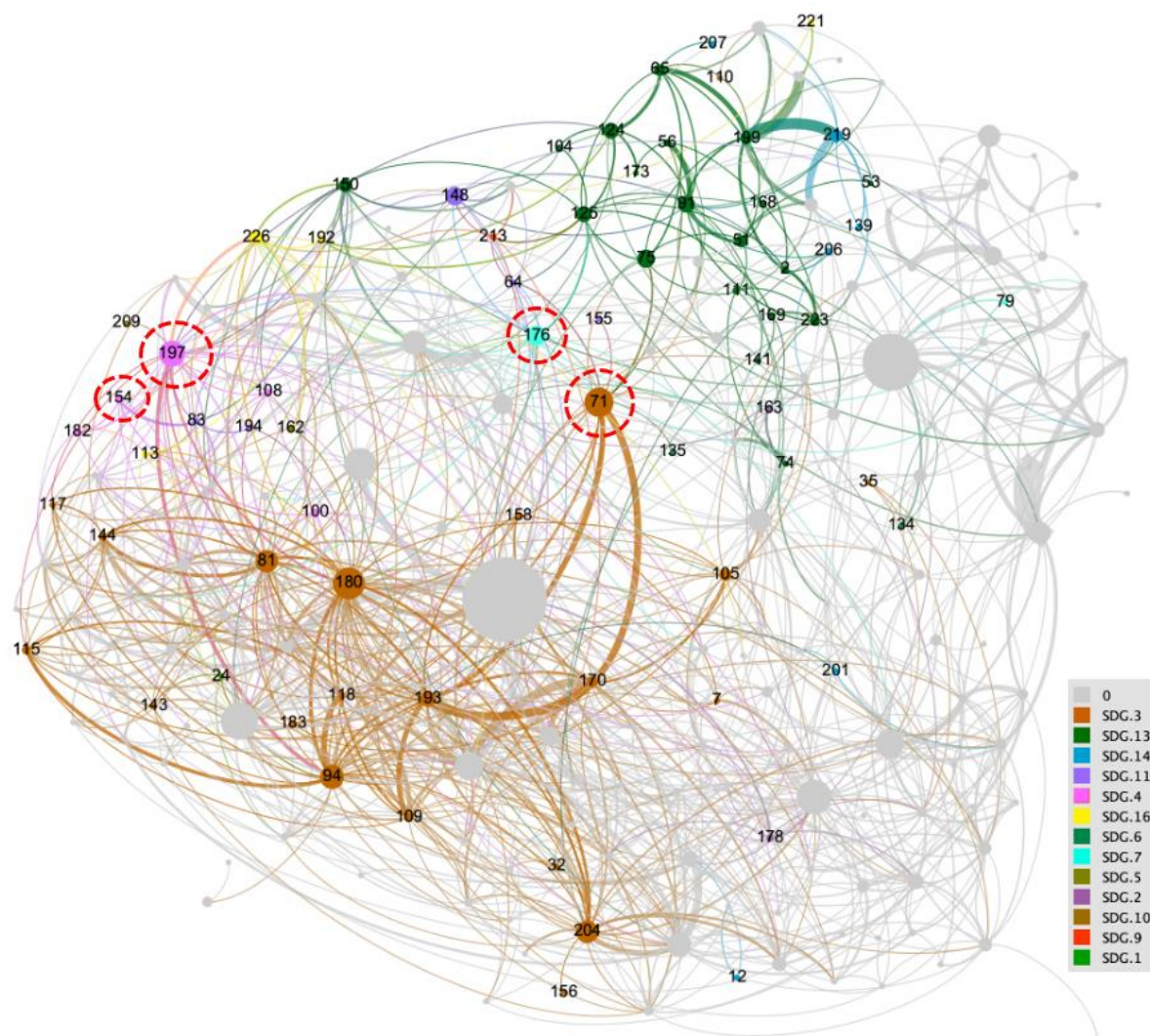


Figure 10: The Utrecht University network. Communities are coloured by their main SDG and labelled by their community number (ID). Node size is betweenness centrality.

Community 176 relates to Affordable and Clean Energy (SDG 7), Climate Action (SDG 13) and Quality Education (SDG 4), and its research areas are energy & fuels, engineering, and physics. In the word-cloud in Figure 12 we see that the topics of the publications in community 176 are related to green and sustainable energy, but also business & economics, and engineering. Community 176 has connections with a diverse set of other SDG communities, such as Good Health and Wellbeing (SDG 3), Sustainable Cities and Communities (SDG 11) and Peace, Justice and Strong Institutions (SDG 16). Community 176 has been formed from many merged communities and a diverse set of research topics. This diversity is visualised in Figure 11, which shows the main research areas of all communities related to community 176 over the past 20 years. The research topics that have been prominent in recent times include transportation, physics, linguistics, energy & fuels and business & economics. The fact that community 176 is formed of many communities with a wide range of research fields illustrates its diversity and how knowledge from diverse fields has been integrated.

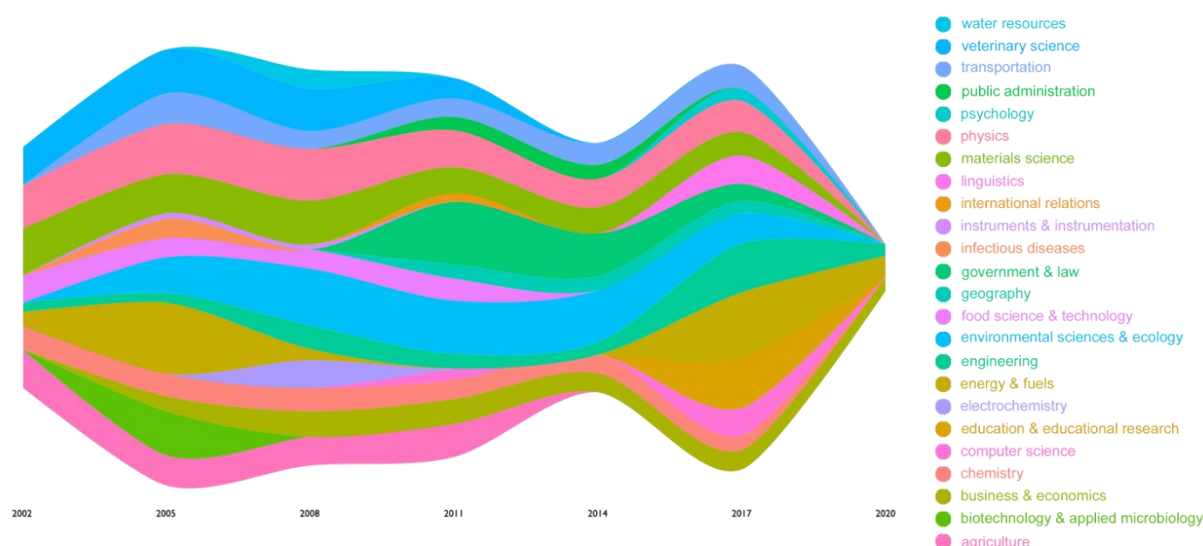


Figure 11: Streamgraph of community 176. Each line represents a main research area of the single communities that formed community 176 in 2020. The thickness of the line indicates how many publications there are pertaining to a research area

Community 154 relates to Quality Education (SDG 4) and Reduced Inequalities (SDG 10), and the main research areas are psychology, sociology and education & educational research. The word-cloud in Figure 12 shows that the publications are on immigrants, ethnicity and discrimination. Community 154 has less connections with other communities in the network as compared to community 176, which is also indicated by the lower betweenness centrality score. It has a strong connection to community 83 on Sustainable Cities and Communities (SDG 11), and is furthermore connected to community 226 on Peace, Justice and Strong Institutions (SDG 16). Community 154 is significantly less diverse compared to community 176, and it formed from four different communities over the past 20 years (**Error! Reference source not found.**). Most of these communities are fully merged into community 154 and have not been split. The main research areas of the communities over the years have remained the same and similar to the main research areas of community 154 (with one exception, the research area demography, which is closely related to the topics of community 154). See Appendix H.2 for a streamgraph with the research areas for community 154, similar to Figure 11. Community 154 was selected because it has a relatively large amount of triads in the FC-ST-TD category. Analysing these triads in the category FC-ST-TD in more depth has showed that despite the triads consisting of SDGs from each of the three categories, the publications are very similar to one other and on similar subjects (such as the employment of immigrants) but have been analysed from a slightly different perspective (leading to the different SDGs attributed to the publication). This implies that the academic research undertaken on this subject includes multiple perspectives.

Community 71 is on Good Health and Wellbeing (SDG 3) and Sustainable Cities and Communities (SDG 11), with main research areas in environmental sciences & ecology, public, environmental & occupational health, and toxicology. It relates to air pollution and particulate matter following from traffic, as can be seen in the word-cloud (Figure 12). Community 71 has a high betweenness centrality and is located centrally in the network. It has strong connections with multiple communities focusing on Good Health and Wellbeing (SDG 3), as well as some connections with communities on Affordable and Clean Energy (SDG 7), Sustainable Cities and Communities (SDG 11) and Climate Action (SDG 13). Over the past 20 years community 71 has not been split or merged, and its research topics have remained the same (also see Appendix Community 71 – Temporal analysis). It has remained stable with a clear research focus.

Community 197 is about Quality Education (SDG 4), Peace, Justice and Strong Institutions (SDG 16) and Good Health and Wellbeing (SDG 3) and its main research areas are education & educational research, health care sciences & services and public, environmental & occupational health, with a focus on topics related to education, human rights and gender (Figure 12). This community has a high betweenness centrality and many connections to other communities. It interacts with communities on Good Health and Wellbeing (SDG 3), Climate Action (SDG 13), Peace, Justice and Strong Institutions (SDG 16) and Gender Equality (SDG 5), amongst others. Community 197 is the most turbulent of the four based on its development over the past 20 years (2000-2020). It is formed from many different communities that have split and merged with others frequently. It has included a diverse range of main research areas over the past years, including government & law, geography, veterinary sciences and business & economics (see also Appendix Community 197 – Temporal analysis). This diversity means that, similar to community 176, community, 197 is able to integrate knowledge from diverse fields and is able to bridge communities with diverse research areas.

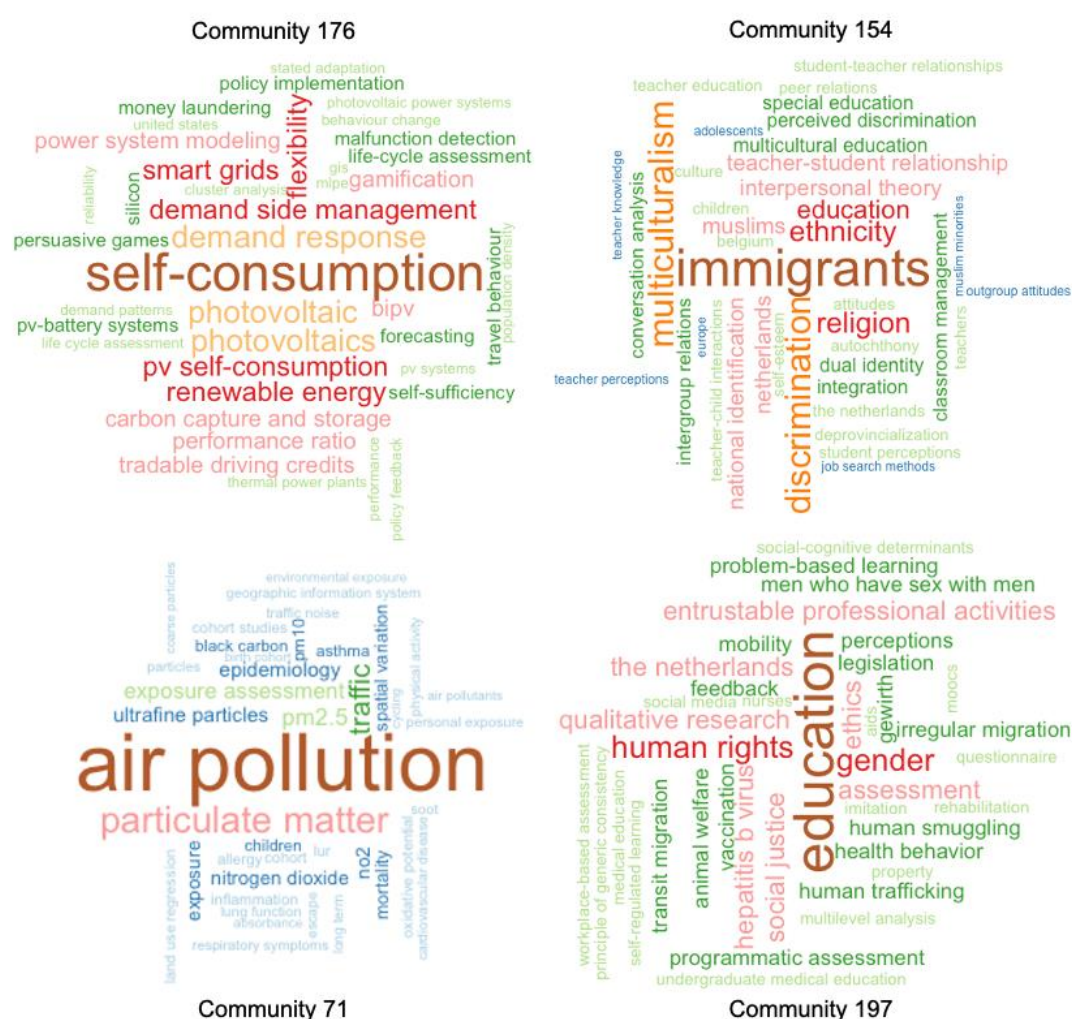


Figure 12: Word-clouds of the author keywords of the publications in the selected communities. The size of the keyword indicates the frequency of the keyword in the publications, with a maximum of 40 words.

Whereas this quantitative phase shows us the characteristics of SDG research at Utrecht University and specific communities that focus on certain SDGs, it does not explain how this research happens and what the bottom-up strategies of researchers are in relation to SDG research. In the qualitative phase of this research we focused on the emergence and development of SDG research

in these communities. The interviews focus on the how and why of the research in these communities that are deeply concerned with the SDGs.

5.2. Qualitative data analysis

5.2.1. Results overview

Firstly, the relationship between the SDG agenda and the personal research agenda was analysed. From the interviews we have ascertained that most of the researchers acknowledge the importance of the SDGs, however they do not identify a strong link between the SDG agenda and their own personal research agenda or activities, despite their work being closely related to SDG topics. The reasons for this are that they already undertaking research on societal relevant topics and do not feel that it is necessary to link them specifically to the SDGs. Moreover, there is no clear incentive for researchers to do so; there are other agendas with more traction worldwide and the additional benefit of linking research to the SDGs is not necessarily evident. Other reasons for this came to light in the workshop, such as a lack of knowledge of the SDGs and the difference between fundamental research and the more applied SDG goals. Participants responded that Utrecht University could improve this by educating and disseminating knowledge about the SDGs and underlining the benefits of linking research to them. This implies that there is a lack of understanding of the SDG agenda, which could be improved by increasing awareness of the SDGs. Ensuring that researchers know that they can contribute to the SDG agenda is something that Utrecht University could facilitate. Researchers could make a strategic decision and contribute to the development of the SDGs if they have better awareness of their location in the research agenda.

We continued with examining researchers' motivations to research topics closely related to the SDGs. The interviews found that the research motivation largely depends on a researcher's personal interest as well as their personal values, meaning that researchers require a research question to be relevant to society or a societal issue and related to topics worldwide which they find important. This also depends on the network or community in which a researcher is located, as researchers often build upon their own research as well as that of colleagues. Some interviewees indicated that they are in a close-knit community with which they do extensive research. Others have more individualistic research and are in this sense less 'bound' in choosing a new research topic.

Relating this to the SDGs, researchers seem to be more focussed on research agendas other than that of the SDGs, as was also identified in previous category. The motivation for their research seems more general, based on intrinsic values, their immediate community and research they had previously undertaken as opposed to the SDG agenda for example. This implies that the relationship between their research and the SDGs is has occurred incidentally rather than by design. The strong and long-existing networks imply that the knowledge trajectories around the SDGs have been building up over a long time and before the formulation of the SDGs. These knowledge trajectories are based on different agendas but are seemingly closely related to the SDGs. Funding opportunities also determine research possibilities and directions: almost all interviewed researchers acknowledged a large indirect influence of funding, whereas research can only be done if funding is available. Some researchers nuance this by arguing that it is often still possible to do a small part of your original research idea within in a grant, and that researchers can also shape calls and influence the text of a call. Following the award of a grant, funding agencies have no direct influence on the research undertaken: they do not participate in research and none of the researchers experienced needing to change their idea because the funding organisation required it. This shows that the feasibility of a research project depends on the

availability of funding, but that other factors such as personal interest and societal relevance play a much more important role in research motivation and starting a new research project. Next, we studied the establishment of these research topics; we looked at the opportunities and barriers for collaboration in these research topics and how the interviewed researchers overcame them. Looking at the interdisciplinary and international collaboration of the interviewees we saw that all were enthusiastic about collaboration, both interdisciplinary and international. They viewed it as an important part of their research and necessary to conduct research of high quality and their continued improving. Many of the researchers indicated that collaborating with researchers in other fields enabled them to work on a topic in a broader sense, study it from different angles and produce more extensive research including aspects from other disciplines. Context is often important for international collaboration specifically, whereas research on societies in other countries is also concerned with other contextual factors. Facilitators for collaboration are networks and networking events, which enable researchers to connect with researchers from other disciplines or countries. In this regard networking events across faculties, organised by Utrecht University, are important in stimulating interdisciplinary collaboration, where researchers meet their equivalents from other faculties and departments, connect with one another and share ideas for future research projects. The Strategic Themes and Focus Areas are an additional catalyst for collaboration within Utrecht University, stimulating collaboration between faculties. Researchers mentioned that interfaculty collaboration is stimulated by the seed money granted by these departments, which shows the importance and advantages of Utrecht University resources in stimulating interfaculty and interdisciplinary research.

The interviewed researchers also mentioned barriers to collaboration. These barriers are mostly epistemological and methodological differences in disciplines, but they reported that none of these barriers were significant enough to prevent collaboration, and that therefore the benefits outweigh the costs. Most interviewees also described how they found several ways to overcome such barriers, such as identifying a common language and establishing a common goal. They reported that funding also has a large influence on collaboration, both as an opportunity and a barrier. It can be an important driver for collaboration for the simple reason that funding calls sometimes require interdisciplinary or international collaboration. Moreover, for some research topics, where there is a business case, co-funding grants with private partners exist such as in community 176 concerning energy resources. In this case companies can become interested in the research, often at a later stage, to develop or improve a pre-existing product. Other research topics, such as education in community 197, do not have such a 'business case' and relatively little public funding is available for this, and large corporations often show little interest in these topics. Availability of funding can also be a significant barrier to collaboration; funding agencies are sometimes more discipline oriented, meaning there is no funding for interdisciplinary projects whereas calls may stipulate interdisciplinary collaboration. However, not all research areas lend themselves to this. Another important barrier with relation to funding is that there are very few funding schemes for research related to global challenges, nor for worldwide research, and SDGs are concerned with worldwide challenges. It is difficult to achieve a balance in this sense, both more individualistic, fundamental research and global, interdisciplinary research is important in relation to the SDGs. Workshop participants reiterated the problem of obtaining global funding, and that Utrecht University could help overcome such barriers by building alliances with international universities including those in developing countries, and by listening to the problems and issues which researchers experience in this regard.

5.2.2. Results per category

For each category the outcomes were analysed in depth. First the opportunities and barriers within the category are analysed and then the influence of funding in each category.

5.2.2.1. *Relation to SDG agenda*

Opportunities

Even though most of the interviewees indicated that they do not consider the SDGs when formulating a new research question, two interviewees said that they did actively think about the SDGs when formulating a research question. One indicated that they use the SDGs to motivate their work, because of a close collaboration with a large supra-national institution where the SDGs are a central part of the work motivating action plans (interview C1). Another interviewee indicated that the SDGs are important for their research and they are also considered when thinking about future research (interview C2). These two researchers are both in community 71, and they both mention that their work is contributing to strategies to reach the SDGs and that their work is mission driven. One possible explanation is that research topics in this community are more mission oriented and follow an agenda with a stronger fit to the SDGs, whereas other research might be more related to agendas that have a fuzzy link with the SDGs and are more concerned with fundamental research and less related to the applied nature of the SDGs.

Of interviewees who responded that they do not actively consider the SDGs in their research, they were however aware that their research relates to the SDGs. One of the interviewees explained that he has been doing his research for many years, and that his research is completely related to SDG 7, but that that happened 'accidentally'. His research has always been on these topics, but it happened to be closely related to SDG 7, which is was actively aware of. Another interviewee explained that he knew his research had societal relevance and was concerned with global problems, so therefore he 'expected' it to be related to the SDGs, but he did not know to which SDGs precisely. Additionally, one interviewee said that through working on topics related to the SDGs, the SDGs kind of 'became natural' (interview A3); another interviewee argued that it depends on the definition of the SDGs as to whether his research related to it. Another stated that 'a lot of what I'm doing, indirectly, bears on them. (...) But I also do think, for example, human rights are important. And then very often, of course, you can put things in the same sort of terminology of SDGs or in terminology of human rights or development' (interview D1).

In the workshop the participants were asked whether it is important to be aware of how research is related to the SDG targets, and why. Most participants answered affirmatively, mostly with the argument that the SDGs provide a framework to build communities, connect and discuss research in the global community. Other arguments are more related to the aim of the SDGs, for example so that no one is left behind or that it is positive to see how we contribute to a certain set of goals. These answers show that most workshop participants think relating research to the SDGs is positive and creates more awareness. Additionally, we asked participants how Utrecht University can make researchers more aware of their contribution to the SDGs. Most answered in the line of educating and disseminating knowledge about the SDGs and underlining the benefits of linking research to the SDGs. For example, one participant answered: 'create incentives (and not requirements) for researchers to make a direct link between their research and a given SDG' (workshop participant).

Barriers

As mentioned previously, eleven of the interviewees indicated that they do not consider the SDGs when formulating new research questions. The reasons for this are diverse, one of which being 'not informed well enough what the benefits of the SDGs would be for me' (interview D3) or not 'suddenly' changing research because of some new framework, such as the SDGs (interview A2). Another interviewee argued that 'to the extent that it becomes the dominant language, then it will be something to which I need to adapt my research', but until then 'what gets most traction internationally where my governance questions then go' (interview D1). Some researchers argued that the SDGs should not play a role in (all) research. One researcher said that 'these SDGs were designed a while ago, while 10-20 years ago I already was working on solar energy anyway'. Also,

this interviewee argues that as a university 'we are focusing on that research groups are doing', and there are links with the SDGs, but they are not guiding (interview B3).

In the workshop, to the question whether it is important to be aware of how research is related to the SDG targets, a couple of participants answered 'no' or 'depends'. Their arguments are that the SDGs are rather new whereas most researchers started their research before their existence, and that the SDGs might be useful to embed research, but not for research itself. Other arguments are that the definition of the SDGs is not clear or that it depends on the field of research. The participants were also asked why researchers do not find a strong fit between SDG topics and their research. Some participants argued in the line of not enough knowledge about the SDGs or a too narrow definition of the targets. One argument was that there is a difference between more fundamental research and more applied SDG goals, and that direct impact and contribution to achieving the SDGs is limited. One participant responded that some researchers may have a longer standing agenda with which they align their research.

Funding

From the interviews followed that different types of grants offer different opportunities, whereas small grants are useful for experimenting with new ideas, methodologies, etc., for example: 'both the larger and the smaller types of funds are important, where the smaller are more important to look at some more innovative approaches' (interview A3), or: 'It's usually the larger grants that we attract and that allow us to really make big steps. But you can also imagine that sometimes you want to work on this very specific component of that research that can be done with a smaller grant' (interview C3). Or they are useful for more practice-based experiments: 'Smaller grants usually, in my domain, are more about small skill, practical projects' (interview D3) and: 'So the smaller grants are more like kind of..., yeah that's why they call them seed money, right, so like it's a seed that you plant somewhere with the hope that it will grow into a bigger idea' (interview A3). Here we see that both small and large grants are important, where the small grants allow for more experimental research to come to a research proposal for a large grant, and the large grant allows for extensive research.

One of the interviewees indicated that: 'So given that there's a certain popularity in thinking about corporate social responsibility in terms of SDG goals, maybe in a couple of years from now, when I search for funding opportunities, I will look at grant schemes which use that framework to go for a next grant, but no actual plans at the moment' (interview D1). This was mentioned by more interviewees and implies that if funding agencies use the SDGs as a framework and require researchers to formulate their research according to the framework of the SDGs, researchers would have to think more actively about how their research is related to them.

In the workshop we asked about the role of small grants in research topics related to the SDGs or in combining the SDGs; some participants responded that this may work if this is the purpose of the call, others answered that this can be used as seed money to take a first dive into the research, by explicitly seeding the development of SDG related project proposals. Some participants answered that difficulties may arise when the SDG goals insufficiently match other research interests, or that they should not play an extra role, and that it is positive regardless of whether the research carried out relates to the SDGs or not.

5.2.2.2. Research motivation

It was evident from the interviews that most participants look for relevance in new research questions and projects, in terms of societal relevance or important worldwide topics. Additionally, the interviewees mentioned that they work on these topics as they have expertise in the subjects, and they build on their own research or the research of colleagues. Funding also plays an important role, because funding opportunities determine the possibilities for research. This means

that a research idea is sometimes not feasible because of the lack of funding opportunities for it, which restricts researchers in their research directions.

Opportunities

Some of the interviewed researchers indicate that they or their respective research communities have been doing research on particular topics for a long time, however, they acknowledge that they are aware of changes in their context (for example scientific, political, etc.) which can influence their research: 'It's, of course, related to what we've been doing in the past, our key expertise, but also current developments in the field, which come together with an interest of the European Union, the green deal, that also very much aligns with the things that we are researching' (interview C3). This means that even though the knowledge trajectories on these topics are long-standing, researchers do see new possibilities and changes in their own and other fields. Two interviewees mentioned that they consider the strategic plan of Utrecht University when developing new research questions and starting a new research project (interview D3 and D4), in the sense that they align their research with the strategic plan of Utrecht University. These are both in community 197, which is concerned with educational research. Other interviewees did not mention the strategic plan.

Barriers

As previously mentioned, some of the interviewed researchers indicated that they had already been undertaking research on these topics for a long time themselves, but also that their respective networks or communities have been doing research on these topics for a significant period of time. As described by one of the interviewees: 'So a research career is like a sort of path with steppingstones in which you are going from stone to stone' (interview D1). This relates to personal interests and the intrinsic motivation of researchers to do research on these topics. As described by one interviewee '(...) while still having a large motivation to work on, to continue working on alternative energy sources. That's why I said I don't need the SDGs for myself, I already was motivated to work on them' (interview B3). Because they have been working on these topics for a substantially time period and are motivated for other reasons, they do not feel the need to link their research to the SDGs.

Funding

Funding plays an important role in the research motivation, whereas interviewees indicate that 'most of what we actually do is answering calls' (interview C1) and 'there is a call and then we try to fit' (interview B2). But even though funding has an influence, interviewees also indicate that 'we would never do research just because of the fact that there is funding, and so there are types of research that we don't engage in because we're simply not interested in it' (interview C1). All interviewees noted that they have never nor would ever change a research idea if the requirements of a grant or funding organization asks for it, after having received the grant.

The interviewed researchers indicated that having received a grant, there is no influence of the funding organization on how the research is performed. Also, as interviewees explained, if a call doesn't fit the research ideas or interests of the researchers, the call is not considered: 'If there's a project, a call, where we think what we want to do does not fit in, we don't consider it from the beginning. (...), it's not that we would tweak our idea, so that they fit the call, but we check if the call, if we can make that fit to develop our ideas and really get our goals implemented.'. This shows the integrity of the researchers is more important than receiving a grant.

On the other hand, most interviewees do acknowledge that funding has a large influence on research in more general terms, in the sense that 'the research goes where the money goes' (interview D4). This means that funding opportunities largely determine which research ideas are feasible and can be implemented and which ones cannot. One of the interviewees said: 'I don't

think I could say that there is no influence of the funding organization at all. And they have strict, I mean, a call itself, of course, limits what you can propose. If they specifically write that they are interested in certain health outcomes or they are interested in children's health or adult health or elderly health. Well, that's clearly shaping the research' (interview C1). This shows that calls limit research in the sense that you can only apply if you are willing to conform to the outcomes they are looking for in the call. Another interviewee said: 'So the first part of that the research goes where the money goes, or where there's money, for instance in industrial partners, yeah that has a huge influence of the research that we are actually doing. So, the people who provide funding have a lot of power' (interview D4). This is more related to industry, whereby the interests of the industry also exert influence on research. One of the interviewed researchers pointed out that there is a difference between research that is more restrictive, that aims to answer certain questions or problems, compared to fundamental research which is more open: 'Of course, I mean calls are restrictive sometimes and there is a tension between curiosity driven research, basically completely blue sky, versus basically addressing societal questions or specific goals. And that of course puts things into a more restrictive framework' (interview C2).

Another important influence of funding mentioned by interviewees is that sometimes there is no focus within a certain area or topic, which also means that there is not yet funding for it. This relates back to the fact that research goes where the money goes, and vice versa, that research will not be carried out in areas for which there is no money. On the other hand, there are some interviewees who are more optimistic. For example: *'And if you don't get it, yeah, then you have to reschedule and rethink at some of the research is not possible then, simply because there are no funds for that. So then you have to reduce it to what your original plans were and see what is possible within the budgets that you have or move it to some other kind of topic that you think perhaps better'* (interview A2), and: *'Yeah sure it plays a role, because if there's no funding, then I cannot do all the things that I want to do. But there is always some funding available to at least do smaller parts of it'* (interview A3). There were also interviewees who mentioned that if they cannot obtain funding for their research ideas at a particular point, the ideas will remain in mind and for which they will try to obtain funding at a later date. One interviewee stated that: *'Researchers play a role in what a call actually is as well, especially in the European Union. There is a lot of input from researchers in what a call, a text will be, so partly it's a matter of responding to it, but it's partly also shaping or at least trying to shape what the call text will be about'* (interview C1), implying that researchers also have influence on how funding is distributed

5.2.2.3. Collaboration

Important reasons for collaborating include to enhance the quality of research with expertise from other disciplines and the context it offers for interdisciplinary or international projects. Networks and networking events have an important role in stimulating connections between researchers from different disciplines and countries and finding the appropriate people for a research project. Epistemological, methodological and philosophical differences between disciplines are challenges for collaboration but can be overcome. The lack of funding opportunities for truly global projects is a barrier for global collaboration, as well as discipline-oriented funding organisations.

Opportunities

The most common reason given by interviewees for interdisciplinary collaboration with researchers from other fields is to complement one other and to add expertise which would otherwise be lacking. This can for example be in an interdisciplinary research question which should be researched from different angles and perspectives: *'(...) the social geography has expertise on all kinds of social processes, choices by people, on which we simply don't have expertise'* (interview C1). Several interviewees also indicated that new possibilities offer new opportunities for their research, where *'this new area of research requires new skills'* (interview A1). These new methods

require different skills that these researchers often do possess. Another reason is to learn more from one other and other disciplines: *'I learn the most from people that are not in my field and less from the people that are in my field'* (interview C2), and: *'we also need people from the outside, to keep us awake, to see the different cultures, different backgrounds, different trainings. It has proven in the past that we benefit from that a lot, as a group'* (interview B3). As explained by another interviewee: *'There's a lot of knowledge related to a certain discipline which could add value to what we are doing in other disciplines'* (interview D3). More specifically, reasons for international collaboration are often the context it offers in a specific country; particularly when doing research on multiple countries or societies, researchers from these countries can offer more context about a country and its practices.

Different factors help in facilitating collaboration such as funding, (detailed later), but also networks and networking events. Most interviewees acknowledged that they do not actively think about how they choose partners for collaboration as this is mostly through their own, existing networks. If researchers want to connect to someone outside of their network (mostly because the expertise they need cannot be accessed within it) they simply e-mail or telephone these researchers. In these cases, such researchers are mostly found through their publications. Networking events are important to facilitate becoming acquainted with people from different disciplines, for example conferences, which enable exposure to the areas of other researchers and collaboration possibilities. A number of interviewees mentioned the networking events and interfaculty meetings organized by Utrecht University which stimulate interdisciplinary collaboration: *'Within Utrecht university, for me, the most important platform there is institutions for open societies. (...) And within that area I went to a lot of meetings over the last five years, met a lot of colleagues, some of them became co-authors. So that was ultimately a stimulus for me to try to write things, for example, on the interface of law and philosophy or economics and philosophy or politics and philosophy. So part of my output and is also sort of more interdisciplinary that would otherwise have been without these kinds of contacts'* (interview D1).

Barriers

The majority of the researchers interviewed identified epistemological barriers that occur in the language or jargon employed in different disciplines and different interpretations following from this. For example: *'Language is also a problem, sometimes, it can be very subtle. You think you understand each other, but then people are talking really about something else'* (interview A1) and *'So people have different habits, have different vocabularies, et cetera. So one of the challenges that we ran into is that we have different interpretations of how you look at the environment and how you link that to health. So that has been, let's say, a learning curve to understand each other's vocabulary and interpretation'* (interview C1). Methods to overcome this barrier include establishing a common language at the outset of the project and ensuring that all involved are talking about the same things and that words have the same meaning for everyone. Another barrier is the difference in methodological approach used in disciplines, *'So we had this really methodological but also some epistemological problem that we as social psychologists tried to generalize across contexts and look for mechanisms that apply everywhere, equally, and historians really are interested in case studies and every case study is different'* (interview A3), but also differences in philosophy or perspective between disciplines were reference, for example: *'And then after several months of work, working together on this proposal, they said, well, yeah, we don't have the same philosophy as sociology, and we think - we don't believe you can study this in a scientific way. So there were all kinds of unexpected, difficult, more philosophical issues that that I hadn't foreseen'* (interview A1). In this example the collaboration ended because of these differences, but despite this, the researcher involved remains positive about interdisciplinary collaboration.

With specific reference to international collaboration, some interviewees mentioned additional barriers such as the privacy laws in other countries, time zones that make communication challenging and the cultural differences. The differences between intellectual cultures was mentioned as well as conceptual and contextual differences: *'some of these questions and some of the developments are in other countries quite different. And this is sometimes difficult to get on the same page if you have questions like ethnicity, racism, discrimination and different historical and cultural context, because they can play out very, very differently'* (interview A2). All these barriers can be overcome and do not mean that the researcher does not collaborate interdisciplinary or internationally anymore. Researchers learned from the past and found ways to overcome these challenges.

Funding

Funding is an important driver for inter-university and international collaboration, whereby collaborating is often a requirement of the grant. For example: *'So if you're applying for a large consortium, and you have to have collaborators from abroad, then that's basically what you do'* (interview A3) and *'(...) often, this is also prescribed by the call requirements. You see a call that might be for a socio-technical challenge, so you need both the technical people and the scientists from social science'* (interview B2). This does stimulate collaboration between countries and universities, but there are also drawbacks. Some of the interviewees are critical about this kind of stimulant for collaboration through funding: *'So, I guess this kind of funding can also become a bit trivial, in the sense that you might reach out to more partners, who won't invite you, because you come from the Netherlands. That's the main criteria, which is a bit strange, right'* (interview B2) and *'But nowadays, one of the requirements is to look for another university, while it may be more logical even to find colleagues within our own university to do that, but then this doesn't fulfil the requirement by NWO'* (interview B3).

Within Utrecht University funding enables interfaculty collaboration; interviewees indicated that smaller grants available within Utrecht University, from the strategic themes for example, stimulate collaboration across faculties. For example: *'But the collaboration with the geography department that really has been prompted by the availability of research funds within the university'* (interview C1), and: *'For these smaller grants, particularly if it's within UU, I really like them, because they enable collaboration across faculties'* (interview A3). These grants require collaboration within Utrecht University and therefore not only stimulate interfaculty collaboration but also make researchers aware that other disciplines could be a useful addition to their own research, as described by one interviewee: *'Now I am also more and more aware that the method and statistics department is also available for people like me to, you know, to work together on research projects'* (interview A1).

In the workshop we gave two statements related to this to participants. The first statement was: *'the Utrecht University Strategic Research Themes, Hubs and Focus Areas enable interactions across faculties and disciplines. These platforms are therefore well placed for addressing SDG research that implies the combination of diverse concepts and methods'*. All participants agreed with this statement. Secondly, we stated that the Utrecht University Strategic Themes should also help researchers to collaborate with researchers outside Utrecht University, to which all participants also agreed.

In contrast, interviewed researchers indicated that funding can be a significant barrier for collaboration. For example: *'So when we started there were strong ambitions to do joint projects (...). But that actually, because of funding, has been very difficult to work in practice. There are very few organizations that fund combined projects, and that's probably because many of these funding organisations are more disciplinary oriented'* (interview C1). This shows that even though researchers wanted to collaborate across disciplines, there were no funding opportunities to do so,

meaning that such joint projects cannot be realised. Other interviewees mentioned that there are projects which are not interdisciplinary, for example: *'But I also think that our research should be guided by the questions that we have, so if a question does not lend itself for interdisciplinary research, so if I have a simple question that is only sociological, then I should be able to also answer that question in that way and not always think okay, I have to do something interdisciplinary so I have to change my question so that I could engage someone from humanities, because that's what now the university wants, because I think that then kind of goes against the research idea itself'* (interview A3). These are important issues, because whereas funding can obstruct collaboration across disciplines, it is also possible that an increasing amount of funding schemes call for collaboration across disciplines, this is not necessary or desirable for all research topics.

Specifically for international collaboration, two interviewees mentioned that one of the serious problems they face is the lack of funding to address real global challenges: *'I think, where we do have large problems is actually addressing real global challenges, so the funding scheme basically for us is very clear if we stay within European boundaries. But to cross European boundaries becomes very difficult, so we do also a lot of research on indoor air pollution in China, Africa, Latin America, but it's almost impossible to find funding for this kind because the European Union will not pay, the Dutch government will not really pay for this kind of research, because it's not a problem that we have within our boundaries, European or nationally'* (interview C2). This is problematic as it prevents collaboration between countries worldwide to research worldwide topics referred to by the SDGs. Additionally, workshop participants were asked what they thought the biggest barrier to working on SDG related global challenges in collaboration with researchers located outside Europe was, to which most responded was funding, in the sense that there are few funding opportunities for truly global projects and that EU projects are restrictive in the countries that can be involved. We posed the follow up question 'In what ways can Utrecht University help researchers to overcome such barriers?', to which a couple of participants responded was to build alliances with universities abroad. Others responded this could be done through listening to researchers and by acknowledging the issues and barriers they experience. The University providing funding for such research was also suggested.

5.2.3. Qualitative results – conclusions and propositions

In **Error! Reference source not found.** the results of the qualitative phase are summarised for each analysis level: the SDG agenda, research motivation and collaboration. The table includes a proposition for each level, which are explained further below the table.

	SDG agenda	Research motivation	Collaboration
<i>Description</i>	Awareness of SDGs and the relation between the SDG agenda and personal research agenda	Motivation for research topic which addresses SDG(s)	Barriers and opportunities for interdisciplinary and international collaboration
<i>Key insights</i>	No good fits between an SDG agenda and personal research agenda	Most significant motivation is personal interests and personal values; research should be socially relevant. Relating to the SDGs seems more incidental as opposed to by design for most researchers	Reasons for collaboration are to improve research and include different views. Collaborating is difficult, but the benefits outweigh the difficulties. Lack of global funding opportunities is a challenge
<i>Opportunities</i>	Most researchers acknowledge the importance of SDGs and of creating awareness of how research relates to SDGs	Researchers see the importance of developments and the opportunities for their own research	Research questions on these topics require an interdisciplinary approach, Grant requirements for collaboration Networks & networking events are important to interact with (new) researchers
<i>Barriers</i>	Research already undertaken on societal relevant topics: no impetus to link research to SDGs. (Extra) benefit of linking research to SDGs unclear; Lack of knowledge about SDGs	Knowledge trajectories around these topics have been accumulating over a long period and researchers build upon their own research and that of colleagues	Epistemological, methodological and philosophical differences between disciplines; Disciplinary-oriented funding agencies; Not all research is, or should be, interdisciplinary
<i>Funding</i>	Smaller grants could offer opportunities to experiment with research in relation to SDGs	Funding opportunities limit the options, but researchers would unlikely do research simply because there is funding available for it	Funding can stimulate collaboration but can become trivial. Lack of global funding opportunities is problematic
<i>Proposition</i>	Utrecht University can play a more active role in disseminating knowledge about the SDGs and creating an incentive to link research to the SDGs	Research is mostly motivated by societal relevance of the research and intrinsic motivation (personal interest). This is more important than the availability of funding	The Utrecht University Strategic Research Themes and Focus Areas are well placed for addressing SDG research that combines diverse concepts, methods, and countries

Table 7: Summary of qualitative results per category

5.2.3.1. *SDG agenda*

Utrecht University could play a more active role in creating awareness about the SDGs and motivating researchers to relate their research to the SDGs.

Most of the researchers acknowledge the importance of the SDGs, they do not however identify a strong relationship between the SDG agenda and their research agenda or activities, even though their work is closely related to SDG topics. Creating awareness about the role of researchers in the SDGs gives researchers the possibility to make strategic choices.

There are two researchers who use the SDGs in their research. Their research is more mission driven and could be more related to agendas that have a strong fit with the SDG agenda, as compared to other research which may be based on agendas that have a tenuous relation to the SDG agenda.

5.2.3.2. *Research motivation*

Researchers have an intrinsic interest in topics related to societal and worldwide relevance of topics. Such interest is beyond funding dynamics.

Despite many of the researchers interviewed not recognising a strong link between their research and the SDGs agenda, their work is closely related to SDG topics. They indicated that their impetus for undertaking their research is its societal relevance as well as their own, intrinsic motivation for the topic. The availability of funding limits their research possibilities, but this does not play a role in the motivation for the research topics.

5.2.3.3. *Collaboration*

The Utrecht University Strategic Research Themes and Focus Areas are well placed for addressing SDG research that implies the combination of diverse concepts and methods.

Possibilities afforded by new methods and developments enable researchers to implement more complete research with views from different perspectives. However, these methods and different views require new and different skills, which encourages researchers to collaborate with other disciplines. The Utrecht University Strategic Themes and Focus Areas facilitate interaction across faculties and disciplines, as providing small grants which researchers can use to experiment or set up new research ideas with researchers from other faculties. This seed money provides an impetus for researchers to carry out interdisciplinary research on the SDGs combining multiple SDGs.

6. Conclusion

This report presents an analysis of the Scientific Knowledge Trajectories related to the Sustainable Development Goals (SDGs) at Utrecht University (UU). A principal conclusion is that research efforts related to the SDGs have grown rapidly in the period since 2000, covering all SDGs but to a differing degree. This reflects the strategic direction which posits the SDGs as major guiding principles and places them at the heart of the operations and ambitions of the University. The quantitative results show that the most frequent SDG trajectories emerge around Health and Wellbeing (SDG 3), Climate Action (SDG 13) and Clean Water and Sanitation (SDG 6). Compared to the national trend, Utrecht University (UU) is particularly strong in research related to Climate Actions (SDG 13).

Our analyses show that there are many interactions across SDGs (and non-SDG) research communities. The interactions of Sociotechnical Systems with Transversal Directionalities (such as SDG 13 and SDG 6) are particularly strong, thus providing indications for an ongoing transformation of the research system. However, we identify that less than 2% of the research at Utrecht University combines SDGs from the three categories (socio-technical systems, transversal directionalities, and framework conditions). It is therefore a key area of research to be developed since the implementation of the SDGs implies that their complex interactions (synergies and trade-offs) are considered.

In this project several workshops engaged researchers and other stakeholders in a dialogue to articulate the evolution of research trajectory over time, inviting new perspectives on what research goals and priorities will contribute to transformative change. These dialogues play an essential role in bridging aligning strategies and will increase the reflexivity of the research system.

The results presented here can support Utrecht University in identifying the thematic orientation of its current research in the framework of the SDGs and will help to increase the transformative potential of Utrecht University research by adding a reflexive layer to be used for navigation by researchers and decision-makers at the University. The results can also be used for university profiling. Our qualitative results demonstrate that researchers at Utrecht University are interested in undertaking research which enhances interactions across the SDGs. The intrinsic interest of researchers in integrating diverse SDGs topics and the current facilities to collaborate at Utrecht University are already having a positive impact. However, Utrecht University may further increase its impact by increasing awareness about the SDGs within the University, generating reflections on SDG research, and employing seed money along with additional mechanisms to nurture and develop knowledge trajectories that integrate diverse SDGs.

We have identified the following opportunities for potential follow-up activities:

- A. Distribute results of this work more widely within the University and facilitate further discussions about how to navigate the results, in which directions the research could and should develop, setting of priorities (if any) and generating more interactions for example;
- B. Develop more insights on how Utrecht University (UU) compares with other institutions, and how its research is complemented and strengthened by its strategic collaborators;
- C. Develop further insights into the nature of national and international scientific collaborations of SDG communities, societal networks and partners of Utrecht University (UU) within these SDG communities;
- D. Applying the methodology to other universities or groups of universities;
- E. Deepen the qualitative work by studying a larger sample of research communities;

- F. Developing the methodologies used in this study, in particular how to measure the transformative potential.

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Appendix A. The Thesauruses

The search results of the Ramirez et al. thesaurus and the STRINGS thesaurus are compared in depth. The Ramirez et al. thesaurus consist of a total of 2155 keywords, describing the 17 SDGs. The STRINGS thesaurus consists of 3718 keywords, describing 16 SDGs (excluding SDG 17). Both thesauruses are used to find SDG publications in the dataset.

The Venn-diagram, which shows the interaction and difference between both datasets, is shown in Figure 13. We see that of all publications retrieved by both the Ramirez and STRINGS keywords, 5573 publications are retrieved by both thesauruses. We also observe that the Ramirez keywords retrieve many more publications, a total of 12,758 (Ramirez) vs. 7,449 (STRINGS) publications. Of the publications that STRINGS retrieves, a large share of 75% is also found by the Ramirez keywords. This implies that the STRINGS thesaurus is more specific, resulting in a smaller dataset, but retrieves largely similar publications. The Ramirez keywords are less strict defined and therefore match more publications.

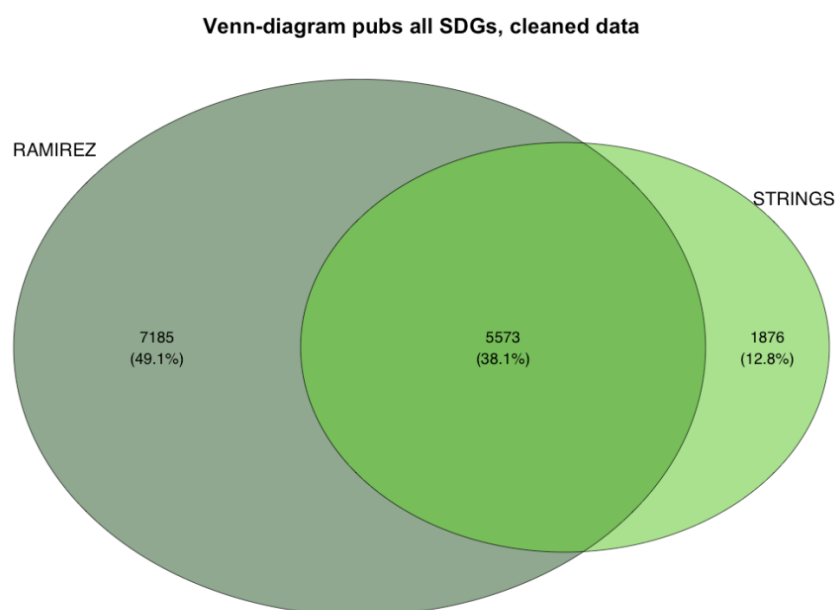


Figure 13: Venn diagram of the overlapping publications between the Ramirez and the STRINGS datasets

Comparing the publications found in each SDG shows that the STRINGS thesaurus is more biased towards SDG 3, whereas the publications retrieved with the Ramirez et al. thesaurus are more evenly distributed across all SDGs. Figure 14 shows the overlapping publications in each SDG. We see that many publications that are defined as SDG 3 using the STRINGS thesaurus are defined as SDG 1 or 2 using the Ramirez thesaurus. When we look at the distributions of the publications per SDG for each thesaurus in Figure 15 we see that for the STRINGS thesaurus nearly 40% of the retrieved publications are in SDG 3. For the Ramirez et al. publications this number is half.

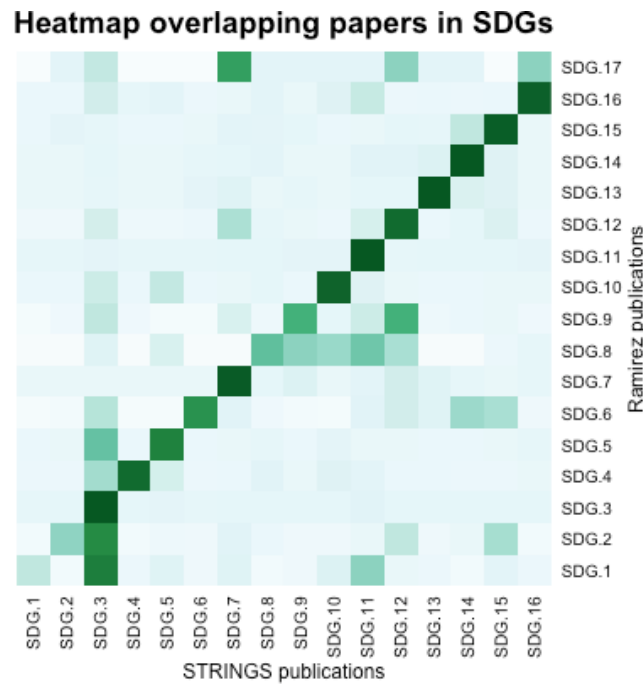


Figure 14: Heatmap with the overlapping publications per SDG for the Ramirez et al. and STRINGS thesaurus (matrix is scaled column-wise)

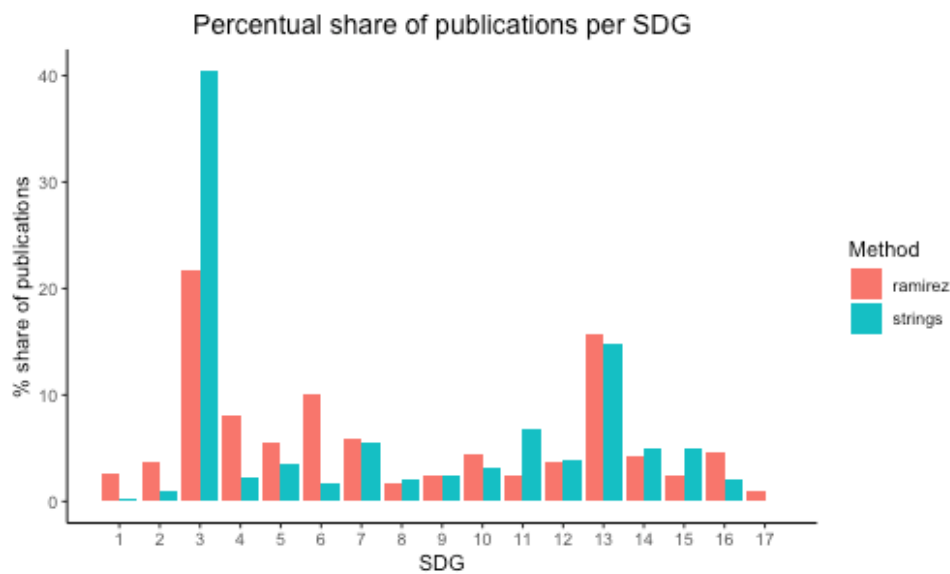


Figure 15: The percentual share of the publications per SDG, for the Ramirez et al. and STRINGS thesaurus

The Ramirez et al. thesaurus is developed to study the interactions between the SDGs and focusses on the transformative lens, whereas the STRINGS thesaurus is developed with more focus on single SDGs. Due to the familiarity of the researchers with the Ramirez thesaurus, as well that it has been developed to study the interactions between the SDGs, this research will continue with the dataset of SDG publications as retrieved by the Ramirez et al. keywords. Combining both thesauruses was considered, but this would mean that two thesauruses developed for a very different research aim would be used together. Moreover, as we see in Figure 25, for most SDGs both thesauruses find publications in the same SDG. The differences are in SDG 1, 2 and 3 and SDG 8.

Appendix B. The Clustering Algorithm

The Louvain clustering algorithm and the Leiden clustering algorithm are both implemented and compared. The Louvain algorithm is a bottom-up hierarchical community detection algorithm introduced by Blondel et al. (2008)⁵. The Leiden algorithm, introduced by Traag et al. (2018)⁶ is based on the Louvain algorithm, but instead of continuously checking all nodes in the network whether they can be moved to a different cluster, it only checks so-called unstable nodes. The heatmap in Figure 16 shows the overlapping publications per community for the clustering algorithms. We see a clear diagonal line in the figure, which means that the publications in the communities are nearly equal for both clustering algorithms. For our analysis the Louvain algorithm showed to be faster. Moreover, the Louvain algorithm is a more broadly used and well-known algorithm. Because of the little difference between both clustering algorithms, we will continue with the Louvain clustering algorithm. The Louvain algorithm results 229 clusters in the network, with a modularity of 0.98.

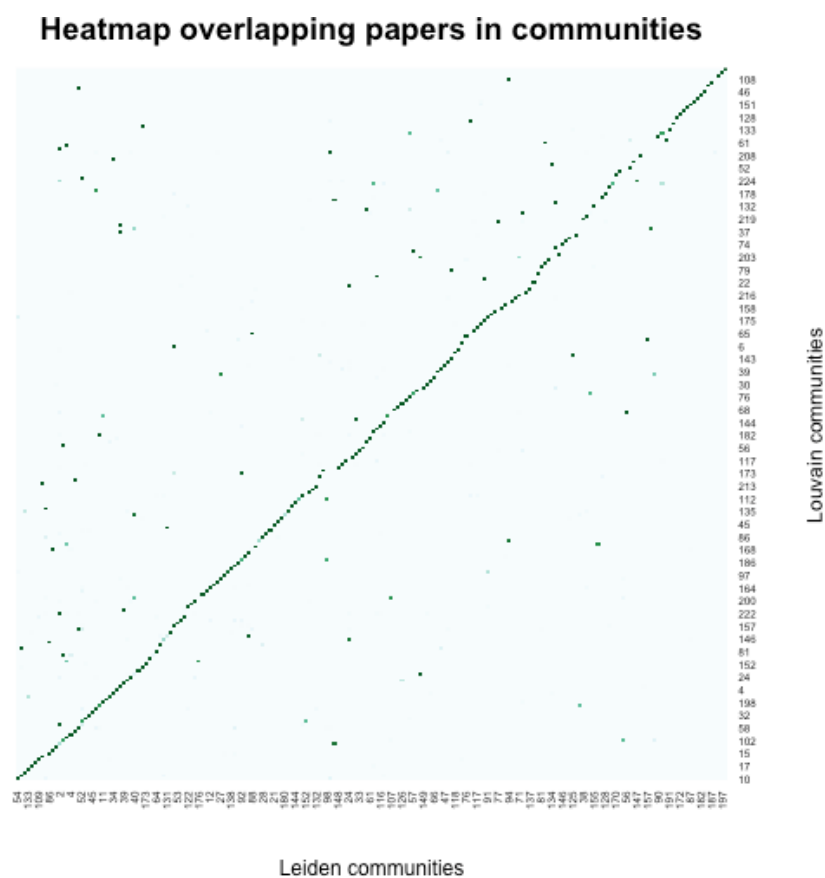


Figure 16: Heatmap with the overlapping publications in the communities by the Leiden and Louvain algorithm

⁵ <https://arxiv.org/abs/0803.0476>

⁶ <https://arxiv.org/abs/1810.08473>

Appendix C. The Co-bibliography Network

The co-bibliography network is created, where the nodes are the bibliometric data sources from Web of Science and the ties are the shared bibliography. To find well defined communities with strong cognitive relationships we set a threshold for a link between two publications to be meaningful (cut-off point). Different thresholds and the corresponding modularity, nodes and communities in the network are evaluated. Figure 17 shows the values for the different thresholds. Based on this figure the threshold for a link to be meaningful is set to be 17, which gives a large set of documents in the network, but also a high modularity of the communities in the network. All non-meaningful links and nodes are removed from the network, resulting in a network with 48,994 nodes and 159,903 links.

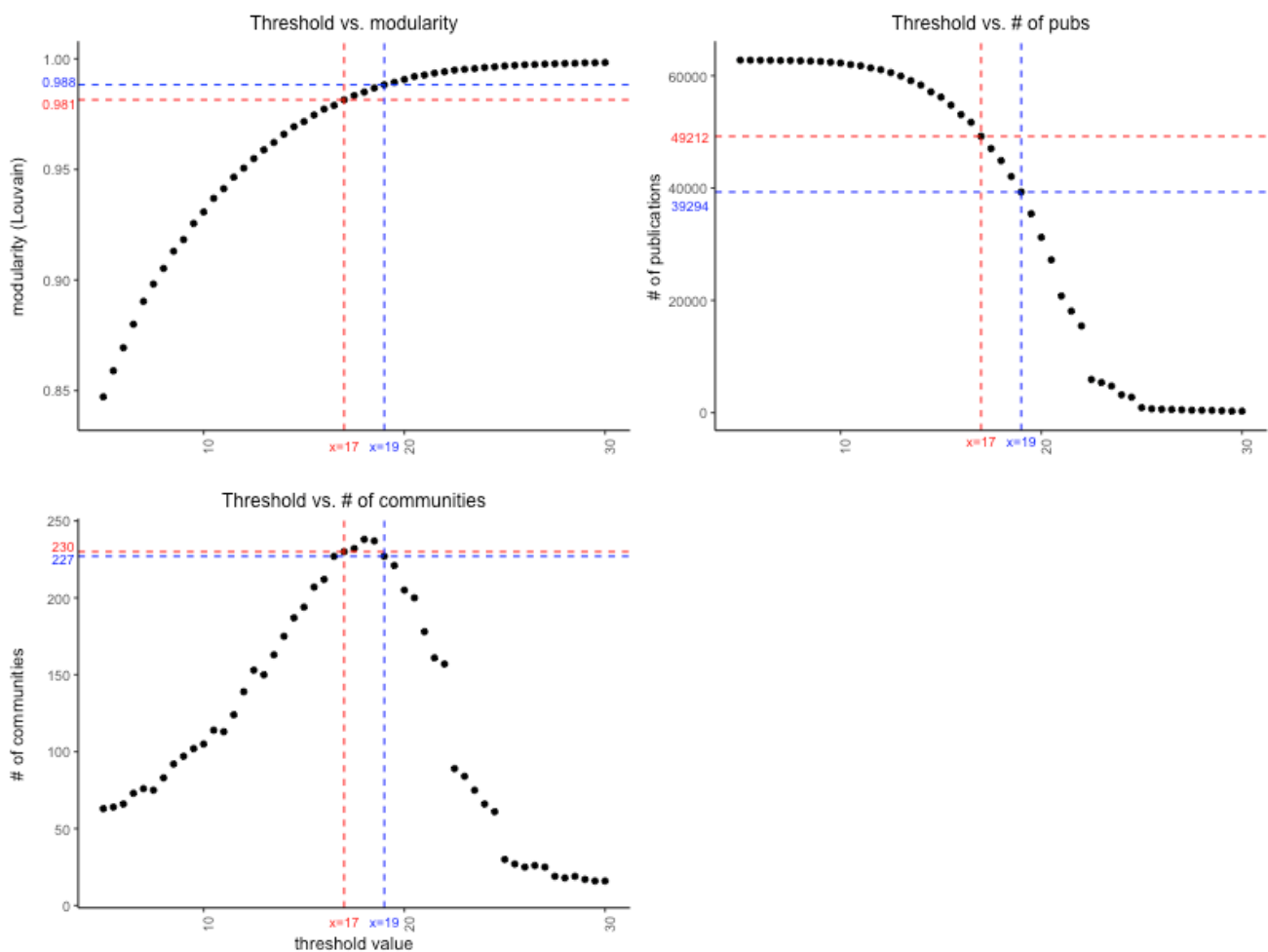


Figure 17: Graphs of the modularity, number of publications and communities for different threshold values

Appendix D. SDG Communities

Based on the previous criteria, a community is defined as an SDG community if it satisfies *at least* one of the following conditions:

The SDG share of the community is higher in T4 than the SDG share in T3 *and* the SDG share in T4 is higher than 0.39

The slope of the trendline of a community is larger than zero *and* the total SDG share is higher than 0.30

The first condition is based on the idea that the SDGs were introduced in 2015. If the SDG publication share of a community did not increase since the introduction of the SDGs, compared to the five years before (T3), it is not regarded as an SDG community. Additionally, the SDG publication share of a community should be at least 0.39 in T4. This is based on the turning point in the left graph in Figure 18. The second condition is based on whether a community shows a promising trajectory towards the SDGs. If the slope of the trendline is larger than zero it means that the SDG publication share in the community shows an increasing trend of the past 20 years. Additionally, the community should have an SDG publication share of at least 0.30, based on the turning point in the right graph in Figure 18.

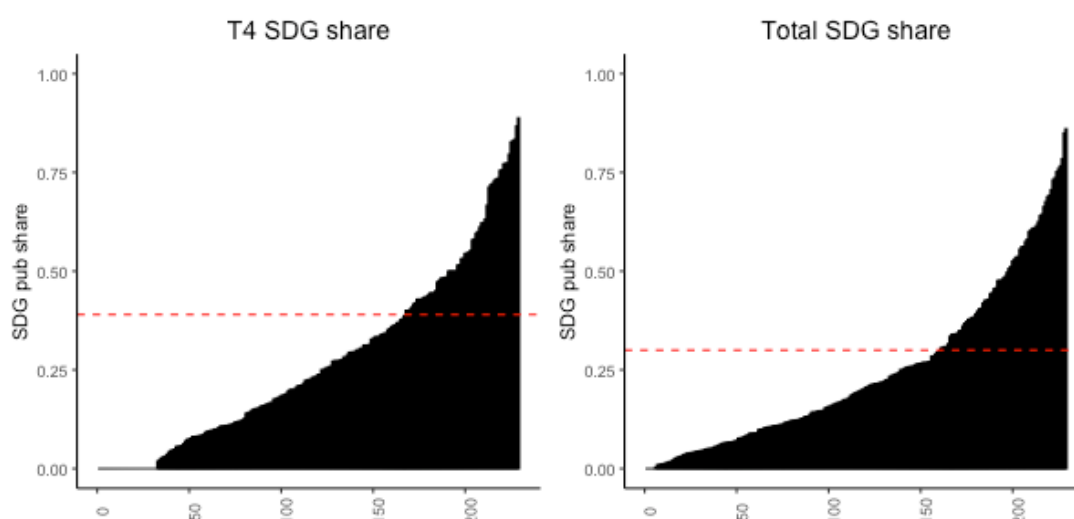


Figure 18: SDG share in T4 (2015-2020) (left), total SDG share (right)

These conditions are defined for this research and allow us to make a distinction between communities focussing on SDG research and communities *less focussed* on SDG research. By analysing the entire network of Utrecht University, the interactions between SDG and non-SDG communities are taken into account. Some 'non-SDG communities' are facilitating knowledge circulation for the SDG communities, or execute the research underlying research on the SDGs. These communities are not marked as 'SDG community' but are nonetheless of importance. The distinction between SDG and non-SDG communities is made for analysing the differences in communities and comparing the communities with a high SDG research focus and communities with a lower SDG research focus, their interactions and research topics.

Appendix E. Details of Temporal Analysis

Because we are interested in where selected communities emerged and how they developed, we do not need to relabel over the timeframes. We create the similarity matrix between communities for each timeframe, and communities in graph G_{T-1} get a similarity score with the communities in the current graph (G_T). The similarity s is defined follows:

$$s_{ij} = \frac{P_i \cap P_j}{P_i}$$

Where P_j is the set of publications in community j in G_{T-1} and P_i the set of publications in community i in G_T . This similarity measure is adapted from the Jaccard similarity, but because we want to know in which community in G_T the publications from community j in G_{T-1} are, we only need to know what the share of P_i in some community in G_T is. The similarity matrix M_s is created where the rows correspond with the communities in G_T and the columns with the communities in G_{T-1} . If the similarity score between community i and j is equal to 1, it means that all publications from community i in G_{T-1} are in community j in G_T . However, over the years new research communities are formed, whereby communities split into new communities, or communities merge together. This is represented in the similarity matrix M_s . If community i from G_{T-1} has a similarity score of 0.5 with community j in G_T and a similarity score of 0.5 with community k in G_T , community i split into two new communities, j and k . On the other hand, if both community i and community l in G_{T-1} have a similarity score of 1 with community j in G_T , community i and l merged together into community j . It is very well possible that communities from G_{T-1} that split, one part of them also merged with another community into a new community in G_T . Due to the nature of the clustering algorithm, it is possible that unstable publications are assigned to a different cluster. Therefore, a threshold of $s_{ij} \geq 0.1$ is implemented for the split and merge of communities.

Appendix F. Interview Documents

F.1. Interview list

Interviewee	Reference	Community	Faculty
1	A1	154	Social Sciences
2	A2	154	Social Sciences
3	A3	154	Social Sciences
4	B1	176	Geosciences
5	B2	176	Geosciences
6	B3	176	Geosciences
7	C1	71	Veterinary Medicine
8	C2	71	Veterinary Medicine
9	C3	71	Veterinary Medicine
10	D1	197	Humanities
11	D2	197	Medicine Education
12	D3	197	Veterinary Medicine
13	D4	197	Medicine Education

Table 8: Interview list (anonymised)

F.2. Interview guide

High-level topic		High-level question	Questions	Answered?
Mechanisms of emergence and development of research topic	<i>Individual</i>	<p>What brings individuals to their research topics and pushes them forward?</p> <p>How is a new research project prepared?</p> <p>Transformative change: how does research on the SDGs interact and are other SDGs considered?</p>	<p>What are the mechanisms for the origination of a new research proposal or project, related to global challenges?</p> <p>How do you set up a new research project? How are tasks in the research conceptualised and divided among researchers / project team members?</p> <p>What is the role of the other SDGs in your research? Do you consider other SDGs when working on some SDG, and if so, why and how?</p>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
	<i>Collective</i>	<p>How do researchers work with respect to the research landscape / community they are in?</p> <p>How does the research landscape (or community that a researcher is in) constrain or limit the individual choices?</p>	<p>How do you attract new researchers to research related to the SDGs?</p> <p>How are your research choices / decisions influenced by the research landscape / community [local capabilities] of the UU?</p> <p>To what extend do the local capabilities at UU influence your research? And your ability to collaborate with researchers from outside the UU?</p>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Funding of research	<i>Collective</i>	<p>How do you get funding for your research?</p> <p>How does funding shape the research agenda?</p> <p>In what ways does funding/money constrain your research?</p>	<p>What are the methods or practices to realise funding for a new research project that is related to the SDGs?</p> <p>How does money or funding influences your research? Do you have examples of research projects that changed due to funding or money?</p> <p>What are typical difficulties you encounter when realising funding for projects or research related to global challenges?</p>	<input type="checkbox"/> <input type="checkbox"/>

High-level topic		High-level question	Questions	Answered?
			How do these difficulties constrain the research possibilities or projects?	<input type="checkbox"/>
	<i>Individual</i>	How are individual choices influenced by funding or money?	In what ways is your research agenda and personal decisions on topics influenced by funding?	<input type="checkbox"/>
Interaction with other communities	<i>Collective</i>	In what ways do you enhance your research by collaborating with other researchers within and outside the university? To what extent do you rely on other people / stakeholders / researchers in your research? [mutual dependence]	How do you establish collaboration with researchers from other fields or departments, both within and outside the UU? What are the barriers and opportunities? How do you bring different, diverse researchers from diverse disciplines together in a research project? What are the barriers and opportunities?	<input type="checkbox"/> <input type="checkbox"/>
	<i>Individual</i>	To what extent do the local capabilities influence your research / your ability to collaborate with outsider researchers?	It is easier to collaborate with people of your own institution [proximity]. What motivates you to collaborate with researchers or stakeholders outside the UU? What are the opportunities and difficulties in collaborating with local researchers and stakeholders in other countries? What are the challenges and how do you overcome them?	<input type="checkbox"/> <input type="checkbox"/>
Teaching	<i>Individual</i>	How do teaching programs shape the research agenda?	How is your research agenda and are decisions influenced by the teaching programs offered at the UU?	<input type="checkbox"/>
	<i>Collective</i>	How is the research agenda of a research topic or community influenced by teaching programs?	How is the research agenda of the SDGs influenced by teaching programs at the UU?	<input type="checkbox"/>
Difficulties related to working on these topics		What are difficulties related to working on these research topics that are at the nexus of various domains?	Do you find any inherent complexities or challenges on interdisciplinary research over research on demarcated topics, that are within one field / research area?	<input type="checkbox"/>

F.3. Interview information sheet

SDG Research transformative potential Information sheet [[dd-mm-yyyy]]

Research description

Centre for Global Challenges uncovers Utrecht University's transformative potential

Utrecht University is working towards a better world. As stated in its recently published [Strategic Plan 2025](#), Utrecht University treats the United Nation's Sustainable Development Goals (SDGs) as major guiding principles and places them at the heart of its operations and ambitions. This ambition resembles with the [mission of the Centre for Global Challenges](#) (UGLOBE). UGLOBE emphasises the increasing interconnectedness of universal issues in an era of rapid globalisation. In order to respond to the new complex dynamics emerging from this a focus on system transformation is needed. This entails questioning the very assumptions on which modern society is built, breaking down silos and enabling collaboration and experimentation amongst actors relevant in change processes, including scientists, students, practitioners and citizens.

In this research project, UGLOBE, in collaboration with the [Copernicus Institute of Sustainable Development](#), strives to unlock the transformative potential of Utrecht University research for addressing the Sustainable Development Goals. By means of mapping synergies and knowledge communities within research conducted on the SDGs, UGLOBE's research results will support the integration of interdisciplinary knowledge and reveal opportunities to progress transformative change. Taking a systemic approach, the project is going beyond an analysis of individual goals but engages in a discussion of the types of interactions taking place in the research system, between which areas and what sort of research is more likely to be a catalyst for transformation. Thereby, new mechanisms for reflecting on SDG research conducted at Utrecht University will be proposed.

The conceptual approach of this project is based on the notion that research which "builds bridges" between science and technology and the social and environmental pillars of sustainable development can facilitate addressing a variety of SDGs simultaneously. Hereby, the research impact and transformative potential is being enhanced. The project applies a mixed methods approach. Firstly, research communities that integrate various SDGs are identified through conducting a Bibliometric Network Analysis using relevant data bases such as Web of Science. And secondly, researchers who are part of the identified research communities are interviewed and a number of exploratory workshops are organised. This qualitative part of the methodology allows for a characterisation of the bottom-up strategies to integrate and enable SDG research at Utrecht University. The mapping of such strategies will contribute to the reflexive capacities of research groups and individual and hence enable long-term transformations of the way SDG research is conducted at Utrecht University.

In the years to come, Utrecht University aims to use the SDGs as an instrument to identify challenges and potential solutions, with its education and research aimed at contributing to enhance knowledge of all 17 SDGs. The methodology and results of UGLOBE's research project can facilitate reaching this ambition and support Utrecht University in becoming a "transformative university".

Information regarding the interview

In order to discover the possibilities and constraints related to research on the SDGs, we would like to interview colleagues researching the SDGs. Your research is focused on education opportunities of disadvantaged children, especially in low- and middle-income countries. This topic is closely related to SDG 4, which is about "*ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*". Moreover, as the director of UGlobe, you are working on addressing the global challenges with interdisciplinary teams and researchers from diverse fields. For these reasons we would like to interview you about your research.

The interview will focus on the emergence and development of your SDG research. In particular we will dive into enabling conditions and cognitive, institutional, financial and other conditions that enable or constrain SDG research. We would like to look at diverse barriers that hamper research related to the SDGs, and how these are or can be overcome. Moreover, we are interested in mechanisms that trigger research that combines multiple SDGs, and how research on different SDGs is bridged. To that end, we will also focus on collaboration and interaction with other researchers in the interview.

With your contribution we can map in what ways SDG research at Utrecht University is enabled or constrained, with the aim to increase the transformative potential of SDG research at Utrecht University.

The interview

The interview will take place online, using Microsoft Teams. We will do the interview with two project members, where one will ask questions and one will take notes and guide the interview. The interview will take approximately 1 hour and will be audio-recorded. The interview will be recorded and stored in Microsoft Teams. Afterwards the interview will be transcribed. Your participation in the interview is completely voluntarily and you have the right to refuse participation, refuse any question or withdraw at any time without any consequences.

Outcome of the research

The research will result in a policy document, an extended report and a knowledge map of the research landscape of Utrecht University.

F.4. Interview consent form

SDG Research transformative potential

Consent form [[dd-mm-yyyy]]

I have read and understood the study information sheet dated [[dd-mm-yyyy]], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

I voluntarily agree to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without any questions of any kind.

I understand that taking part in the study involves being interviewed by one of the researchers about my research topics that are related to the SDGs. The interview will focus on the emergence, development and funding of my SDG-related research, as well as the collaboration with others and the difficulties related to SDG research.

I agree to my interview being audio-recorded and transcribed as text. The audio-recording will be deleted after transcription.

I understand that the information I provide will be used for a final report, as well as a scientific publication and presentation.

I understand that information I give in this research will be treated confidential. I understand that personal information collected about me that can identify me, such as my name, will not be shared beyond the study team.

I agree that my information can be quoted in research output. I understand that in any report on the results of this research my identity will remain anonymous.

I understand that the signed forms, transcripts and audio files will be safely stored and only opened by the research team.

I understand that I can request the transcriptions or audio files of my interviews at all times.

I understand that I can approach the researchers at all times to seek further clarification and information.

Oscar Yandy Romero Goyeneche
PhD candidate
o.y.romerogoyeneche@uu.nl

Enric Vila i de Villasante
Researcher
e.vila@uu.nl

Jolynde Vis
Researcher
j.t.vis@uu.nl

Signature of research participant

Name of participant

Signature

Date

Signature of researchers

Name of researcher

Signature

Date

Appendix G. Workshop Propositions & Questions

Most of the researchers acknowledge the importance of the SDGs. However, they do not experience a strong fit between the SDGs agenda and their research agenda or activities, even though their work is closely related to SDG topics.

Is it important to be aware of how research is related to the SDG targets, and why?

Why do you think that researchers do not find a strong fit between the SDG topics and their research?

How can UU make researchers more aware of their contribution to the SDGs?

Researchers indicate that instead of the SDG agenda, other societal and policy agendas, have more direct influence on their research topics. Three examples are the agenda of the inter-American human rights system, the EU Green Deal agenda, and topics posted by the World Health Organization.

What are possible reasons for the better alignment of these agendas over the agenda of the SDGs?

Other agendas...

- ... are more established
- ... have existed for longer
- ... are wider recognized
- ... are more legitimate
- ... are more specific
- ... have a closer relation to research
- Other

In what ways can the diversity of agendas restrict or trigger the implementation of the SDGs?

Researchers build up international networks to undertake research related to global challenges as expressed in SDGs (e.g., migration, environmental health). However, researchers acknowledge multiple barriers to working in topics outside of Europe, for example, culture or time differences, but also diverse epistemologies and different funding cultures.

What is the most important barrier for working on SDG related global challenges in collaboration with researchers located outside Europe?

In what ways can Utrecht University help researchers to overcome such barriers?

The Utrecht University Strategic Research Themes, Hubs and Focus areas enable interactions across faculties and disciplines. These platforms are therefore well placed for addressing SDGs research that implies the combination of diverse concepts and methods.

Do you agree with this proposition? (Yes/No)

Should the UU strategic teams also help researchers to collaborate with researchers outside of UU? (Yes/No)

Researchers use small grants to experiment with new avenues of research or new methods. These small grants help researchers to apply for big grants and create the opportunity for interdisciplinary SDG related research by interconnecting diverse scholars and topics.

What role do these small grants play in research topics related to the SDGs / combining SDGs?

Emerging research topics are often associated with multiple SDGs (e.g., climate migration, environmental health, environmental justice).

What are the difficulties to work on these topics?

How can UU better facilitate this type of research?

Appendix H. Community Characteristics

H.1. Community 176

Community 176 has a total of 290 publications, of which 144 are SDG-related publications. It has a betweenness centrality score of 0.027 (7th highest of the SDG communities). There are 26 different triads combinations in the community.

	SDGs	Triads	Research areas
1	7 (39.8%)	7-7-7 (ST-ST-ST) 30.3%	Energy & fuels (71x)
2	13 (18.8%)	11-7-7 (ST-ST-ST) 15.6%	Engineering (41x)
3	4 (6.3%)	17-7-7 (FC-ST-ST) 9.0%	Physics (21x)

Table 9: Main SDGs, triads and research areas of community 176

When we dive deeper into the characteristics of community 176 (Table 9) and analyse the most frequent SDGs in the publications of the community, we see that the three most prominent SDGs are SDG 7, 13 and 4, which are about affordable and clean energy, climate action, and quality education. The most frequent triads in community 176 are 7-7-7, 11-7-7 and 17-7-7, of which the first two fall in the ST-ST-ST group and the last one in the FC-ST-ST group. The last one shows an interesting connection between the sociotechnical systems and framework conditions.

The most frequent research areas of the publications in this community are energy & fuels, engineering, and physics, which are in line with SDG 7 and 13. They seem somewhat less related to SDG 4 – quality education, but the publications could be about physics education. The most frequent keywords of the publications in community 176 are shown in the word-cloud in Figure 19. Most are related to green and sustainable energy topics, such as 'self-consumption' and 'photovoltaic(s)'. The keywords 'demand response' and 'demand side management' indicate a business and economics side, which could be more related to SDG 4, while 'smart grids' is more related to engineering.

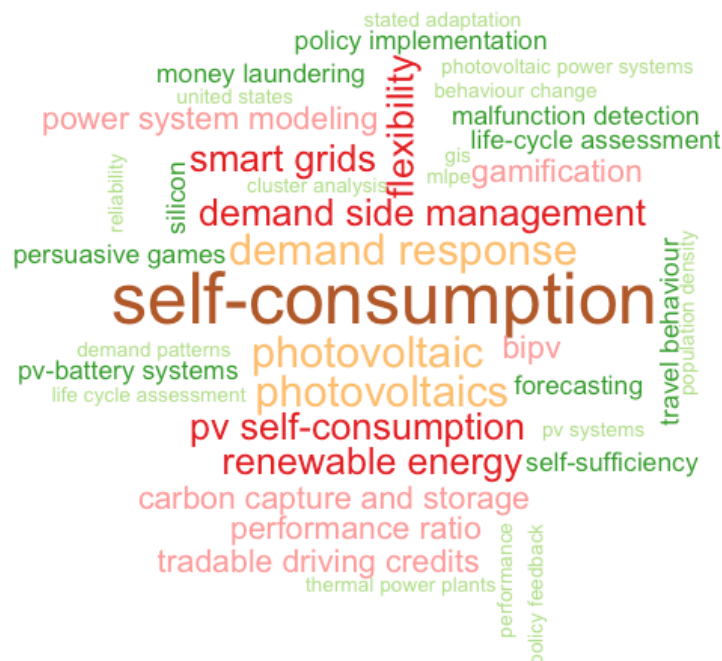


Figure 19: Word-cloud of the author keywords of the publications in community 176. The size of the keyword indicates the frequency of the keyword in the publications, with a maximum of 40 words.

To analyse the connections that community 176 has with other communities and its location in the network, we look at the egocentric network. The ego network in Figure 20 shows the communities with which community 176 has a direct link. Community 176 is connected to many SDG communities related to a diverse set of SDGs, such as SDG 3, 11 and 16 (health care, sustainable cities, and peace, justice and strong institutions). The thickness of the line indicates how strong the connection is (when the publications in a community have more shared bibliographies with the publications in another community, there is a stronger connection between the two communities). Community 176 shows a strong connection with community 226, which is about SDG 16, and with community 180, which is about SDG 3.

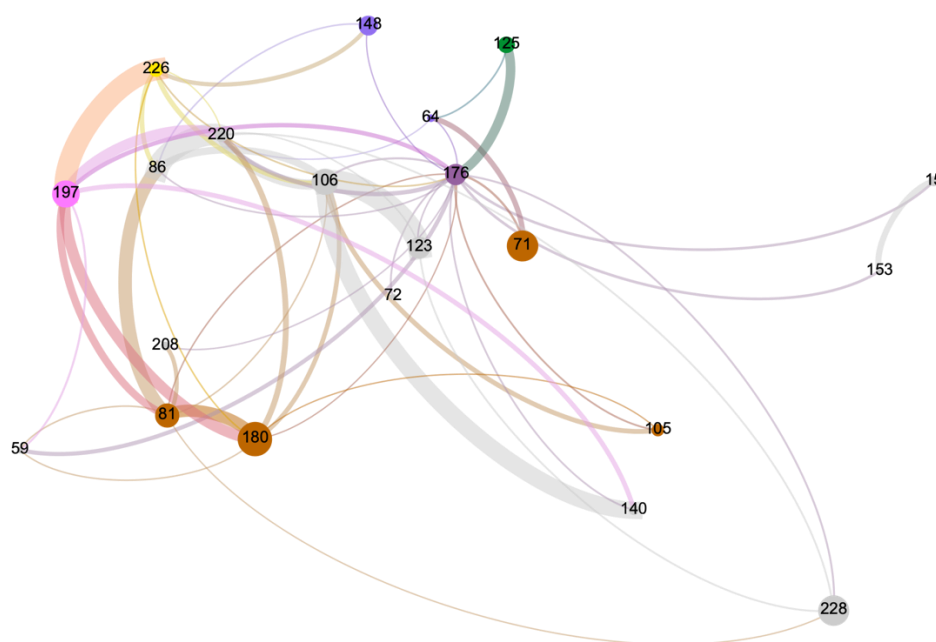


Figure 20: Ego network of community 176. Node size is betweenness centrality.

Temporal analysis

The temporal analysis shows how community 176 developed over the years. This community was formed from six communities in T6 (2015-2017). Three of these six communities emerged in T6, meaning they did not exist in T5 (2012-2014) and were formed from new publications that were published after 2014. These three communities, combined, are accountable for 25% of the publications of community 176. From the other three communities in T6 of which community 176 was formed, only a part of their publications went to community 176. These communities were split in T6, where a small part of the publications went to community 176, but most publications went to other communities. These latter three communities show a longer existence over the years, whereas each of them can be traced back to T2 (2003-2005). These three communities are accountable for 35% of the publications in community 176. The other 40% of the publications in community 176 are published after 2017 (after T6) and were included in community 176 in T7. Figure 21 shows the timeline of the communities over the past 17 years, up to T2. Each rectangle represents a community, and each column represents a timeframe. In the column T7 is the community of interest, in this case community 176. The figure shows from which communities a community is formed, and how many publications of the community in the previous timeframe (T-1) went to the community of interest (indicated by the large grey arrow). The small grey arrow indicates into how many communities a community split. For example, community 101 in T6 split into 3 communities, where 22% of its publications went to community 176 (and the other 78% of the publications went to 2 other communities in T7). The numbers in T2 indicate from how many communities the community in T3 is formed, i.e., community 35 in T3 came from one community, whereas community 116 comes from two merged communities.

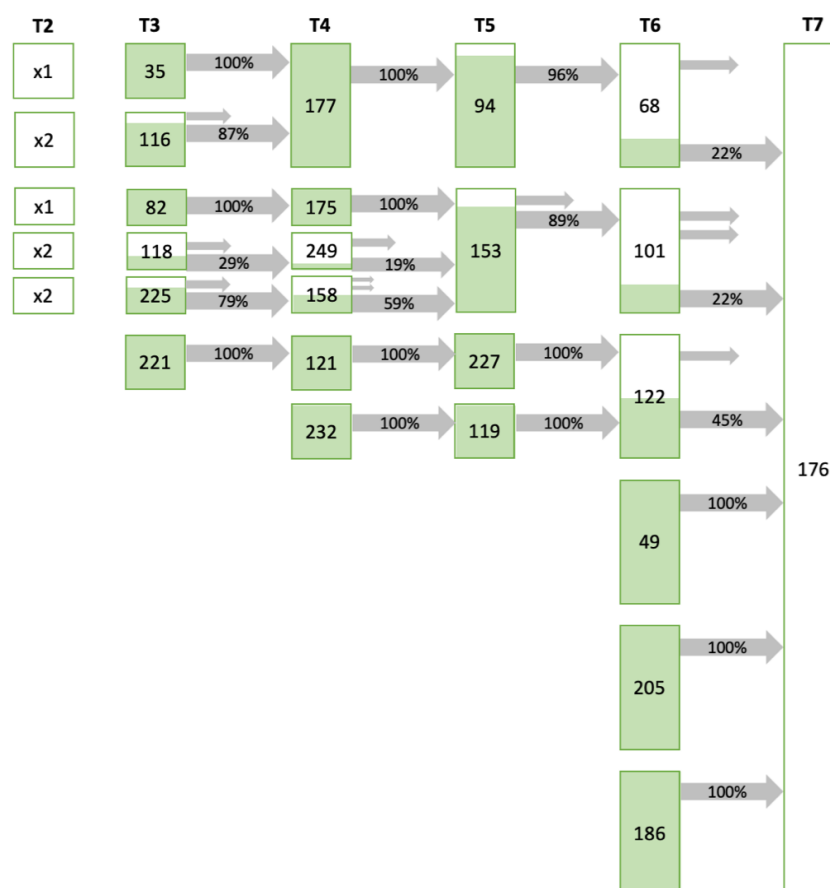


Figure 21: The emergence and development of community 176

To see from which research areas community 176 comes, we first look into the six communities in T6, from which community 176 is formed. These have the following most frequent research area(s):

- Physics, and material science (community 68)
- Transportation, and business & economics (community 101)
- Environmental sciences & ecology, and government & law (community 122)
- Linguistics and psychology (community 49)
- Education & educational research (community 205)
- Energy & fuels (community 186)

Each community has different research areas, which indicates the diversity of community 176. The community is formed from six different communities with many different research areas. It is most likely that from the first three communities (community 68, 101 and 122), which were split from T6>T7, the research publications with similar topics went to community 176, and the more unrelated to other communities. However, from the last three communities, all of the publications went to community 176 (100% of the publications in the community in T6 went to community 176 in T7). This means that community 176 contains the publications on each of these research areas and is a combination of these research areas, combined with the publications from the first three communities. Furthermore, we look at the main research areas of each of the communities over the past 20 years. The diversity of the research areas in community 176 is visualised in Figure 22, which shows a streamgraph of the research areas over the years. Each colour represents a research area, and the thickness of the line represents the number of publications within that research area in each year. For each year, the top three most frequent research areas for each

community are used. The figure shows that community 176 has been formed from many different research areas over the past 20 years.

Concluding, community 176 is a diverse community which is formed from different communities and research areas over time.

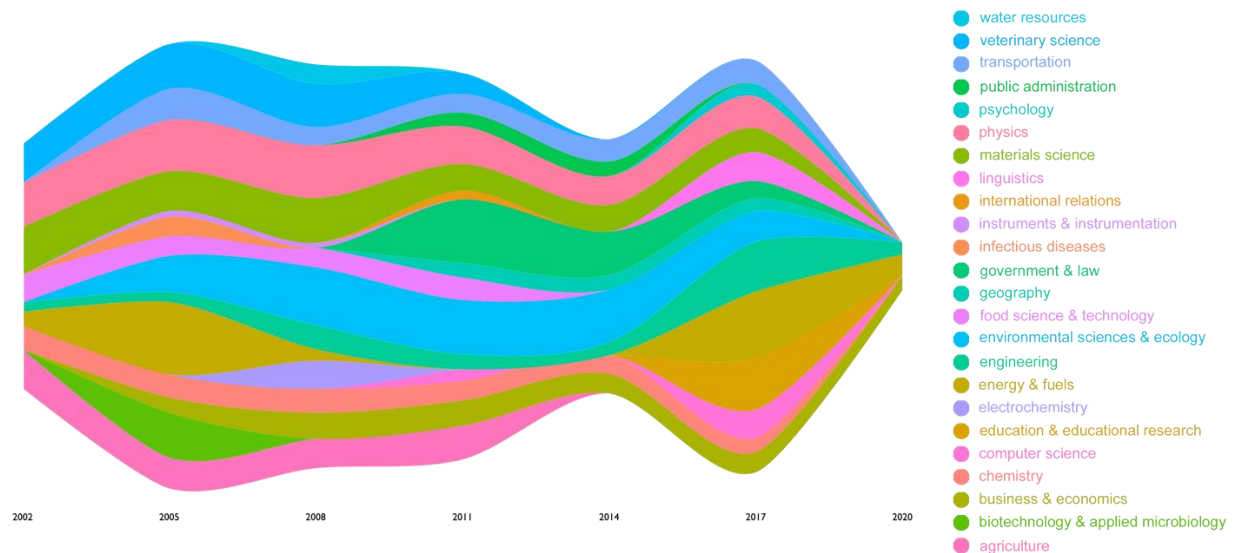


Figure 22: Streamgraph of the main research areas of community 176 over the past 20 years (2000-2020)

H.2. Community 154

Community 154 has a total of 317 publications, of which 141 are SDG-related publications. It has a betweenness centrality score of 0.00069. There are 24 different triads combinations in the community.

	SDGs	Triads	Research areas
1	4 (37.1%)	16-16-4 (FC-FC-ST) 12.5%	Psychology (80x)
2	10 (24.3%)	16-4-4 (FC-ST-ST) 11.7%	Sociology (30x)
3	-	10-16-4 (FC-ST-TD) 10.0%	Education & educational research (25x)

Table 10: Main SDGs, triads and research areas of community 154

In community 154 the most prominent SDGs are SDG 4 and 10, which are about quality education and reduced inequalities (Table 10). The most frequent triads in community 154 are 16-16-4, 16-4-4 and 10-16-4, of which the first two combine framework conditions and sociotechnical systems. The last one combines all three SDG categories and is of interest for the transformative potential of this research.

The most frequent research areas are psychology, sociology and education & educational research. Both psychology and sociology could be related to SDG 10 but are both very broad. Education & educational research is very closely linked to SDG 4. The most frequent keywords of the publications in community 154 are shown in the word-cloud in Figure 23. There is a strong focus on immigrants and ethnicity, combined with religion and discrimination. There are also multiple keywords related to education, such as 'teacher-student relationship', and 'classroom management'.

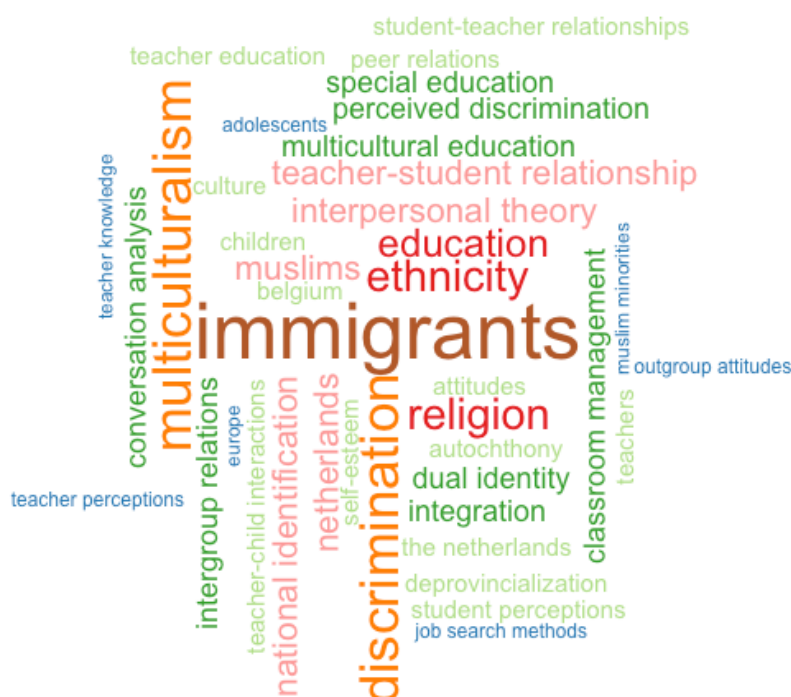


Figure 23: Word-cloud of the author keywords of the publications in community 154. The size of the keyword indicates the frequency of the keyword in the publications, with a maximum of 40 words.

The ego network of community 154 shows that this community has less connections as compared to community 176 (Figure 24). This is also shown in its much lower betweenness centrality score. It does show a strong connection with community 83, which is about SDG 11 (sustainable cities)

mostly. It also shows a connection with community 226, which has as main SDG 16 (peace, justice and strong institutions).

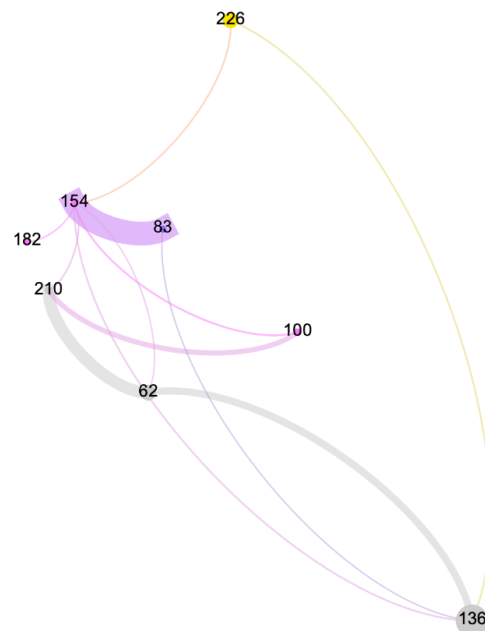


Figure 24: Ego network of community 154. Node size is betweenness centrality.

Temporal analysis

The temporal analysis shows how community 154 developed over the years (Figure 25). This community already existed in T6 (2015-2017) as one community, in T7 only publications were added to the community. Looking at Figure 8 we see that community 154 comes from three different communities that split and merged over the years. None of the communities existed before T3. Moreover, the development of community 154 is fairly consistent over the years. Only once was a community split (community 251 in T5), but mostly it is comprised of communities that are merged together.

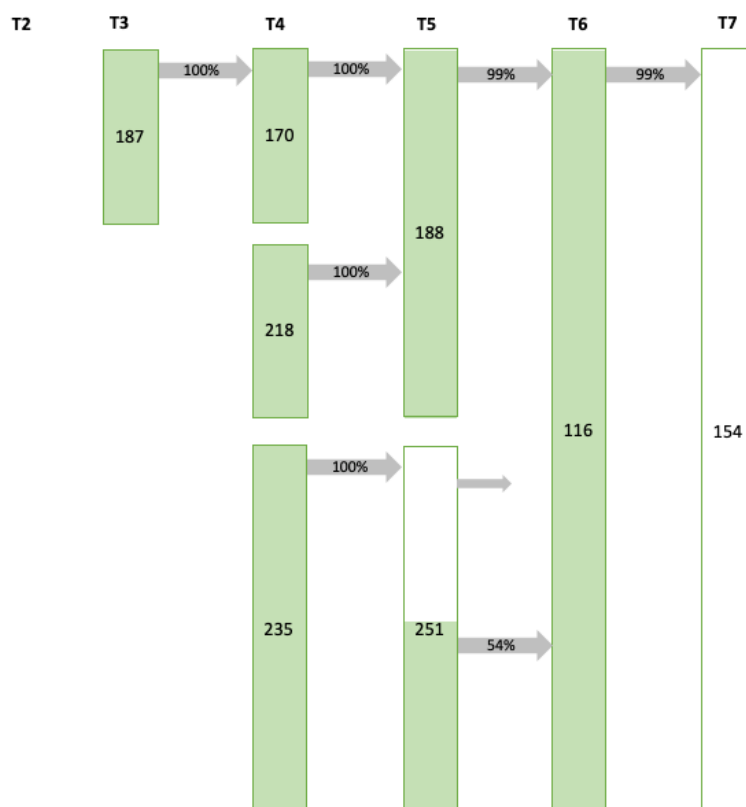


Figure 25: The emergence and development of community 154

Looking at the main research areas over the years, the streamgraph of community 154 in Figure 26 shows that there have only been seven different research areas in the communities from which community 154 has been formed. Largely the research areas stayed the same over the years, whereas sociology (pink) and psychology (light blue) have been the most important research areas over the past 20 years. Education & educational research was introduced in 2008 and is still an important research area in the community. This shows how stable the research areas of community 154 are over the years. Psychology, sociology and education & educational research are the main research areas of community 154 and have been the same throughout the years. The only deviant research area is demography but, looking back at the word-cloud in Figure 5 this is also closely related to the topics of community 154.

Community 154 is a very stable community throughout the time, with a strong research focus that stayed the same over the past 20 years. If we compare this to community 197 we see that community 154 has a more specific focus which stayed similar over the years, whereas community 197 has been build up from many diverse research areas and communities.

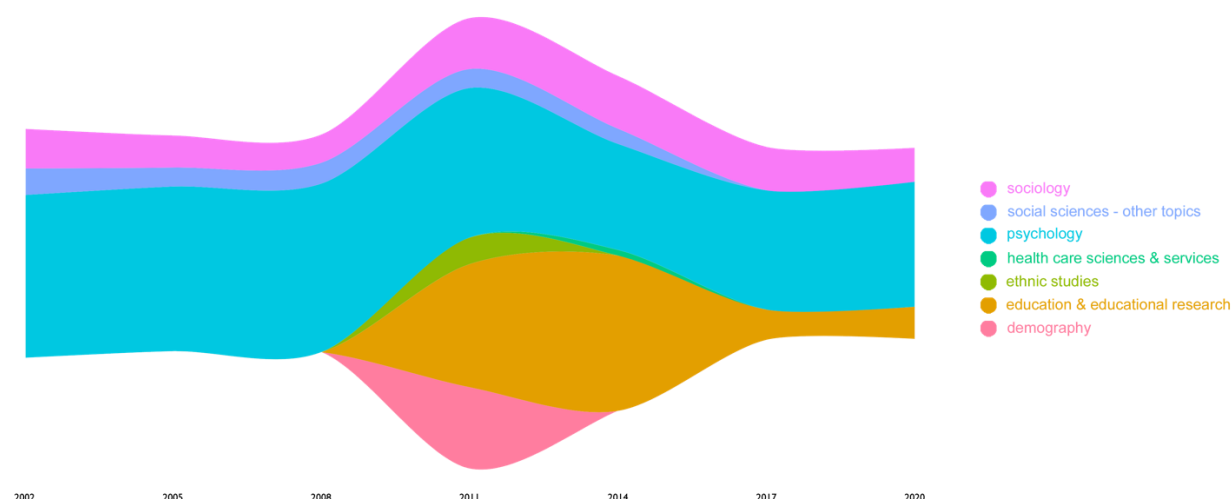


Figure 26: Streamgraph of the man research areas of community 154 over the past 20 years (2000-2020)

Triad analysis

Community 154 was selected because it has a relative high frequency of FC-ST-TD triads. The most frequent triad that combines SDGs in these categories is 10-16-4, there are 12 of these triads in community 154. A couple of these triads are analysed in more depth, to see which publications that combine the three SDG categories are related to each other. Table 11 shows the titles of these publications.

Publication 1	Publication 2	Publication 3
WOS:000214608400018-1 Social psychology and multiculturalism (SDG 10)	WOS:000250050400007-1 Tolerance of Muslim beliefs and practices: age related differences and context effects (SDG 4)	WOS:000255944700002-1 Muslim and non-Muslim adolescents' reasoning about freedom of speech and minority rights (SDG 16)
WOS:000222212600001-1 Global and ethnic self-esteem in school context: minority and majority groups in the Netherlands (SDG 4)	WOS:000169604000006-1 Peer victimisation and self-esteem of ethnic minority group children (SDG 16)	WOS:000181918500004-1 Positive and negative self-esteem among ethnic minority early adolescents: social and cultural sources and threats (SDG 10)
WOS:000220517900006-1 Psychological disidentification with the academic domain among ethnic minority adolescents in the Netherlands (SDG 4)	WOS:000169604000006-1 Peer victimisation and self-esteem of ethnic minority group children (SDG 16)	WOS:000180296900001-2 Perceptions of ethnic discrimination by minority and majority early adolescents in the Netherlands (SDG 10)

Table 11: Titles of publications in the FC-ST-TD triads in community 154

We see that even though these are triads with SDGs in all three categories, the publications themselves are very similar to each other and are actually about similar subjects (like employment of immigrants) but analysed from a slightly different point of view (leading to the different SDG attributed to the publication).

H.3. Community 71

Community 71 has a total of 366 publications, of which 223 are SDG publications. It has a betweenness centrality score of 0.045 (2nd highest of the SDG communities). There are 98 different triads combinations in the community.

	SDGs	Triads	Research areas
1	3 (57.2%)	11-3-3 (ST-ST-ST) 21.8%	Environmental sciences & ecology (141x)
2	11 (23.2%)	3-3-3 (ST-ST-ST) 19.0%	Public, environmental & occupational health (94x)
3	-	11-11-3 (ST-ST-ST) 11.6%	Toxicology (44x)

Table 12: Main SDGs, triads and research areas of community 71

In community 71 the most prominent SDGs are SDG 3 and 11, which are about health care and sustainable cities (Table 12). The most frequent triads are 11-3-3, 3-3-3 and 11-11-3, which all combine SDGs that fall within the sociotechnical systems.

The most frequent research areas are environmental sciences & ecology, public, environmental & occupational health and toxicology. The first one is closely related to SDG 11, sustainable cities, whereas the latter two are connected to healthcare, SDG 3. The most frequent keywords of the publications in community 71 are shown in the word-cloud in Figure 27. There is a strong focus on air pollution and particulates, as well as traffic. This relates to a combination of SDG 3 and SDG 11, for example research on air pollution (SDG 3 – health care) due to traffic in cities (SDG 11 – sustainable cities).



Figure 27: Word-cloud of the author keywords of the publications in community 71. The size of the keyword indicates the frequency of the keyword in the publications, with a maximum of 40 words.

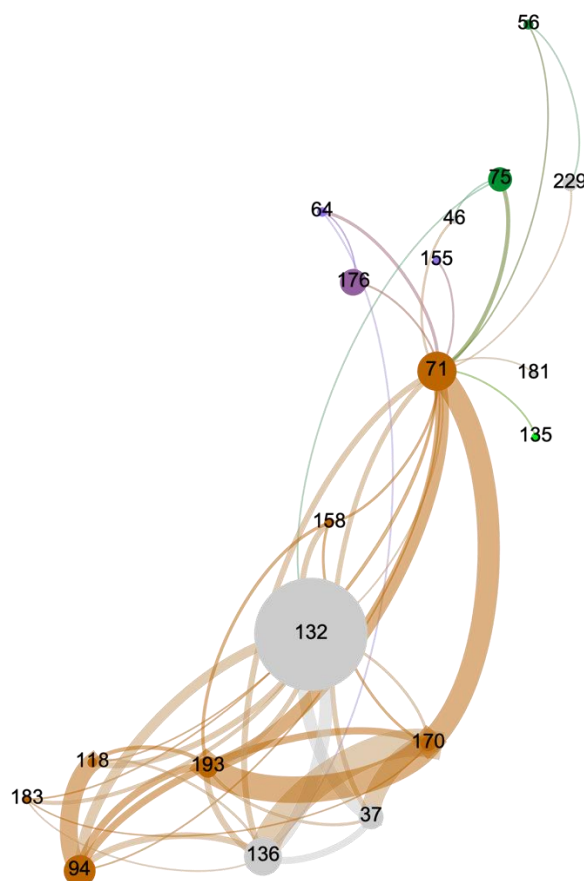


Figure 28: Ego network of community 71. Node size is betweenness centrality.

The ego network of community 71 in Figure 28 shows multiple strong connections to communities related to SDG 3 (especially community 170 and 139). On the other side, it shows connections to communities about a diverse range of SDGs, such as community 176 about SDG 7, community 155 about SDG 11 and community 75 about SDG 13.

Temporal analysis

Looking at the development of community 71 over the years we see an even more stable development than we saw for community 154 (Figure 29). Over the years, the community hasn't split or been merged from different communities. Community 71 has been existing since T1 as one community. The research areas from community 71 over the years have also been very stable. If we look at the streamgraph in Figure 30 we see that environmental sciences & ecology is the main research area of community 71 and has been since 2000. The research areas general & internal medicine and meteorology & atmospheric sciences disappeared from the community over the years, and public, environmental & occupational health and toxicology were introduced over the years.

Concluding, community 71 is a well-established community with a clear research focus. It has been very stable over the years and has a central location in the network. If we compare this to the previous two communities, we see that community 71 is even more stable over the years than community 154. This could be explained by the very specific research topic of community 71 and the clear research focus, which stayed important over the years.

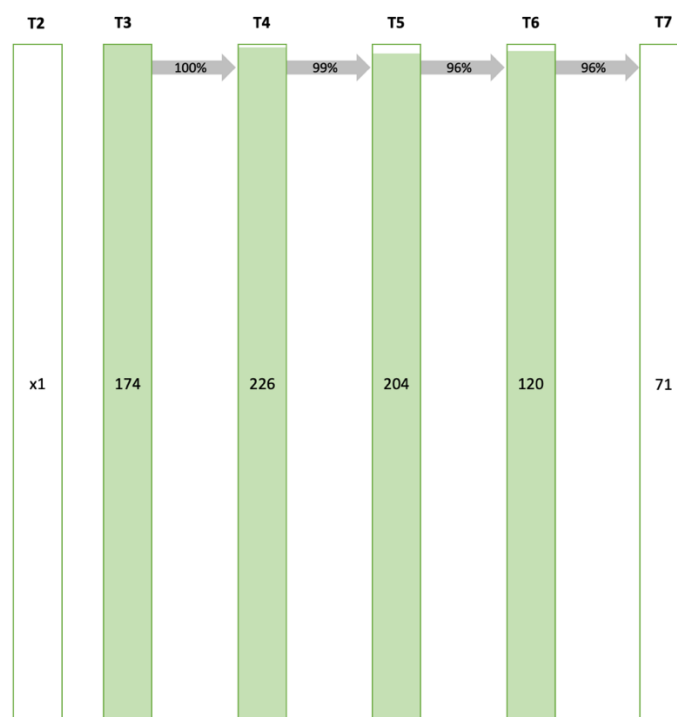


Figure 29: The emergence and development of community 71

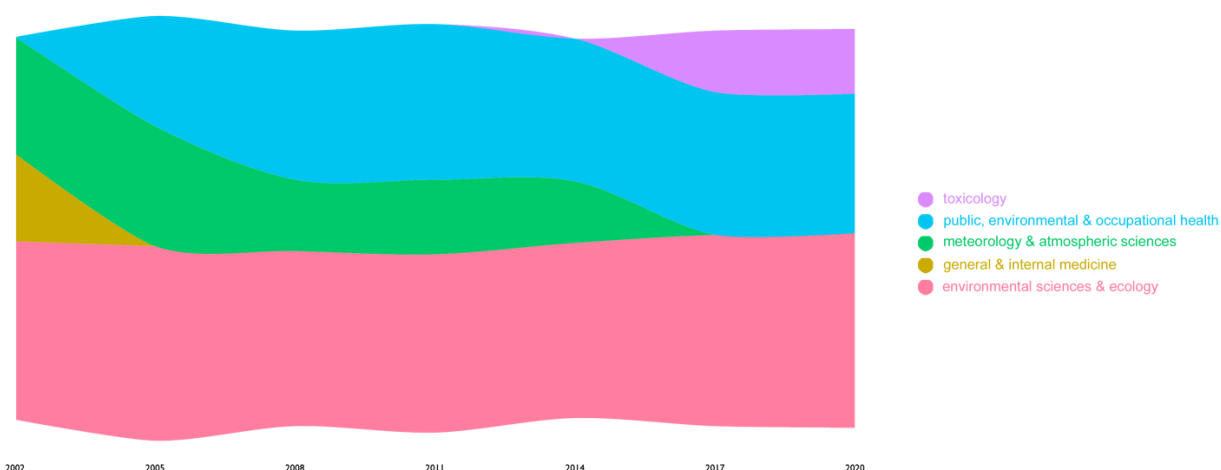


Figure 30: Streamgraph of the main research areas of community 71 over the past 20 years (2000-2020)

H.4. Community 197

Community 197 has a total of 366 publications, of which 223 are SDG publications. It has a betweenness centrality score of 0.038 (3th highest of the SDG communities) There are 37 different triad combinations in the community.

	SDGs	Triads	Research areas
1	4 (30.7%)	4-4-4 (ST-ST-ST) 17.9%	Education & educational research (47x)
2	16 (23.3%)	12-4-4 (ST-ST-TD) 9.7%	Health care sciences & services (35x)
3	3 (21.3%)	16-5-5 (FC-TD-TD) 8.2%	Public, environmental & occupational health (28x)

Table 13: Main SDGs, triads and research areas of community 197

In community 197 the most prominent SDGs are SDG 4, 16 and 3, which are about quality education, peace, justice & strong institutions and healthcare (Table 13). The most frequent triads are 4-4-4, 12-4-4 and 16-5-5. The latter two show an interaction between different SDG categories, whereas 12-4-4 combines sociotechnical systems with transversal directionalities and 16-5-5 combines framework conditions with transversal directionalities. Interesting in this community is that even though its second most frequent SDG is SDG 16, it has only *one* triad that combines SDG 16 (framework conditions) with sociotechnical systems and transversal directionalities (this triad is 12-16-4). So even though they have research on SDGs in all three categories, they are not able to combine this research.

The most frequent research areas are education & educational research, health care sciences & services and public, environmental & occupational health. The first one is related to SDG 4, whereas the latter two are both strongly related to SDG 3. The public health and health care services indicates SDG 16. The most frequent keywords of the publications in community 197 are shown in the word-cloud in Figure 31. There is a large focus on education, human rights and gender. This is mostly in line with SDG 4 and SDG 16. There are also multiple keywords indicating SDG 3, such as 'vaccination' and 'health behaviour'.



Figure 31: Word-cloud of the author keywords of the publications in community 197. The size of the keyword indicates the frequency of the keyword in the publications, with a maximum of 40 words.

The ego network of community 197 shows many relations to communities related to SDG 3, such as community 94, 180 and 81 (Figure 32). It also shows interaction with communities on SDG 13 (community 150 and 124), on SDG 16 (community 226) and SDG 5 (community 209). It is connected to 17 non-SDG communities and 16 SDG communities.

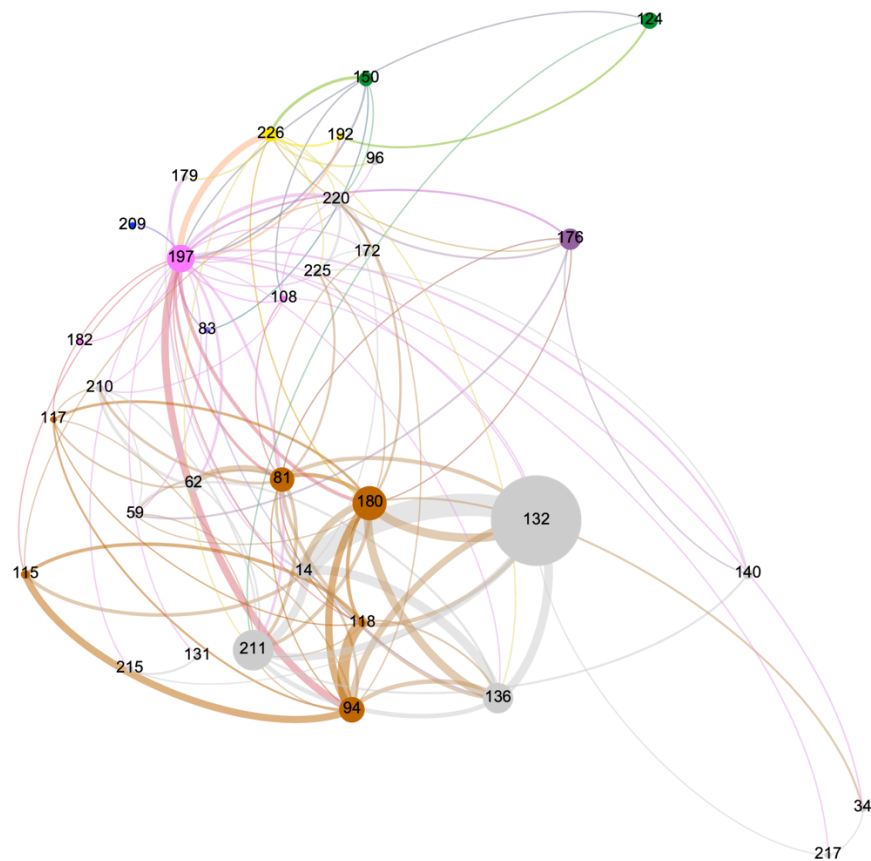


Figure 32: Ego network of community 71. Node size is betweenness centrality.

Temporal analysis

Analysing at the development of community 197 we see that this community has its roots in many different communities (Figure 33). Community 197 in T7 is formed from three communities in T6, of which one was fully attributed to community 197 (153), and the other two were split and a part of the publications went to community 197. Going further back, we see that the origin of community 197 goes back to T2 and comes from 8 communities in T2.

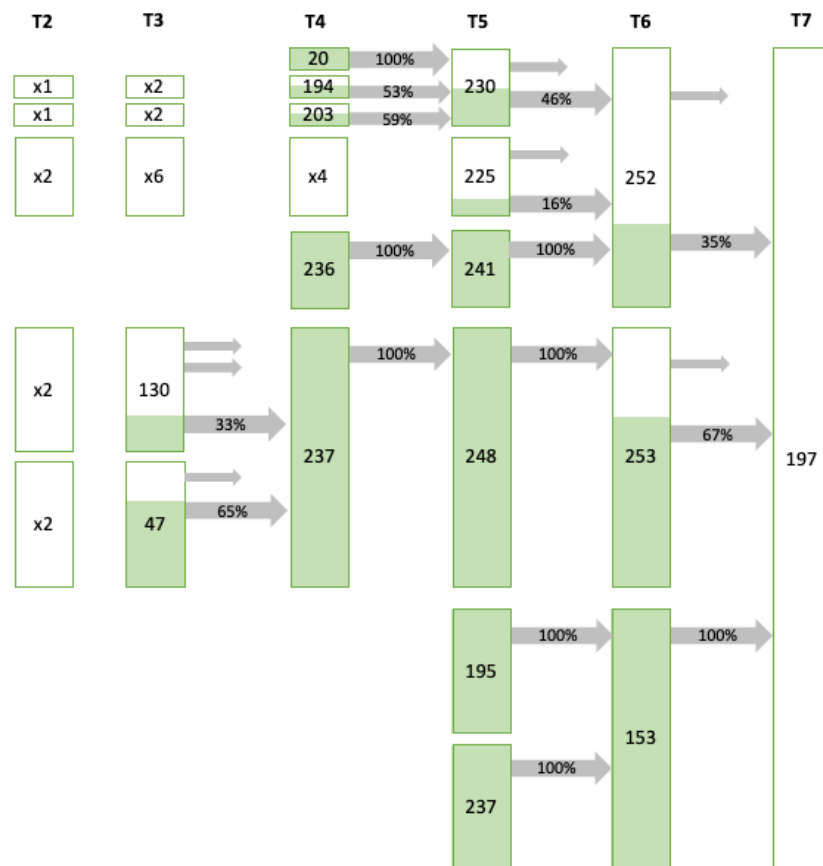


Figure 33: The emergence and development of community 197

The research areas of the many communities that 197 is formed upon are diverse. Similar to community 176, it is based on a diverse range of research areas. This is also because many communities were split, whereby the least relevant part of the research went to another community. If we look at the streamgraph of the research areas over the past years (Figure 34) we see the research areas are diverse, from zoology to oncology and cell biology. This diverse set of main research areas of the communities shows the diversity of community 197. It could also explain its high betweenness centrality, whereas over the years many communities split partly into community 197 and partly into different communities, meaning that community 197 has a relation with many other communities, that are closely related to it.

Concluding, community 197 is, similar to community 176, a very diverse community which is formed from different communities and build upon different research areas over time. It integrates different knowledge topics and is therefore an important community in the network.

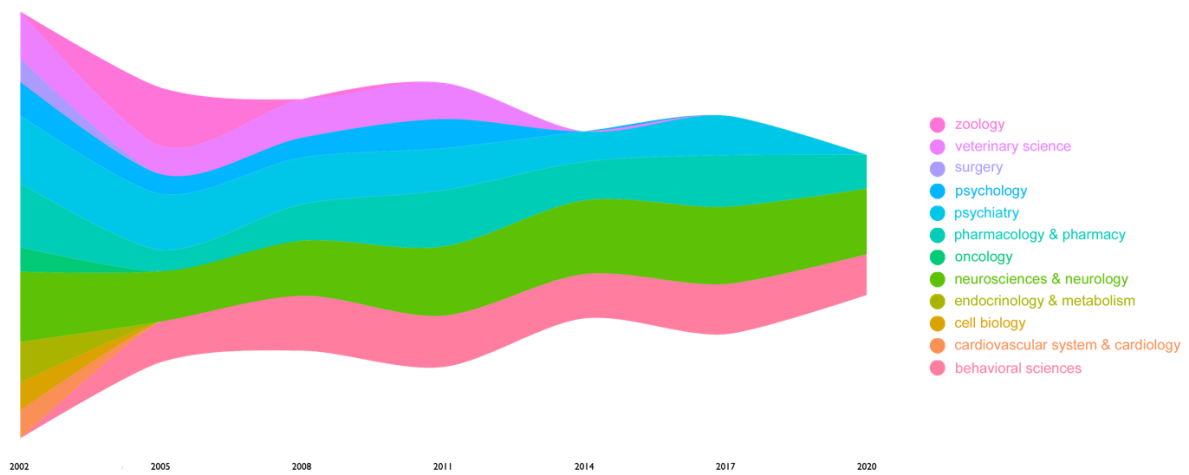


Figure 34: Streamgraph of the man research areas of community 176 over the past 20 years (2000-2020)