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TRANSFORMING OUR WORLD: IMPLEMENTING THE SUSTAINABLE DEVELOPMENT GOALS

PROPOSAL FOR A COLOMBIAN SCIENCE, TECHNOLOGY AND INNOVATION POLICY PROGRAMME OF EXPERIMENTATION WITH A STRONG REGIONAL FOCUS

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EXECUTIVE SUMMARY (ENGLISH)

Science, Technology and Innovation policy play a central role in achieving the Sustainable Development Goals (SDGs). Colombia has been very active in the implementation of the 2030 Agenda, which embodies the most pressing challenges of today, from education and equality to climate change. These goals are not just targets, and they should not be seen in isolation: together, they provide a roadmap for the transformations required to support our future.

This report describes the Transformative Innovation Policy approach to innovation policy, to address the SDGs through science, technology and innovation in Colombia. This approach departs from conventional assumptions about the value of innovation in society, often linked to economic growth, and instead proposes that innovation should focus on systems change, that is, changes in the practices, infrastructures, capabilities, culture, technologies, etc. of the socio-technical systems that that sustain the way we live (cities, water supply, transportation, food, healthcare, etc.). From this perspective, the environment and society are not just externalities, but instead they are a central and active part of the innovation process. In addition to socio-technical systems, a key notion of a transformative innovation approach is "directionality", by which we mean the societal values and attributes desired in a process of change. In fact, the SDGs can be read in terms of "socio-technical systems" (i.e. clean water and sanitation, affordable clean energy, etc.) and "directionalities" (i.e. gender equality, reduction of inequalities, climate change).

To further develop a Transformative Innovation Policy approach requires an understanding of how the scientific research system can be oriented and contribute to this approach. We conducted an analysis of the knowledge production system in Colombia and its potential to contribute to the SDGs based on publication data from 2006 to 2017 (Web of Science and SciELO repositories), using a method developed by Ramirez, Romero, Schot, & Arroyave, (2019) that combines scientometric and network analysis techniques. In this period, we observe an increase in the total number of publications as well as in the publications related to SDGs. Most of the publications refer to specific socio-technical systems and to a lesser extent to directionalities. Furthermore, we identified "knowledge communities" (a group of publications that strongly share bibliography) related to the SDGs, for each of the databases. This approach allows us to identify the strengths in research and the connections between different disciplines and areas of research. We assume that communities that are conducting more SDG interactions have more transformative potential. We identified a total of 104 communities for SciELO and Web of Science. Both of these databases demonstrate that an important number of communities refer to Public Health and Medicine, some of which are connected to issues such as poverty or education. In SciELO, communities related to climate change and conservation are strongly represented, often in connection with water systems, responsible production and innovation. In Web of Science, Governance and peace are highly relevant, as well as clean energy and water. We also observe a higher number of communities working on directionalities such as gender and poverty. Overall, our analysis indicates that communities related to health, water and education are well established and represented in the research system in Colombia, while there is a lack of research in issues such as sustainable cities, equality and equity, poverty and no hunger.

In a following analysis, these research communities were aggregated in clusters, identifying twelve knowledge clusters, which represent capabilities to address the SDGs in Colombia. This reveals a clear pattern: clusters 1-3 refer to health, clusters 4-7 refer to education, governance and peace, systems management, and pollution and mitigation. Most of these clusters present some connection with directionalities. Cluster 8 refers to solar energy, and is considerably less interdisciplinary than other clusters. Clusters 9 and 10 relate to water treatment, and cluster 11 and 12 to ecological processes and biodiversity. These results show that there is already a strong basis in the research system, with growing interactions between goals that can be mobilised to achieve the SDGs.

It is important to note that Transformative Innovation Policy not only depends on a strong scientific basis. A socio-technical perspective on transformation acknowledges that many processes of change, which we could call "transformational", are informal. These changes occur outside the realm of established institutions and are often led by social movements and local needs. This is why in Chapter 4 we analyse some of the transformative processes that are already taking place in Colombia. In fact, much of what is called "social innovation" occurs under the radar of science and innovation funding institutions, and Colombia is very rich in these examples. The four cases that we describe touch different aspects of transformative process.

The case of the Alexander von Humboldt Biological Resources Research Institute (IAVH) shows how transformative knowledge can be incorporated in formal institutions and translated into action. As part of the National Policy for the Integral Management of Biodiversity and its Ecosystem Services, the IAVH proposed ten socio-ecological transformations to address the challenge of sustainable biodiversity management in the country, which incorporated sound scientific evidence, attention to social and cultural contexts and the effective participation of communities involved in each of these transformations, with a strong emphasis on social justice, inclusion and democracy. This shows that promoting scientific research goes hand in hand with supporting social dialogue for impact, and provides some clear indications of the type of institutions required for transformative change.

In the case of the wetlands of Bogotá it becomes clear that through the years various social movements have contributed to the protection of these ecological systems. This has a been a long process in which the concerns of different groups have come together, and where the scientific community played an important role by generating evidence of the pollution of the wetlands and its public health effects. This in turn was used to lobby authorities to provide an adequate regulatory framework for the wetlands' protection. This case-study shows that researchers can engage with social movements in order to address pressing social problems. The case also shows that research councils and similar funding organisations could pay attention to these social movements and act as brokers between them and researchers, facilitating the use of their available funds for impact.

The case of the municipality of Iza, where a single-use plastic ban regulation was introduced, shows how local needs and contingencies can empower social movements to look for solutions "outside the box". In 2018, and due to a collapse of the local landfill, the municipality of Iza, together with the Dessert's Vendors Association, conducted their own "experiment": they searched for local alternatives to polystyrene, they tested them, shared their knowledge with the community and started a process of transformation aimed at eliminating plastic packaging from their locality. Through this process, they constructed knowledge, raised innovative funding mechanisms and built a strong network. They did this without any support from external institutions, nor the scientific community. Their story inspired other communities and their experience was extended to the regional level. The case shows how experimentation can happen outside formalised research contexts, and that there is a strong need to connect with these ongoing experiments through programmes and funding mechanisms that are adequate to their needs.

The last case, the transition to speciality coffee production systems in Colombia, shows how self-organisation and pressures from the external system can trigger and support transformation. The Coffee industry is one of the most well recognised productive sectors in Colombia. In recent years, a social movement created by coffee farmers re-organised an important part of the productive system to pay more attention to ecological and social conditions of production. The movement was able to mobilise government support, as well as research funds for the development of speciality coffee, building new knowledge, practices, infrastructures, and markets. This case shows how it is possible to develop alternatives to dominant production systems that are socially, ecologically and economically sustainable. Such processes require important changes in practices and infrastructure; research plays a central role in this respect.

These four cases illustrate opportunities that, to a different extent, have mobilised the research community to address pressing social challenges and promote transformative change. There are many more of these initiatives happening today in Colombia that could be seeds of transformation if supported adequately.

The Mision de Sabios is proposing to create a number of emblematic missions clustered around three key challenges: Colombia Bio, Productive Colombia and Equity Colombia. However, to realise missions knowledge production alone is not sufficient. A bottom-up implementation of missions is important to produce transformations that are better suited to the different regional contexts in Colombia. Scientific knowledge and capabilities are highly relevant for addressing challenges and SDGs, but we suggest they need to be integrated with local knowledge, actors and necessities to have the maximum impact. Therefore, we propose to complement the mission-oriented approach with bottom-up principles from transformative innovation. This can be done by implementing the missions through experimentation (pilot projects at the local level) and nurture and evaluate these experiments as seedbeds for transformation. The experiments could be cases discussed above, led by civil society and small producers, as well as more high-tech projects led by business, and e.g. focused on digital transformation. For transformations to take place, it is important for individual experiments to become connected and coordinated across regions. The new STI Ministry should take responsibility for making connections between various projects (and regions), coordinating various activities, organising learning across missions and projects, and support training in transformative project management and formative evaluation on transformation. This can be done by creating a national programme of experimentation with a strong regional focus. Here the STI Ministry can work with several universities in Colombia who have begun to explore transformative innovation principles and with the Transformative Innovation Policy Consortium, of which Colombia is a member.

RESUMEN EJECUTIVO (SPANISH EXECUTIVE SUMMARY)

Las políticas de Ciencia, Tecnología e Innovación juegan un papel central en alcanzar los Objetivos de Desarrollo Sostenible (ODS). Colombia ha trabajado activamente en la implementación de la Agenda 2030, la cual representa los desafíos más urgentes de nuestra sociedad. Dentro de estos desafíos se encuentran la educación, equidad, biodiversidad, y un cambio global hacia la sustentabilidad. Estos objetivos no deben ser entendidos solo como metas, y no deben ser abordados de forma aislada: juntos, proveen una hoja de ruta de las transformaciones requeridas para asegurar nuestro futuro.

Este reporte se centra en la Innovación Transformativa, como un marco que permite abordar los ODS desde la ciencia, la tecnología y la innovación en Colombia. Este marco complementa algunas aproximaciones tradicionales acerca del valor de la innovación para la sociedad, tales como el crecimiento económico y los sistemas nacionales de investigación. Propone que la innovación se debe enfocar en los cambios de sistema; es decir, cambios en las prácticas, infraestructuras, competencias, cultura y tecnologías, que conforman los sistemas socio-técnicos que sostienen nuestra forma de vivir (ciudades, saneamiento, transporte, salud, educación etc.). El segundo concepto central de la política de innovación transformativa es el de direccionalidad, que se refiere a los valores sociales y atributos deseados en procesos de cambio. Desde esta perspectiva, el medio ambiente y la sociedad no se consideran meras externalidades, sino que son un componente central de los procesos de innovación y cambio. Así mismo, los ODS pueden ser entendidos en términos de sistemas sociotécnicos, como son agua limpia y saneamiento, energía asequible y no contaminante, entre otros; entendidos bajo direccionalidades como la reducción de las desigualdades, acción por el clima o disminución de la deforestación.

Para desarrollar en mayor profundidad el marco de Innovación Transformativa, se requiere entender cómo el sistema de investigación científica puede ser orientado al cumplimiento de los ODS. Para ello, hemos realizado un análisis del sistema de producción de conocimiento colombiano y su potencial de contribución a los ODS, basados en datos de publicaciones científicas (de los repositorios Web of Science y SciELO, 2006-2017). Se utilizó el método desarrollado por Ramirez et al., (2019) que combina metodologías de cienciometría con análisis de redes. Para el periodo evaluado, se observa un aumento en el número total de publicaciones relacionadas con los ODS. La mayoría de las publicaciones se relacionan con temáticas concernientes a sistemas sociotécnicos (agua, salud, transporte) y en menor medida, a direccionalidades (género, pobreza, inequidad, etc.) que son problemáticas recurrentes en Colombia.

Adicionalmente, se identificaron "comunidades de conocimiento" (grupos de publicaciones que comparten fuertemente bibliografía) relacionadas con los ODS para ambas bases de datos. Este análisis permitió identificar fortalezas y conexiones en la investigación en distintas disciplinas y áreas del conocimiento. Este parte del supuesto que aquellas investigaciones que combinan una mayor variedad de ODS (Nexus) pueden llegar a tener un mayor potencial de ser transformativa. Se identificaron un total de 104 comunidades en SciELO y Web of Science, y un número importante de comunidades relacionadas con Salud Pública y Medicina, algunas de las cuales están conectadas con temáticas de prevención a la malnutrición o la contaminación. En SciELO las comunidades relacionadas a Cambio Climático y Conservación están fuertemente representadas, en muchos casos en conexión con Sistemas Acuáticos, Producción Responsable e Innovación. En Web of Science, Gobernanza y Paz son temas altamente relevantes, así como Energía Limpia y Agua. En esta base de datos también se observa un mayor número de comunidades trabajando en direccionalidades tales como Género y Pobreza. En resumen, nuestro análisis indica que las comunidades relacionadas con Salud, Agua, y Educación están bien establecidas y representadas en el sistema de investigación de Colombia. Por el contrario, existe una brecha en temáticas relacionadas con Ciudades Sostenibles, Equidad, Pobreza y Hambre Cero.

En un análisis subsecuente, estas comunidades fueron agregadas en clúster. Esto permitió identificar 12 grandes grupos de comunidades de conocimiento (clúster) que representan capacidades para abordar los ODS en Colombia. Este análisis muestra un patrón bastante claro: los clúster 1 al 3 se refieren a temas de Salud, 4 al 7 a Educación, Gobernanza y Paz, Sistemas de Gestión, y Contaminación y Migración. La mayoría de estos clúster presenta alguna conexión con direccionalidades. El clúster 8 se refiere a Energía Solar, el cual esta enfocando en tan solo un ODS. Los clúster 9 y 10 se relacionan con Tratamiento de Agua, y los clúster 11 y 12 con Procesos Ecológicos y Biodiversidad. Estos resultados muestran la existencia de una fuerte base de conocimientos en el sistema de investigación para abordar los ODS, con capacidades

interdisciplinarias de alto potencial.

Por otra parte, la innovación transformativa no sólo depende de una base científica sólida. Una perspectiva sociotécnica de las transformaciones reconoce que hay muchos procesos de cambio, que ocurren fuera del alcance de las instituciones establecidas, usualmente motivados por necesidades locales y liderados por movimientos sociales. En el Capítulo 4 caracterizamos algunos de estos procesos que están ocurriendo en Colombia, con el potencial de contribuir a la innovación transformativa. De hecho, mucho de lo que conocemos como "innovación social" ocurre fuera de los marcos institucionales de financiación de la ciencia y tecnología. Colombia es un país muy rico en este tipo de iniciativas y procesos sociales. Los cuatro ejemplos que se describen a continuación tocan distintos aspectos de los procesos transformadores.

El caso del Instituto de Investigación de Recursos Biológicos Alexander Von Humboldt (IAVH) muestra como el conocimiento transformativo puede ser incorporado en instituciones formales y traducido en acciones. Como parte de la Política Nacional para el Manejo Integral de la Biodiversidad y los Servicios Ecosistémicos, el IAVH ha propuesto diez transformaciones socio-ecológicas para abordar el desafío de la gestión sostenible de la biodiversidad en el país. Estas incorporan evidencia científica, entendimiento de los contextos sociales y culturas, y la participación efectiva de las comunidades involucradas en cada una de estas transformaciones. Así mismo, tienen un fuerte énfasis en la justicia social, inclusión y democracia. Esto demuestra que es posible promover la investigación científica que vaya de la mano con los diálogos sociales, y generen un impacto positivo en la sociedad, brindándonos algunas pistas del tipo de instituciones que se requieren para los cambios transformativos.

En el caso de los humedales de Bogotá, múltiples movimientos sociales han contribuido a través de los años a la protección social de estos sistemas ecológicos. Este ha sido un largo proceso en el cual distintos grupos, con distintas motivaciones, se han unido y movilizado para permitir la protección de los humedales en la Sabana de Bogotá. En estos procesos, la comunidad científica ha jugado un rol importante al contribuir al entendimiento de factores sociales de la degradación y contaminación de los humedales, sus efectos en la salud de las personas y generando conocimiento científico con la participación activada de las comunidades. Este conocimiento de la mano de la acción social ha propiciado negociaciones con las autoridades locales, regionales y nacionales. Permitiendo la generación de marcos regulatorios más acordes a las necesidades y demandas sociales. Por lo tanto, este caso muestra de forma clara como los investigadores se pueden involucrar con los movimientos sociales para responder a demandas y necesidades sociales. También demuestra que las agencias de financiamiento de la investigación debiesen prestar más atención a estos movimientos sociales y actuar como intermediarios entre ellos y los investigadores, facilitando el uso de los recursos disponibles para generar ciencia con impacto en problemas concretos.

El siguiente caso estudiado es en la municipalidad de Iza, donde se instauró una prohibición de plásticos no reutilizables. Este caso muestra como las necesidades locales y contingencias (cambios en política) pueden empoderar a los movimientos sociales en la búsqueda de soluciones innovadoras. Durante el año 2018, y debido al colapso del relleno sanitario que suplía al pueblo, la municipalidad de Iza junto con la Asociación de vendedores de Postres, condujeron su propio experimento: buscaron alternativas locales al poliestireno, las evaluaron, compartieron su conocimiento con la comunidad y dieron comienzo a un proceso de transformación con el objetivo de eliminar los envases plásticos de su localidad. A través de este proceso, generaron nuevo conocimiento, consiguieron financiamiento y construyeron una red sólida. Todo esto, sin el apoyo formal de instituciones externas, ni de la comunidad científica. Su historia ha inspirado a otras comunidades y se ha venido extendiendo al nivel regional. Este caso muestra que la experimentación en búsqueda de soluciones puede ocurrir fuera de contextos institucionales o formales. Sin embargo, la conexión desde estos experimentos con programas y mecanismos de financiamiento podrían generar un mayor impacto social y ambiental. Así mismo, la conexión de estos experimentos con otras iniciativas del mismo tipo podría generan un impacto a mayor escala en el país.

Finalmente, el caso de cafés de especialidad en Colombia es relevante para ilustrar como la organización entre productores y las presiones de cambio externas pueden propiciar y apoyar transformaciones. La industria del café es una de las más reconocidas de Colombia. En los últimos años, múltiples actores involucrados en el cultivo del café reconfiguraron una porción importante del sistema de producción, poniendo mayor atención a las condiciones sociales y ecológicas en que este se realiza. Este movimiento fue capaz de obtener apoyo gubernamental, así como fondos de investigación para el desarrollo de cafés de especialidad, creando nuevos conocimientos, prácticas, infraestructuras y accediendo a nuevos mercados. Este caso muestra, que es posible desarrollar alternativas más sostenibles que los sistemas de producción dominantes. Estos procesos requieren de cambios importantes en las prácticas e infraestructuras existentes, y en ellos la investigación, innovación y desarrollo juegan un rol central.

Estos cuatro casos ilustran oportunidades que, en mayor o menor medida, han movilizado la comunidad de investigadores para abordar desafíos sociales y promover

transformaciones. Existen muchos más de estos casos en Colombia hoy, los cuales pueden ser semillas para la transformación si son apoyados adecuadamente.

La misión de sabios propone crear misiones emblemáticas relacionadas con tres grandes desafíos: Colombia bio, Colombia productiva y Colombia equitativa. Sin embargo, para desarrollar estas misiones, no es suficiente enfocarse solo en la producción de conocimiento académico. Es así como la implementación de estrategias desde las bases (bottom-up) son importantes para generar transformaciones acordes a los diferentes contextos regionales en Colombia. El conocimiento y las capacidades científicas son relevantes para direccionar desafíos y los ODS, sin embargo, sugerimos que éstas necesitan ser integradas con el conocimiento, actores y necesidades locales para tener un mayor impacto.

Por lo tanto, proponemos complementar el enfoque de misiones con principios bottom-up de la innovación transformadora. Esto puede ser realizado implementado las misiones a través de experimentos (pilotos) como semillas para la transformación. Los experimentos pueden ser casos de estudios como los discutidos en este informe, liderados por la sociedad civil y pequeños productores, así como proyectos de alta tecnología liderados por empresarios, por ejemplo, transformación digital. Para que la transformación tome lugar, es importante que los experimentos estén conectados y coordinados a través de las regiones. El nuevo Ministerio debería asumir la responsabilidad de generar estas conexiones entre proyectos de diferentes regiones, coordinando actividades, organizando el aprendizaje a través de las misiones y proyectos, y soportando el entrenamiento en el manejo de proyectos transformativos y la evaluación formativa en transformaciones. Esto puede ser desarrollado creando un programa nacional de experimentación con un fuerte enfoque regional. Aquí el Ministerio puede trabajar con varias universidades colombianas las cuales han comenzado a explorar principios de la innovación transformadora y con el consorcio de política de innovación transformativa (TIPC) del cual el gobierno colombiano es parte.

LIST OF ACRONYMS

COLCIENCIAS: Administrative Department of Science, Technology and Innovation
DNP: National Planning Department
DAMA: Agency for Environment Administration
IAVH: Research Institute of Biological Resources Alexander von Humboldt
MADS: Ministry of Environment and Sustainable Development
PAB: Action Plan for the implementation of the PNGIBSE
PNGISBE: National Policy for the Integral Management of Biodiversity and its Ecosystem Services
SINA: Environmental National System
TSS: Socio-ecological transitions towards sustainability
FNC: Colombian Coffee Growers Federation
EPS: Expanded Polystyrene
GSR: General System of Royalties
IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC: Intergovernmental Panel of Climate Change
APAI: Iza's Dessert vendor Association
SDGs: Sustainable Development Goals
STI: Science, Technology and Innovation
TIP: Transformative innovation policy
TIPC: Transformative innovation policy consortium
UNDP: United Nations Development Programme (UNDP)

1. INTRODUCTION

Colombia has been very active in the process of developing and adopting the United Nations 2030 Agenda and its seventeen Sustainable Development Goals (SDGs). These goals summarise the major challenges of our world: the eradication of poverty, gender equality, the promotion of clean energy, and sustainable consumption and production. To successfully address the SDGs, these should not be understood as individual targets, but rather as missions for transformation. This is reflected in the subtitle of the United Nations 2030 Agenda logo: seventeen Goals to Transform our World (United Nations, 2015). While the definition and meaning of the notion of transformation remains vague in the document, it is clear that it refers to a process of fundamental change, and to the need for a new development model in which economic, social and environmental goals are not just juxtaposed but integrated (United Nations Development Platform, 2015).

While the Agenda 2030 recognises the importance of science, technology and innovation (STI) through a separate goal (no.9), referring to industry, innovation and infrastructure, fostering innovation and technological progress for promoting inclusive and sustainable industrial development, it is a central argument of this report that STI can be a game changer for realising transformations, precisely because it is cross cutting all individual SDGs. This critical role for STI was recognised by the 2017 UN High Political Forum on Sustainable Development synthesis report on voluntary national reviews. It argues that STI is a great enabler for SDG implementation and to help countries deal with emerging issues (United Nations, 2017). The Colombian High-Level-Institutional Commission for the Preparation and Effective Implementation of the Post-2015 Development Agenda and SDGs (hereinafter SDG Commission) led by the National Planning Department (DNP) has recognised this important role by inviting the Administrative Department of Science, Technology and Innovation (Colciencias) to the table. In response Colciencias designed a new strategy, published in the 2030 Green Book (Colciencias, 2018). It contains new thinking on how STI-policy can serve the SDGs. This new type of STI-policy is called transformation innovation policy. It strongly relates to mission-oriented policy because both types of policies take as their starting points societal challenges (or SDGs), but transformative innovation policy adds a perspective. In order to implement missions, the mission-oriented policy should enable bottom-up transformations (Dag Hammarskjöld Foundation, 2018; Schot & Steinmueller, 2018b, 2018a).

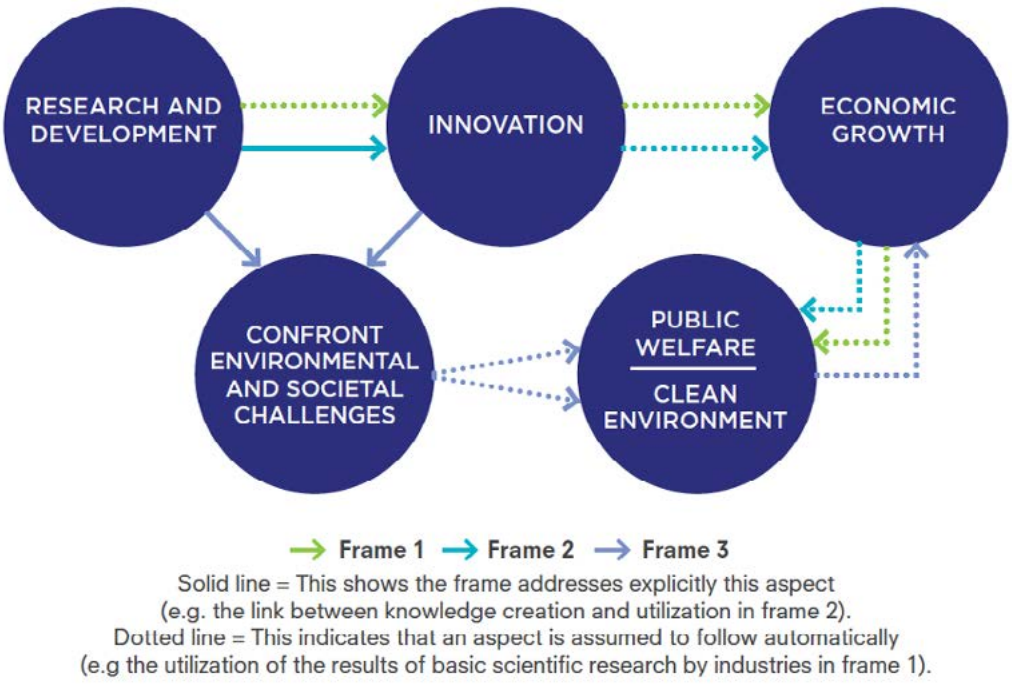
This report builds on this strong foundation of recent developments in STI-policy. It argues that STI-policy should seek to work on a number of key transformations. The identification of these transformations could be derived from a specific understanding of the SDGs which not only considers synergies and trade-offs between various SDGs, but is also grounded in a transformation approach. This approach is explained in chapter 2, as well as the core concept of transformative innovation policy. In chapter 3 this approach is then used to assess the current knowledge base in Colombia. What are its strengths in relation to a transformational approach of the SDGs? Transformative innovation policy builds on a broader innovation concept, which allows it to be integrated into the policy domain, to link up with innovative attempts by companies and with innovation activities of societal actors that are generally not counted in the R&D statistics and ignored by the traditional STI system. In chapter 4 we provide a number of these examples rooted in various regions. We conclude with a proposal on how to implement transformative innovation policy in Colombia, building upon its knowledge base and ongoing transformative initiatives in various regions.

2. REVISITING THE SUSTAINABLE DEVELOPMENTS GOALS

The formulation and implementation of a transformative innovation policy should be seen not only as a contribution to the articulation of the transformation narrative of Agenda 2030 (United Nations Development Platform, 2015), but also as a key success factor for implementing ambitious challenge-driven programmes. Transformative innovation policy can play this role by offering an integrated and system approach which targets the underlying connections and trade-offs among SDGs. It does not treat SDGs as individual targets to engage with through a ticking the box or checklist exercise. It focuses on transformation processes that can deliver on missions as defined by the entire collection of SDGs. A transformation approach has thus important opportunities for the definition of a national implementation strategy for Agenda 2030.

Over the last decades the interest of policy-makers and researchers in Colombia and abroad has focused on STI as drivers for economic growth, innovation and job creation. However, innovation has also become connected to green growth, eco-innovation, social innovation, and inclusive innovation serving other non-economic goals. Yet, the framing of these initiatives has usually been subordinated to directly stimulating economic growth. The report builds on the growing realisation that environmental and social goals should no longer serve mainly as a static framework of conditions for innovation, something they may help to accomplish. Instead environmental and social goals can be seen as strategic and dynamic drivers of long-term growth and competitiveness (Lundin & Schwaag-Serger, 2018). In others words, the relationship needs to be reversed. Economic growth will result from a focus of innovation and innovation policy on social and environmental goals (see figure 1). This will be a qualitatively different type of economic growth, which is in fact captured by the notion of sustainable development, and expresses the need of creating new development paths, which go far beyond business as usual and will require new type of GDP growth measurements such as the UN Human Development Index, or OECD Well-Being index (OECD, 2017; J. Sachs, Schmidt-Traub, Kroll, Durand-Delacre, & Teksoz, 2017.

Figure 1. Logics behind three frames of innovation policy



2.1. STI POLICY NEEDS TO TRANSFORM ITSELF

If STI can be positioned as one of the key success factors, two relevant questions to ask are whether current STI policy is fit for purpose? Can it indeed address all SDGs and be a force for transforming the world? This report argues that for this purpose STI policy needs to take new steps. Up until now STI policy development in Colombia and elsewhere has gone through two main phases and framings: R&D, and national system of innovation. It is time to incorporate a third framing, that of transformative change. The third framing is relatively new and needs articulation, not only in terms of strategy and policy process but also in terms of instruments. It promotes an experimental approach to policy-making. Frames 1 and 2 are well established but need to become more aligned with frame 3 to ensure all policies work towards transformations, and lead to better outcomes in terms of the SDGs (Schot & Steinmueller, 2018b; see also Weber & Rohracher, 2012).

2.2. R&D AND NATIONAL SYSTEMS OF INNOVATION FRAMES FOR STI POLICY

In the first framing which emerged during the 1950s-1980s, STI policy was developed to overcome market failure resulting from low R&D investments of firms. The aim of the policy was to provide incentives for the market to produce socially and economically desired levels of science knowledge (R&D) or for the government to invest itself in public facilities, including universities and research facilities. The assumption is that firms will not invest themselves, since the returns on investment are too long-term and too risky. Market failure is the justification for governments to step in. Investing in R&D is a key to economic success and job creation, and will help to generate tax income for funding other social public purposes. STI policy here is mainly science and technology policy, it leaves innovation to the market. This type of policy is mainly implemented by providing various R&D incentives (subsidies, tax credits etc.) and for example the creation of an IPRs regime.

During the late 1980s STI policies began to evolve. A second STI framing emerged, aiming to make better use of knowledge production, support commercialisation and bridge the gap between science, technology discovery and application or innovation. This framing makes central various forms of learning, including learning by using, producing and interacting, linkages between various actors, absorptive capacity, (STEM) skills, firm capability formation, and entrepreneurship. In particular, in developing countries a central focus became building local absorptive capacity to be able to use and build on foreign technology. The rationale for policy intervention is system failure: the inability to make the most out of available knowledge, including R&D but not limited to it, due to missing or malfunctioning links and framework conditions between the main actors in the innovation system: between firms, governments, and universities. Innovation policy began to focus on building national, regional and sectoral systems of innovation, stimulating entrepreneurship, and promoting public-private partnerships.

These developments and framings are very visible in Colombian STI policies. The policies supported a wide range of universities and science research groups as well as funded the development of a knowledge infrastructure and building up of human resources in STI. Since the 1990s there was an increased emphasis on innovation and entrepreneurship as a consequence of the adopted national innovation systems thinking. There was a shift towards innovation in the firm in order to support Colombian productive sectors facing an economy that opened up to international markets. Colombia established a National System of Science and Technology (NSST by its initials in English) by decree in 1991, in 1995 complemented with a national system of innovation, and by Law 1286 in 2009 transformed into one National Science, Technology and Innovation system. The structure of the system is defined at three levels: national, regional and sectorial. Each of these levels has a coordinating body (councils). The establishment of the Francisco Jose de Caldas Fund as part of the new General Royalty System (GRS) collecting and managing the royalties from the exploitation of the country's mineral resources. The GRS allocates 10% of the total revenues to the STI Fund which aims to promote regional STI. The royalty fund represents an important milestone in Colombian STI policy since it triples resources (M Salazar, 2013). Despite these attempts to strengthen the productive sector, the Colombian innovation system is still characterised by a comparatively weak role of industry, offset by the concentration of innovation activities in public research organisations (OECD, 2015). Colombia has not become more competitive, continues to rely on exporting primary commodities and economic, environmental and social problems persist.

In both R&D and national system of innovation framings negative social and environmental consequences of innovation are externalities. They have to be managed through regulation. The assumption is that science, technology and innovation are to be encouraged since they are the motor for producing economic growth and competitiveness. A third frame for innovation policy, transformative change, began to emerge during the first decade of the twenty-first century. It takes as its starting point that the first two framings are important for building a knowledge base, technological upgrading and constructing productive capacity but do not address sustainable development. This led to attempts to focus more on environmentally and socially sustainable innovation, for example clean technologies, pro-poor innovations, inclusive innovations, grassroots innovation and social innovations. This meant that STI policy began to broaden its understanding of innovation, including more actors who incorporate civil society and citizens not only as consumers and adopters of innovation but also as promotors and

sources for innovations, which address social and environmental needs. STI policy also began to include new forms of innovation, which focused on organisational changes, new business models and new collaborative arrangements between actors with environmental and social benefit, moving beyond public-private partnerships to include civil society actors.

A third frame of innovation policy is also visible in Colombia. Since 2010, Colciencias began activities aimed towards social inclusion, social innovation and appropriation of science. This was reflected in the launch of the National Strategy for Social Appropriation of Science, Technology and Innovation Document. The main objective of this document was the inclusion of communities and civil society in the knowledge production and appropriation programmes. Several instruments and programmes that came afterwards were characterised by a social innovation approach that perceives technology as a tool for development and social transformation. The Ideas para el Cambio and A Ciencia Cierta programmes are excellent examples. The former one was launched in 2012 and aims to involve local communities in the articulation of problems to be solved by R&D and innovation; the latter one goes one step further by welcoming ideas for solutions from local communities. The ideas to be implemented are decided through a national ballot of all citizens in Colombia (Mónica Salazar, Lozano-Borda, & Lucio-Arias, 2014). A major issue of these frame three policies is their relatively small size (in terms of funding), their limited impacts and limited coordination with other STI policies. In short, they have not realised to the full extent their transformative potential.

The extremely high degree of inequality in levels of regional development and welfare represent the biggest societal challenge for Colombia. Reducing these inequalities through science, technology and innovation policy was one of the motivations for important STI policy initiatives such as the GRS Program. What it aims for is the development of regional initiatives that are less centralised, more inclusive in terms of economic development and programmes whose investments are directed deliberately to resolve specific local problems. Local actors need to be empowered to develop initiatives and solutions that respond to unique local challenges and technological options that respond to these demands. Such an objective needs frame 2 policies focused on building up regional innovation systems, but this will not be sufficient as many STI policies tend to focus on social and environmental issues. Many national STI policies often benefit regions that are already equipped with high-level infrastructure, further concentrating the activities of STI and consolidating regional polarisation. Frame 3 policies with a regional focus may be needed to develop specific regional development pathways.

To make STI policy to respond more and better to social and environmental needs and become transformative both on the national and regional level, it needs to change focus and acquire new characteristics. The focus should be on socio-technical system change. It should embrace notions such as experimental delivery and learning, directionality, and inclusivity. These notions can be integrated in frame 1 and frame 3 policies too. Frame 1 R&D policies could focus more on realising specific SDGs goals. Frame 2 policies could become more experimental and inclusive. Yet this will not be sufficient. These types of policies need to be complemented with frame 3 policies which sole purpose is not to build up a knowledge infrastructure or a system of innovation and enhance entrepreneurship, but to enable a transformative change process which addresses SDGs.

2.3. SOCIO-TECHNICAL SYSTEM CHANGE

From an STI policy perspective, the UN Agenda on Transforming our World can be interpreted as a call for a new form of innovation. This is what is called system innovation among others by the OECD (Grin, Rotmans, & Schot, 2010; OECD, 2015). Such innovations provoke a broader system change not only in the technology used, but also in consumer practices and preferences, skills and capabilities of all actors involved, infrastructures, governance, regulation, industry strategies, business models and cultural perceptions. To emphasise this broad scope, including both social and technological elements, these systems are called socio-technical systems. Each economy has a large number of socio-technical systems in place that fulfil important societal functions in application areas such as energy, sanitation, food, healthcare, mobility and communication. Transformative innovation policies aim to change these socio-technical systems into a more sustainable direction. Transforming these systems implies transforming the economy, social relationships and the relationship between people and their natural environment.

This report includes in chapter 4 a case-study of such a system innovation: the introduction of speciality coffee (Arond, Ramírez, Armando Yepes, Chavarro, & Romero, 2017). Colombia is currently the world's third leading exporter of coffee, and since 2002 Colombia's speciality coffee production has grown significantly, from 2% of total coffee exports in 2000 to 28% in 2013. The shift to this coffee has altered producer practices, strategies, norms and routines. It led to more vertical control in relationships between producers and other value chain actors for a globally traded agricultural commodity, and more relationships with research and innovation institutions, with research projects, and programmes funded in the in the context of the new General System of Royalties (GRS). For example, the Antioquia department was able to fund experimental research (with a particular emphasis on woman and youth) in building new capacities crucial for speciality coffee. Overall it was not a policy induced process, but it was a bottom-up change process led by the farmers. It involved changing farmers' perceptions of themselves, what they produce, how they produce, and their role and possibilities for experimentation. The introduction

of speciality coffee led to empowerment and voice amplification of small producers and created new collective relationships between all producers, new skills for tasting, and experimentation for quality and climate adaptability and exporting. There is growing potential for the establishment of local distribution chains and peri-urban producer-consumer networks, and more research and development in service of rural development, particularly in the context of post-conflict Colombia.

Another example – not from Colombia – is the development of mobility services (Kanger & Kivimaa, 2017). This case also shows that socio-technical system transformation is very different from only developing new radical technological solutions. For example, science, technology and innovation policy can focus on the introduction of electric vehicles and its weak spot: overcoming the limited range through battery development. However, if the electric vehicle only is a substitute for the current car and we continue with a car dominated mobility system, the low carbon and inclusive economy will still be far away. Industry structures may be transformed but ambitious SDGs are not met. Therefore, it was argued, it would be better to focus innovation policies on supporting the emergence of new mobility systems, in which for example private car ownership is less important, other mobility modalities such as small taxi vans, public transportation, walking and bicycling are more used in combination with e.g. electric vehicles provided by companies dedicated to the provision of mobility services using ICT capabilities. In this new system, mobility planning and thus also reduction of mobility has become an objective of all actors, and even a symbol of modern behaviour. Only then it becomes an example of transformative change since it involves social, behavioural and technological change in an interrelated way.

2.4. DIRECTIONALITY AS A STARTING POINT

This change in coffee production entailed a shift from a focus on productivity and homogeneous offer of a single type of Colombian coffee to an increasing focus on taste and differentiation with speciality coffees, which requires different production supports and greater attention to cultivation and processing practices. The coffee producers, but also consumers, regulators and policy-makers had to open up to new opportunities. This is a critical aspect of transformative innovation policy; the ability to open up for new radical alternatives which are often not perceived as feasible or even desirable. These alternatives should not be seen as only technological solutions. On the contrary they involve social choices too with environmental consequences. The aim is to make visible the connections between specific options, and social and environmental consequences. Speciality coffee and single type coffee represent different development options with different consequences for people and the environment. In other words they contain a different directionality. Similarly, the choice between electric vehicles or mobility services also contain different social and environmental consequences. The transformative change frame takes directionality as a starting point and engages actors with a process of opening up, engaging with all consequences, and setting collective priorities. Such a process involves the creation of visions about the sustainable future of the sector and connecting these visions to specific development trajectories and technical options.

2.5. EXPERIMENTATION AND NICHE DEVELOPMENT AS A MODE OF INNOVATING

The opening up of new options may promise success in new directions, however, exploring this promise needs experimentation. Transformative change is a search process which has to be informed by experience and deep learning. This type of learning refers to learning about the mind-sets and assumptions embedded in the dominant practices, for example in the coffee case the assumption about the possibilities of moving away from production of quantity to quality, taste, the use of fertilisers, good farming practices and opportunities for collaboration. Coffee farmers had to experiment with different aspects of their practices in order to improve the coffee quality. This type of experimentation is crucial for any transformative change process. It is the best way to build an alternative practice or niche which can begin to compete with the dominant unsustainable practice or socio-technical system (or regime). These alternative practices start to develop at a local and regional level. The proximity of actors creates a space for experimentations and different social groups to work together. Transformative STI policies should therefore have a strong regional focus. At the same time public policies may play a strong role in upscaling and acceleration of local initiative for transformative change. This often requires new intermediation between many local initiatives, new regulatory, and institutional frameworks, and coordination and coherence between a range of policies, from the local to the national and international level, and horizontally between various areas. For up-scaling and acceleration purposes and in order to enable socio-technical systems in various application areas, STI policies need to become more coordinated with various sector policies for transport, mobility, energy, agriculture and healthcare.

2.6. INCLUSION AS A PREREQUISITE OF TRANSFORMATIVE CHANGE

The process of experimentation needs to be inclusive in terms participation but also in terms of outcomes. It needs to have a positive impact on the livelihoods of all involved actors. Inclusion does not just mean to be informed about developments, but also to be empowered and influential. For transformative change to happen it is important to bring not only dominant actors but also niche actors who represent new possible directions into the process, as well as actors from various sectors including producers, civil

society, users/consumers and policy-making. Inclusive processes may lead to incorporation of conflictual views, but this should not be avoided but be seen as a necessary condition for transformative change. Public policy should take on an important responsibility for creating the right kind of framework conditions for inclusive participation and helping actors to navigate conflicts, and generate more trust in the process.

2.7. TRANSFORMATIVE STI POLICY AND SDGS

This report argues that the SDGs provide a new and fundamental challenge to STI policy. It needs to transform itself in order to lead on a broader process of transformative change. The formulation and implementation of such a STI policy is a key strategic action for bringing Agenda 2030 forward in Colombia and in the world. It brings a specific definition to the notion of transformation as change of socio-technical systems transforming the economy and society, and points at the need for experimenting with transformation pathways addressing SDGs, and evaluating their success.

Such a Transformative STI policy provides a new way of looking at the SDGs and their mutual relationships. From a transformative STI policy point of view, three types of SDGs can be distinguished (see figure 2 this chapter, first published in the Green Book (Libro Verde) of Colciencias) 2018:

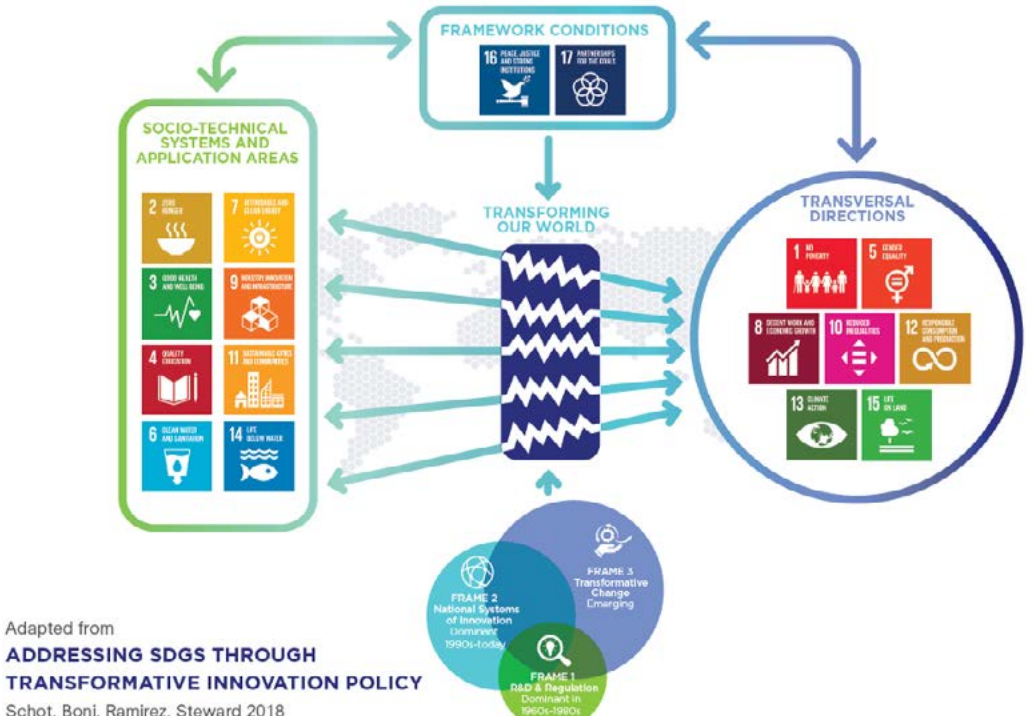
1. SDGs which cover specific or a wider range of socio-technical systems or application areas. For example, SDG 2 Zero Hunger which refers to the agriculture and food system; SDG 3 on Health, SDG 4 on Education, SDG 6 on Clean Water and Sanitation, SDG 7 on Affordable and Clean Energy, but also SDG 9 on Innovation, Industry and Infrastructure, SDG 11 on Sustainable Cities and Communities, and SDG 14 Life Below Water.

2. SDGs which emphasises "transversal directions" or directionality. SDGs 1 No Poverty; SDG 2 Zero Hunger; SDG 5 Gender Equality; SDG 8 Decent Work and Economic Growth; SDG 10 Reduced Inequalities; SDG 12 Responsible Consumption and Production and consumption, SDG 13 Climate Action, and SDG 15 which is about Life on Land, and focuses on biodiversity.

3. SDGs which focus on participation and structural transformation in framework conditions necessary for realising transformation. This includes changing governance arrangements among the state, the market, civil society and science. These are expressed in the remaining two SDGs: SDG 16 Peace, Justice and Strong Institutions and SDG 17 Partnerships for the SDGs.

These distinctions allow STI policy makers to focus their efforts on transforming socio-technical systems (SDG type 1), using Directionality as a main principle (SDG 2 type 2) and in a participatory manner reforming governance conditions (SDG type 3).

Figure 2. Addressing SDGs through transformative innovation policy



3. MOBILISING THE TRANSFORMATIVE POWER OF THE SUSTAINABLE DEVELOPMENT GOALS IN COLOMBIA

This chapter presents an analysis of the potential of the Colombian research system as a key enabler to achieve the Sustainable Development Goals (SDGs), by showing how the research currently conducted in Colombia relates to them, identifying weak spots and suggesting the selection of a number of key transformations that address a specific set of SDGs in a transformative way. This research is based on a specific understanding the SDGs, discussed in chapter 2.

This analysis provides two core insights. First, that it is necessary to strengthen the scientific base in certain under-researched areas related to the SDGs, such as the poverty and inequality. Second, it is essential to create linkages between different areas of research that currently address the SDGs in "silos" in order to promote a more holistic and systemic understanding and implementation of the SDGs in Colombia; for example, SDG 2 (Zero Hunger) should be put in conversation with SDG 1 (No Poverty), SDG 5 (Gender Equality) SDG 10 (Reduced Inequality) and SDG 13 (Climate Action). This is already happening in some areas, but much of the research in the country remains focused on single goals.

The methodology consists of a bibliometric study of the Colombian research system from journal publications in Web of Science and SciELO Citation Index repositories (articles, reviews, conference papers and books). We evaluate SDGs nexus in knowledge production that may focus on sociotechnical systems, transversal directionalities, framework conditions or building bridges between them. Our hypothesis is that it is more likely to find transformative activities emerging from SDGs nexus within the research system.

Our results indicate that most of the research related to SDGs is currently conducted in sociotechnical SDGs. However, we found evidence of some SDGs nexus in research based on our analysis of research communities where transformative activities take place, by which we mean research that addresses directionalities within sociotechnical systems. For instance, education is a key enabler to address poverty and inequality, while management of water and agriculture offer means to address climate change and land degradation.

The chapter is structured as follows: section 3.1 gives a first overview of research related to SDGs in Colombia. Section 3.2 provides a detailed discussion of frequent SDGs topics and nexus efforts based on cognitive communities around SDGs topics in Colombia. Section 3.3 discusses illustrative research that address SDGs from a transformative scope. To enhance readability, we included the methods section at the end of this chapter.

3.1. KNOWLEDGE PRODUCTION CAPABILITIES TO ADDRESS SDGS IN COLOMBIA

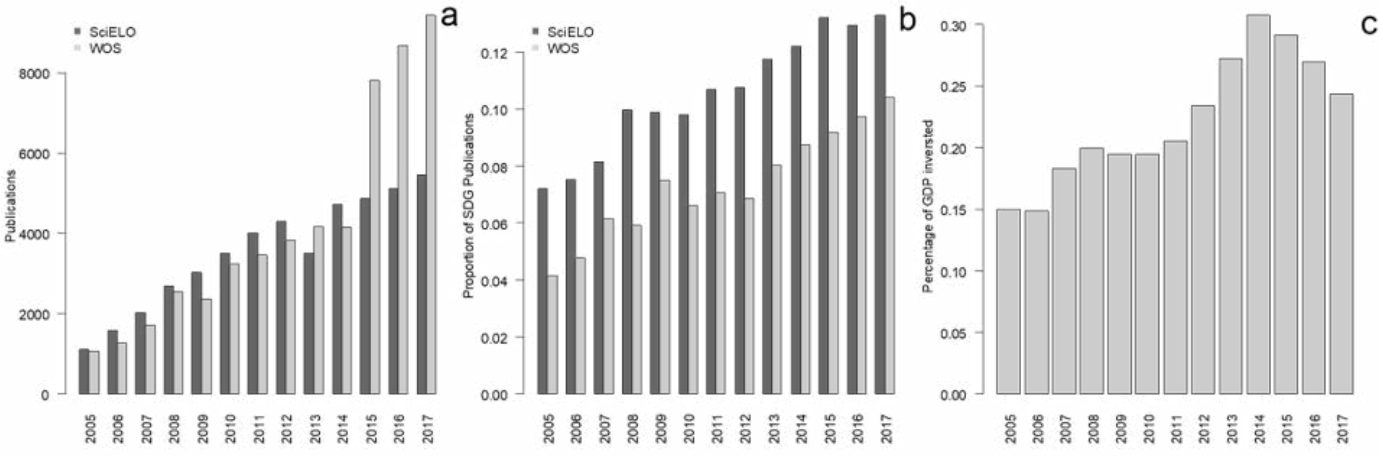
In this section, we describe the analysis conducted to examine the relation between the scientific base of the Colombian research system and the SDGs, in the period between 2006 and 2017. We evaluate scientific publications (e.g. articles, books, reviews) from Web of Science (WoS) and SciELO Citation Index (SciELO) repositories (English and Spanish or Portuguese languages respectively). We identified 5,204 scientific publications related to the SDGs in WoS and 4,586 in SciELO, following the method developed by Ramirez et al., (2019). These publications correspond to 8 (WoS) to 12% (SciELO) of the total scientific publication output in Colombian in the aforementioned period. A detailed description of this approach can be found in the methods section at the end of this chapter.

3.1.1 EVALUATION OF SDGS CAPABILITIES IN COLOMBIA

A cursory analysis of Colombia research and SDGs shows a somewhat mixed picture. In terms of our measure of publications related to SDGs, which we will call "bibliometric sources", between 2006-2017 we observe an increase of both the total number of Colombian publications in WoS and SciELO and the proportion of publications related to SDGs (Figures 3a and 3b). This represents significant progress in knowledge production in the country. On the other hand, in terms of investment in the overall system, according to the World Bank,[1] the national expenditure in STI in Colombia shows a considerable decrease between 2014 and 2017 (figure 3b). According to the OCyT (2016), expenditure on STI in Colombia has been reduced during the last years in several activities (e.g. R&D, S&T services, and support to training in S&T) except for innovation activities.

[1]Data recovered from https://data.worldbank.org/indicator/gb.xpd.rsdv.gd.zs. National expenditure is defined as "Gross domestic expenditures on research and development (R&D), expressed as a percent of GDP. They include current expenditures in the four main sectors: Business enterprise, Government, Higher education and Private non-profit. R&D covers basic research, applied research, and experimental development".

Figure 3. Comparative of annual publications in Colombia and investment in research and development.[2]

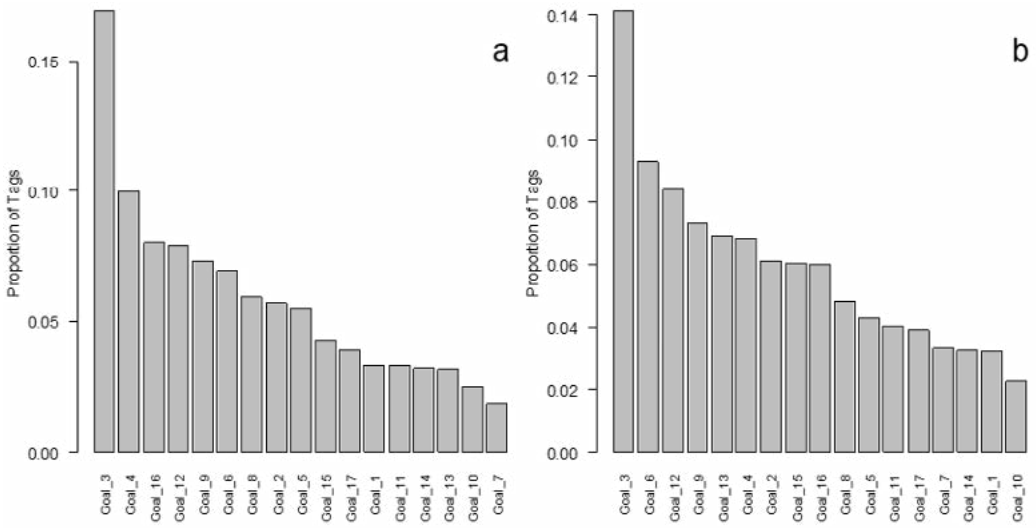


We compared the frequency of research related to SDGs in WoS and SciELO. We found that different topics are more common in different repositories (Fig.4). SciELO sources are mostly associated with SDG 3 (Health) and SDG4 (Quality Education), while SDGs 10 (Reduced Inequalities) and 7 (Clean Energy) are poorly covered. In the WoS, bibliometric sources are highly related to SDGs 3 (Health), 6 (Clean Water) and 12 (Consumption and Production). SDGs 14 (Life Below Water), SDG1 (No Poverty) and 10 (Reduced Inequality) are underrepresented in this database. This finding illustrates that most of the research conducted in Colombia related to SDGs is approached from sociotechnical systems perspective (namely, water, transport, energy, etc.), considering the transversal directionalities of the SDGs to a lesser extent (namely, gender, inequality, etc.). This suggests important imbalances in the SDG's related research in the country.

Our findings coincide with other studies about actions to address the SDGs in Colombia. For example Chavarro et al. (2017), based on an analysis of public policy programmes at regional level, suggest that there is an important effort to implement agendas related to SDGs 3 (Health), 4 (Education), 8 (Labour conditions and economic growth), 11 (Sustainable Cities and Communities) and 16 (Peace, Justice and Strong Institutions). They also suggest that SDGs 1, 12, 14 and 15 have not been incorporated extensively into public policy (which have been classified as transversal directionalities according to Figure 1, in Chapter 1). Similarly, the Sustainable Development Goals Voluntary Report from Colombia identified low progress in addressing poverty and inequality. The report highlights the efforts to address SDG 6, 7, 12 and 15 (DNP, 2018), but identifies difficulties in doubling the recycling rate (SDG 12), doubling internet coverage –SDG 9-; halving multidimensional poverty (SDG 1), increasing marine (3%) and terrestrial (18%) protected areas (SDGs 14 and 15), reducing GINI index by 0.04% (SDG 10) and increasing the formalisation of labour by 10% (SDG 8).

[2]A) Publications developed by researchers with a Colombian affiliation. b) Proportion of publications in Colombia that are strongly associated to SDGs. c) National.

Figure 4. Proportion of SDG tags found in the bibliometric sources published between 2005 and 2017.[3]



Finally, there is the Colciencias National Strategy Report on meeting the SDGs, Libro Verde (Green Book) produced in 2018. This book identified existing capabilities in achieving important SDGs such as 12, 13, 14 and 15 (planetary boundaries), but weaker capacities to address important social challenges related to SDG 1 (No Poverty), SDG 3 and 6 (Health and Water access), SDG 15 (Life on Land) and SDG 8 (Labour). This study suggests that there is a misalignment between knowledge production and societal demands, and that the STI system can play a central role in reducing this gap (Colciencias, 2018a).

Overall, these studies suggest that current knowledge production in Colombia related to the 2030 Agenda focuses mainly on sociotechnical systems, with a limited inclusion of transversal directionalities. This could represent a misalignment between the challenges that Colombia is currently facing and the knowledge production system (represented by research publications). It suggests that there is a need to identify or develop strategies that connect scientific and technological approaches with social demands. To explore this aspect, we conducted a more systemic analysis based on research communities, in order to develop possible strategies to connect knowledge production and societal goals, as described in the following section

3.2. RESEARCH COMMUNITIES

This section incorporates a systemic view of SDGs into our analysis. We argue that research with transformational potential is more likely to emerge from an SDGs nexus within the research system.

3.2.1 SDGS NEXUS IN BODIES OF KNOWLEDGE

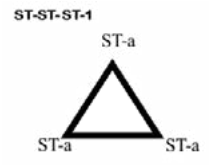
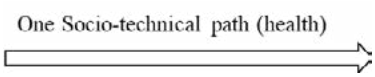
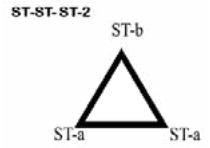
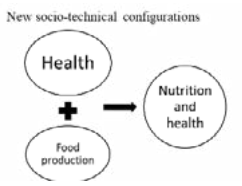
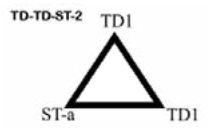
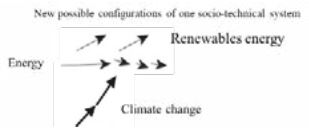
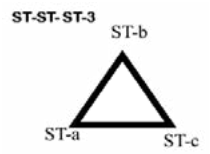
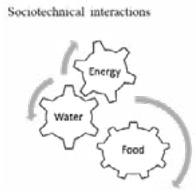
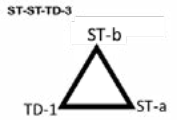
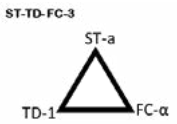
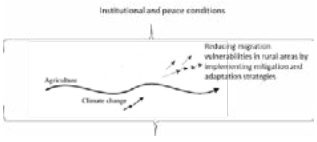
We build on a literature that is increasingly focusing on interaction between SDGs (Nakamura et al., 2019; Nilsson et al., 2018) for addressing transformations (Cervantes & Hong, 2018; Sachs et al, 2019). Our approach goes beyond mapping interactions and engages in a discussion about what sorts of interactions and SDGs nexus in research is likely to be a catalytic for transformations (Ramirez et al., 2019)

Our understanding of SDGs nexus focuses on four related types of possible paths of knowledge production (table 1; figure 2). The first type corresponds to research that focuses on sociotechnical systems (e.g. energy and food), which might produce: new knowledge that remains within a similar cognitive framework, new sociotechnical configurations such as links between health and nutrition, or knowledge that supports further complex SDGs alignments (e.g. the nexus project https://www.water-energy-food.org/resources/projects/). The second type, which we call research on transversal directionalities (e.g. poverty) may contribute to open up debates about social and ecological problems: from the perspective of one directionality (climate change); building alignments between two directionalities (climate change and biodiversity loss); or promoting simultaneously multiple directionalities (climate change, biodiversity loss and inequality). The third type focuses on participatory process and governance structures needed for transformative change (SDG 16 and 17). The fourth type corresponds to a path that builds bridges between sociotechnical systems, transversal directionalities and directionalities (e.g. addressing inequality and climate change in agriculture), and we consider this type to be more transformative, because it can change pathways in sociotechnical systems directly. These configurations represent particularly promising research that is breaking multi-disciplinary barriers and that supports efforts towards deeper (Ramirez et al., (2019)

[3]Each proportion corresponds to the number of tags of one SDG with respect to the total number of tags. a) SDGs tagged in SciELO. b) SDGs tagged in WOS.

To identify SDGs Nexus in knowledge production, we identify bodies of knowledge that address SDG topics. To do so, we evaluate the SDGs publications detected in WOS and SciELO using a co-biography networks approach.[4] We identified knowledge communities (bodies of knowledge) and groups of three SDGs publication (triads) in the co-bibliography networks. A "knowledge community" refers to a group of publications that strongly share bibliography, while triads are three scientific publications connected in the co-bibliography networks (table 1). A detailed description of this methodology can be found in the Methods section.

Table 1. Types of triads according to transformative innovation perspective of Social Development Goals. Taken from Ramirez et al., (2019)

Triad Types	An illustrative example	
1. These Triads are composed by only one SDGs which can come from only one SDG category (sociotechnical systems, Transversal directionalities and framework conditions. One category: ST-ST-ST-1 TD-TD-TD-1 FC-FC-FC-1	One category 	
2. These triads are composed by two SDGs which can be come from one or two SDGs categories: One category: ST-ST- ST-2 TD-TD-TD-2 FC-FC-FC-2 Two categories: ST-ST-TD-2 TD-TD-SD-2 ST-ST-FC-2 TD-TD-FC-2 FC-FC-ST-2 FC-FC-TD-2	One category 	
	Two categories 	
3. These triads are composed by three SDGs which can be come from one, two or three different SDGs categories. One category: ST-ST-ST-3 TD-TD-TD-3 Two categories: ST-ST-TD-3 TD-TD-SD-3 ST-ST-FC-3 TD-TD-FC-3 FC-FC-SD-3 FCFC-TD-3 Three categories: ST-TD-FC-3	One category 	
	Two categories 	
	Three categories 	

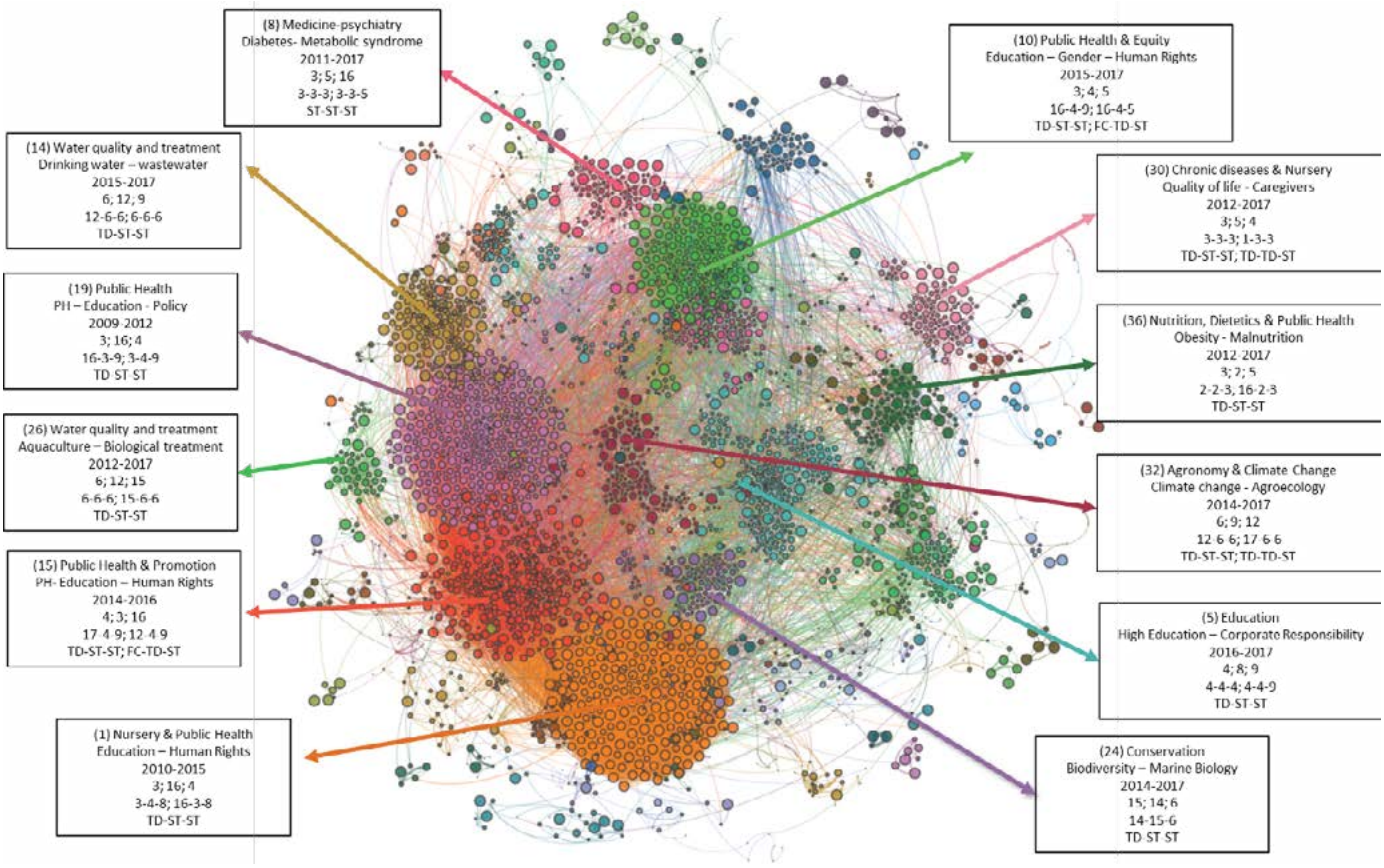
Note. ST: sociotechnical systems; FC: Framework Conditions TD: Transversal directionalities (figure 1)

[4]This methodology applies bibliographic coupling (BC) for detecting group of publication that strongly share bibliography. This networks is defined by nodes (scientific publications) and ties (common bibliography).

3.2.2 CHARACTERISING RESEARCH COMMUNITIES

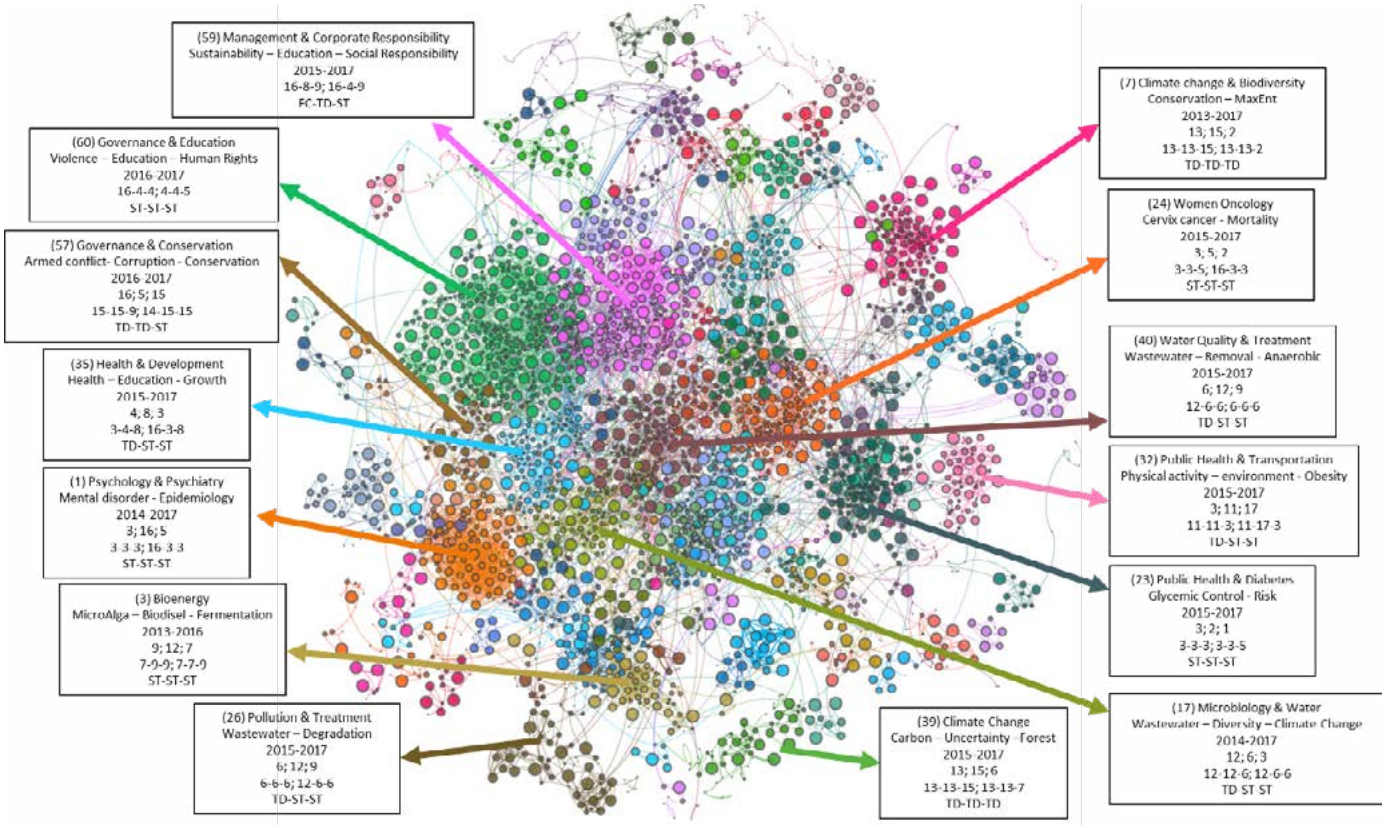
We found 39 research communities in SciELO that are composed of at least 10 bibliometric sources.[5] Figure 5 shows the composition and main characteristics of the largest communities. A number of these communities are related to issues of Public Health and Medicine. Significantly, some of these communities combine health with research on education, human rights and nutrition, this introducing directionality. For instance, we identified publications related to the effects of SDG 1 (Poverty) or SDG 10 (Inequality) or on SDG 3 (Health) (see figure 5, community 10). Other communities well represented in SciELO are those related to water issues with a strong focus on water treatment and water quality (Figure 5, community 14). In these communities, SDG 6 is associated with directionalities such as responsible production (SDG 12) or including biodiversity (figure 5, community 26). Conservation and climate change represent a prominent community in SciELO. These communities are strongly associated with water systems (figure 5, community 24), responsible production (SDG 12) and innovation (SDG9).

Figure 5. SciELO knowledge network.[6]



[5]We only considered research communities found in the giant component. The giant component is the network with the greatest number of connected articles. Further research should involve evaluating communities in disconnected components. This implies that we analysed 4,586 bibliometric sources (publications).
[6]Nodes are coloured according to the community structure. The size of the node represents its number of ties. Each community is labelled with the main topic, the most common keywords, the timespan when the community has been more active, the most common SDG tagged, the most recurrent triads and the most frequent triad type. The principal network measures are: Average Degree: 13.347; Network Diameter: 18; Modularity: 0.705; Average Clustering: 0.331 and Average path Length 5.57.

Figure 6. WoS knowledge network.[7]



[7]Nodes are coloured according to the community structure. The size of the node represents its number of ties. For each community it is shown the main topic, the most common keywords, the timespan when the community has been more active, the most common SDG tagged, the most recurrent triads and the most frequent triad type. The principal network measures are: Average Degree: 3.772; Network Diameter: 39; Modularity: 0.948; Average Clustering: 0.322 and Average path Length 12.127.

In contrast, the map of knowledge in WoS is composed of 65 communities (Figure 6).[8] Similarly to SciELO, some communities are strongly related to health issues, but in this case these communities are more focused on sociotechnical systems, and directionalities are less frequent. Some exceptions to this include decent work (figure 6, community 35), inequality and vulnerable populations (figure 6, community 1). Governance and peace are highly relevant in Colombia and these communities are associated with directionalities such as gender equality (figure 6, community 60). We found some communities that explore how alternative ways of producing energy can be developed in Colombia (figure 6, community 3). Although these communities are mostly focussed on technical issues, some of their research addresses questions such as how to embody sustainable production (SDG 12). Two communities related to climate change include other directionalities such as species diversity (figure 6, communities 7) and sociotechnical elements such food security (SDG 2). Finally, a community that assess life and health in cities is interesting (figure 6, community 32). This community combines sociotechnical issues (SDG 3) with sustainable cities and inclusiveness.

These maps of knowledge are a first step to understand systemically the capabilities present in Colombia to address SDGs. Health, water, education, and to some extent sustainable energy are fields in which a large body of knowledge already exists. These fields correspond to sociotechnical systems that in some cases are connected with transversal directionalities. However, there is a relative lack of knowledge in fields such as sustainable cities, equality and equity, poverty and no hunger.

3.2.3. KNOWLEDGE CLUSTERS AND SDGS NEXUS

We identified a high number of research communities across WoS and SciELO (104 in total). We performed a cluster analysis to aggregate communities that focus on certain SDG(s), which identified the more manageable number of 12 knowledge clusters (Nakamura et al., 2019). This cluster represents capabilities to address SDGs in Colombia that could help to develop transformative agendas in STI. This analysis is possible because multiple research communities address similar SDGs. We identified some clusters taking a different perspective on the same SDG, for example working in the area of health (SDG3) but focusing more on diseases or on health policy. The results of this analysis are summarised in Figure 7 and Table 2.

Table 2 describes and names the 12 knowledge clusters according to the main research areas they address. Figure 7 orders these 12 knowledge clusters according to the similarity between the SDGs addressed in each cluster. This reveals a clear pattern. Clusters 1-3 represent research related to SDG3 (Health). The presence of three clusters indicates the importance of health-related research in Colombia, and each of these clusters represent primarily socio-technical system triads (table 1). However, cluster 3 has a stronger emphasis on governance in the context of health, leading to overlaps with the knowledge clusters relating to education, governance and peace. As Table 2 indicates this also involves towards building bridges between socio-technical system triads to include transversal directionalities. Cluster 4, education, includes a specific triad of transversal directionality, and clusters 4-7, which represent research on education, governance and peace, systems management (which includes governance of education, innovation and the environment) and pollution and mitigation, meaning an overall emphasis on transformative triads – triads which include both sociotechnical systems and transversal directionalities.

It is important to note that there is an exception to the general pattern found in cluster 8, Solar Energy, which has little similarity with any of the other knowledge clusters. Notably, this cluster exhibits very little SDGs nexus as it emphasises homogeneous sociotechnical system triads. There are also overlap between cluster 7 (pollution and mitigation) and clusters 9 and 10 which relate to water treatment and the water cycle, which include a mixture of sociotechnical system triads and transformative triads. These are similar to clusters 11 and 12 which relate to ecological processes and threats to biodiversity. These final two knowledge clusters include transversal directionality triads and transformative triads, but overall, they include more research related to transversal directionalities indicating a focus on SDG 15 (Life on Land).

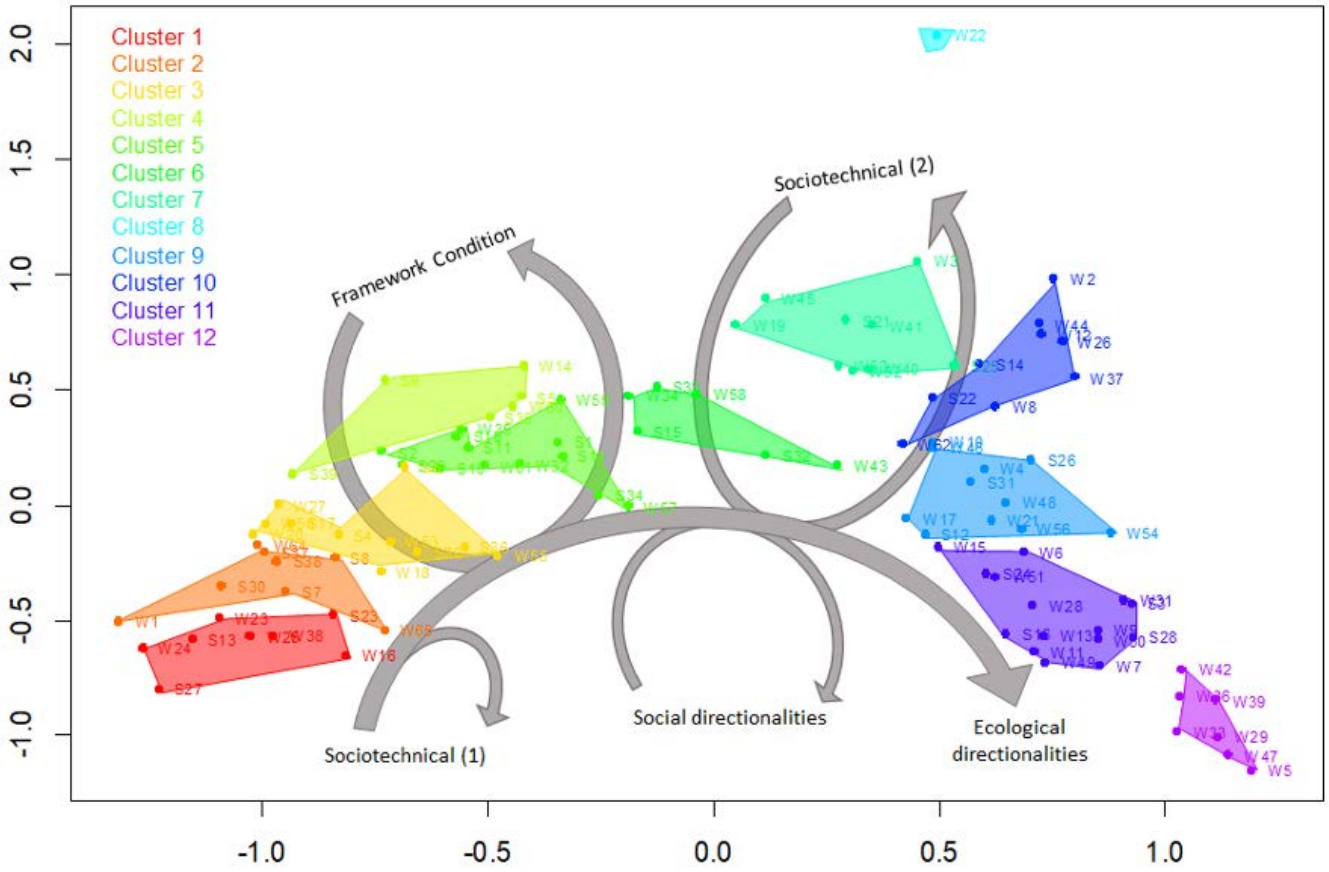
[8]We evaluated 5204 bibliometric sources in the great component of the network.

Table 2. Characterisation of Clusters identified. Under each cluster's name, "n" refers to the number of bibliometric sources represented in each cluster

Cluster	Name	Research Communities	Research areas	Frequent of triads	Source example
1	Medicine 1 (n=684)	8	Transmissible (e.g. Dengue) and non-transmissible (e.g. cancer) diseases	ST-ST-ST-1	Epidemiology and risk factors of hepatocellular carcinoma (Toro, Sanín & Navas, 2007).
2	Medicine 2 (n=775)	8	General diseases Health Policy	ST-ST-ST-1 Framework	Health Reform and Reconfiguration of the Trajectory of Access to Health Services from the Experience of Users in Medellin, Colombia (Echeverry López, 2011).
3	Public Health (n=795)	11	Mental health Health equity & promotion Quality of life	ST-ST-ST-1 TD-ST-ST-2 Framework	Cognitive development and nutritional status: a subject of social determinants of health inequities (Castro, 2009).
4	Education (n=1284	6	Education for poverty, inequalities, and peace	Framework TD-TD-TD-1 TD-ST-ST-3	Education, inequality and forced displacement in Colombia (Sandoval, Botón & Botero, 2011).
5	Governance & Peace (n=2206)	13	Human rights on education, equity and, economy.	Framework TD-ST-ST-3 TD-TD-ST-3	Medellin youth experiences before, during and after belonging to an illegal armed group (Hernández Holguín & Alzate Gutiérrez, 2016).
6	Systems Management (n=1041)	6	Governance of education, innovation and the environment	Framework TD-ST-ST-3 TD-TD-ST-3	Participative construction of a socio-ecological model for the social inclusion of people with disabilities (Díaz, García & Fergusson, 2007).
7	Pollution & Mitigation (n=628)	9	Economics and politics on clean and drinking water	TD-ST-ST-3 TD-ST-ST-2	Using the microalgae Chlorella sp. live suspended in decolouration wastewater from a textile factory (Vacca Jimeno, et al., 2017).
8	Solar Energy (n=30)	1	Technologies for solar energy development	ST-ST-ST-1	High efficiency single-junction semi-transparent perovskite solar cells (Roldan Carmona, et al., 2014).
9	Water Cycle (n=569)	11	Socio-economics and socio-ecology of water usage	TD-ST-ST-3 TD-ST-ST-2 TD-ST-ST-1	Cleaner production and feasibility of biological treatment for slaughterhouses effluents in small towns: Case: Municipality of Tambo (Colombia)(Chaux, Rojas & Bolaños, 2009).
10	Water Treatment (n=594)	9	Technologies for water cleaning and sanitation	ST-ST-ST-1 ST- ST-ST-2	Evaluation of three methods for the inactivation of coliforms and Escherichia coli present in domestic wastewaters used in irrigation (Rojas Higuera et al., 2010).
11	Ecological processes (n=870)	15	Effects of natural and human-driven variability on ecosystems and food security	TD-TD-TD-1 TD-TD-ST-2 TD-ST-ST-2	Relationship between edaphic macro-fauna and soil chemical attributes in different agroecosystems(de Lima, de Aquino, Leite, Velásquez & Lavelle, 2010)
12	Threat to Biodiversity (n=216)	7	Natural dynamics, Climate change, deforestation, and fire	TD-TD-TD-1 TD-TD-TD-2	Amazonia Through Time: Andean Uplift, Climate Change, Landscape Evolution, and Biodiversity (Hoorn et al., 2010).

These clusters permit us to devise knowledge capabilities (SDGs topics) and nexus approaches that can help develop transformative policies. In the following section, we give some examples about possible approaches, as detected in these clusters, to address the SDGs in Colombia.

Figure 7. Hierarchical clustering based on a Correspondence Analysis of communities in SciELO (S*) and WOS (W*).[9]



3.3. RESEARCH ABOUT SDGS IN COLOMBIA

Our analysis of knowledge production identified four research clusters that address the SDGs in the Colombian context. They can be taken as critical inputs in four key transformations that address a whole set of interactions between SDGs. This section provides details about these clusters.

Cluster 1: Health in connection with education, well-being, inequality, human rights

We observed different types of approaches to research on health in this cluster. A first type of approach is a disciplinary approach that focusses only on technological developments for prevention of illnesses such as diabetes or overweight (e.g. "Prevalence of glycemic control and associated factors in type 2 diabetes mellitus patients at the Hospital Universitario de San Ignacio, Bogota-Colombia" see: Alba et al., 2009). We also see nexus approaches that connect health with other socio-technical systems to address illnesses. For instance, using education for preventive health and improving the quality of life of patients (e.g. "Effects of ludic-education activities in the quality of life of patients on hemodialysis" see: Hurtado, Arango and González, 2005). Moreover, there is some evidence connecting health to the reduction of vulnerabilities and inequalities (through promoting access to health; e.g. "Socioeconomic inequalities in premature mortality in Colombia, 1998-2007: The double burden of non-communicable diseases and injuries" see: Arroyave et al., 2014). Finally, health can also be connected to framework conditions related to human rights, as in the case research that addresses violence against women, which is a prevalent issue in Colombia ("The Right to Health of Internally Displaced Population: The Case of Women of Auto 092, Medellin, Antioquia" see:

[9]Communities are ordered according the occurrence of SDGs in the sources that constitute each community. Each axis shows the percentage of variance explained by dimensions – artificial variables created during the dimensional reduction procedure - obtained in the Correspondence Analysis. Clusters (demarked by polygons) correspond to groups detected by the Hierarchical Clustering Analysis based on the spatial location of communities in the Correspondence space. Grey arrows indicate the turnover of SDG categories across the clusters.

Fernández Moreno, 2010). Thus, we can contrast individual examples of research that focus on a single SDGs, mixing SDGs within Sociotechnical systems category and that build bridges between SDGs categories. Although all types of research are valuable in society, the spirit of the SDGs suggests that further investment that links health with the social sciences may have positive impacts.

Cluster 2: Education in connection to poverty and inequality reduction, health and peace

Other examples of research with transformative potential can be found in the area of education, which is linked to poverty and inequality. For instance, Education of Citizens is a project in Tunja that aims to reframe universities as sustainable organisations through activities that encourage students to consider their roles as citizens. This project is part of the Citizenship Education Program from the Colombian Ministry of Education that aims to address endemic problems related to violence and encourage environmental education (Jaramillo & Mesa, 2009). There are also projects about "native communities"[10] and afro-communities[11] that aim to understand the role of an intercultural school in the context of global agendas related to sustainability (Bolaños, Daza & Rivera, 2018; Escobar, Gonzalez & Manco, 2016). "For a better future: programme for healthcare in afro-communities" is another example where education became an enabler to achieve other SDGs such as health, equity and peace through the social recognition of needs and strategies of education (Velásquez Gutierrez, López Díaz, Puerto, Cataño Ordoñez, & Muñoz, 2016). These projects show how the transformation of education is relevant to address the 2030 agenda encouraging new narratives of citizenship, including other narratives of development from local communities and the reduction of violence.

Cluster 3: Climate Change in connection with conservation, agriculture, inequality

The issue of climate change mitigation needs to be addressed with urgency. In Colombia, this appears to be quite closely tied with forest conservation (Castro-Nunez, 2018). Deforestation has produced several impacts in rainforests and mountain forests that are key to address climate change globally. Conservation strategies are also important to build peace in many regions that have been affected by illegal crops. It is been also suggested that funding mechanisms to preserve and encourage sustainable agriculture practices are relevant to address deforestation in the Orinoquía region (Castro-Nunez, 2018). Local policies and institutions could help to leverage conservation as a development strategy. It could also have a positive effect by reducing inequalities in rural regions where there is a high disparity in the ownership of land.

Cluster 4: Food security in relation to climate change, agriculture and water management

Finally, agriculture and food security are key for interventions under climate change in Latin America (Vermeulen et al., 2012). According to Ramirez-Villegas et al. (2012:1) climate change might impact "3.5 million people, 14 % of national GDP corresponding to agriculture, employment of 21 % of the population, agro-industries, supply chains, and food and nutritional security in Colombia". Therefore, it is of high relevance to implement strategies to help farmers adapt their practices to address climate change and reduce emissions. For instance, Rahn et al. (2014), shows the relevance of water as a key strategy to manage the impact of high temperatures on coffee crops that could result from climate change. They also suggested that this sector needs to improve knowledge and technologies to identify weather variations that help manage their crops (Rahn et al., 2014; Rahn et al., 2018). These examples show how knowledge is a key enabler of the 2030 agenda connecting scientific research with local dynamics. They also suggest that directional SDGs have a great potential to connect several types of knowledge bringing new paths and helping to achieve the 2030 Agenda.

3.4. CONCLUSIONS

A critical argument that has underpinned our methodological approach is that addressing the SDGs requires research that develops knowledge and practices for opening-up new sustainable pathways of development. We have also argued that SDGs research that is able to build bridges between what we have classified as sociotechnical systems, framework conditions and transversal directionalities, is more likely to be able to embrace the complexities posed by simultaneously addressing different SDGs, in which trade-offs as well as complementarities may exist. In this context, the bibliometric study of SDG-related outputs carried out in this report highlights both strengths and weaknesses of the Colombian research system. We observe a significant increase in publications related to SDGs in Colombia over the last decade, which suggests that Colombia has a strong body of knowledge and research capabilities in the fields of health, water, education, and to a lesser extent renewable energy, with focus on solar energy.

Nevertheless, our analysis also shows that cognitive communities in Colombia clearly address SDG topics in different ways with different levels of disciplinarily. It is important to support a range of approaches. However, we argue that the transformational nature of the challenges posed by adopting new sustainable pathways are more likely to be met by opening up the research system to building links between parts of the research system. Through a "bottom-up" analysis of publications we show that some of this research already exists in Colombia. We

[10]Piapoco indigenous communities located in the municipality of Puerto Lopez in Meta.
[11]Families of the Afro-Colombian Women Association of Medellin and of the "Golodrinas Foundation of the 8th district of Medellin".

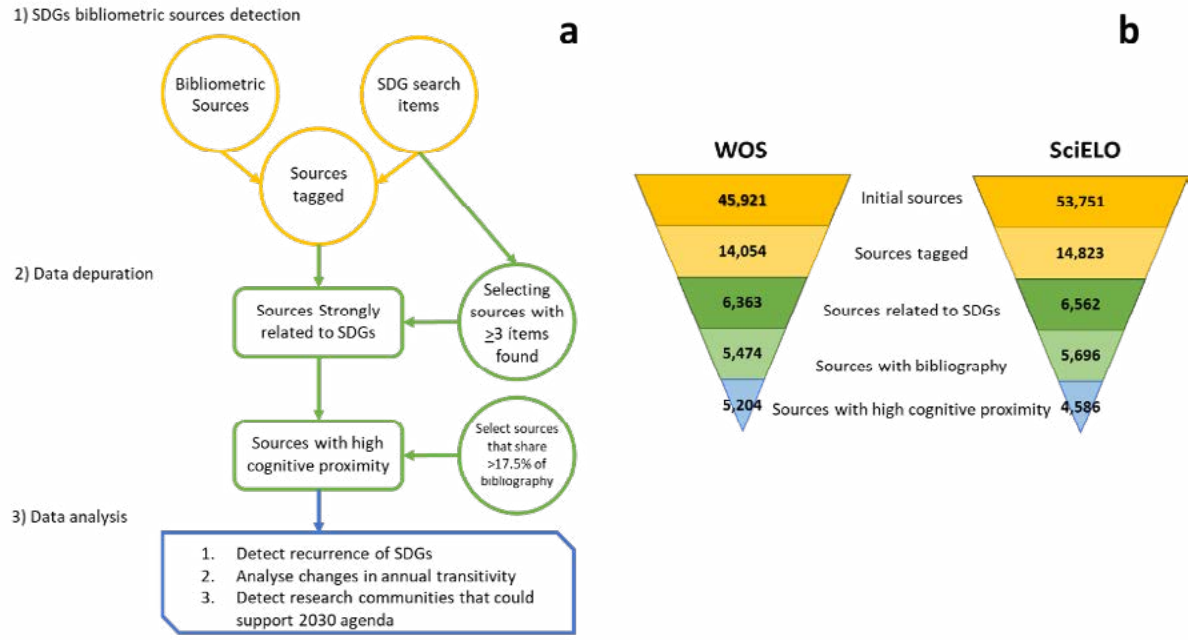
argue in this report that a national strategy that makes this sort of research more visible and more funded can support a stronger knowledge base for the implementation of the SDGs.

3.5. METHODOLOGY (APPENDIX)

This section provides a more detailed descriptions of the methodology used in this chapter. To identify bibliometric sources we focused on citation indices because these have been used widely as an indicator of knowledge output, knowledge diffusion and to measure collaborations around particular agendas (Bornmann, 2013; Garfield, 2006; Rafols, Porter & Leydesdorff, 2010) both in the natural and social sciences. "Maps of knowledge" are commonly used to understand the relationship between knowledge areas (Grauwin & Jensen, 2011; Rafols et al., 2010). These maps are commonly developed using network analysis, which is implemented to visualise and develop specific measures of knowledge integration (Leydesdorff, 2007; Rafols & Meyer, 2010; Shiffrin & Börner, 2004; Wagner & Leydesdorff, 2005). According to Nakamura, et al., (2019) bibliometric analyses provides an unique background view for policy makers to understand the direction of development of the SDGs in the knowledge system of a country or region. Therefore, this approach is well suited to identify and evaluate the current state of the SDGs in the Colombian scientific system.

We identified and labelled bibliometric data sources following the method developed by (Ramirez et al., 2019). First, using the total of bibliometric sources for Colombia between 2005-2017 (45,921 in WoS and 53,751 in SciELO), which correspond to the total scientific output for this period, we searched for 1,162 search items related to SDGs[12] within these publications (title, abstract and key words).[13] This provided a subset of bibliometric sources related to SDGs, which we call tagged sources (figure 2a). Second, from these tagged sources we selected those that have at least three search items in the text (figure 8a)[14]. This step allowed us to select only those bibliometric sources that are very likely to be related to SDGs. This strategy permitted us to reduce uncertainties of possible publications that might be not related to SDGs (Figure.8a). Third, using a method known as co-bibliography coupling, we selected those bibliometric sources that share a high proportion bibliography.[15] After this data refinement, we could detect that around 8-12 % of the bibliometric sources from the scientific output 2005-2017 were strongly related to SDGs (Figure 8b). Finally, each bibliometric source was labelled as relevant to one or more SDGs according to the frequency of search items[16] (for more detail see methods section)

Figure 8. Bibliometric database.[17]



[12]A search item is a group of key words related to SDGs topics (e.g. climate change, or public access transport).
[13]The query was CU=Colombia* in WOS, and AD=Colombia* in SciELO. We gathered information from 2005 to 2017. It was only considered research sources that had mostly complete information (tittle, abstract, key words and bibliography).
[14]The frequency of search items found in every bibliometric source was considered instead of the number of search items found. For instance, a search item might be found three times, or three different search items may be found one time. In our methodology, it is considered as a frequency of three in both cases. This threshold was considered for reducing ambiguities or uncertainties and increase the confidence of our analysis by doing so.
[15]This approach, called bibliographic coupling, applies bibliographic coupling (BC) similarity to determinate publication that are strongly connected to bodies of knowledge.
[16]Ramirez et al., 2019 suggested two rules to label SDGs. "First, it was considered one SDG when the frequency of search items related to one SDG were greater than 60% of the total search items found in a bibliometric source. Second, when this was not the case, the bibliometric source was labelled with additional SDGs until the sum of the frequency of SDGs search items were equal to 75% of the search items in that bibliometric source. This cut-off point was implemented to avoid labelling articles with SDGs that were only mentioned peripherally".
[17] Steps of the construction and analysis of the bibliometric database. a) Process of data cleaning, depuration and analysis. b) Number or bibliometric sources remaining after each step of processing.

We evaluate knowledge production by applying two complementary methods of co-bibliography Network Analysis.[18] The first method evaluates research communities as groups of publication that share a high proportion of their bibliography indicating research in a particular field or topic (for a detailed explanation, see Louvain network modularity optimisation; De Meo et al., 2011; Grauwin & Jensen, 2011; Nakamura et al., 2019). Analysing research communities allows us to detect and describe research related to different SDG topics (Grauwin & Jensen, 2011; Nakamura et al., 2019; Yan & Ding, 2012), and to identify SDGs nexus in knowledge production (Ramirez et al., 2019). To complement this approach, the second method identifies groups of three interconnected nodes, called "triads" in social network analysis. Triads are groups of three bibliometric data sources which share bibliography. According to (Ramirez et al., 2019), "triads generate circuits (a key features of communities) and therefore aid diffusion".[19] We use triads analysis to capture relationships between SDGs in the Map of Knowledge, which provides more information about nexus approaches to address SDGs (table 1).

To connect these complementary methods, we focus on finding the most common triads (Aarstad, 2013) in every research community. Referring back to figure 1, we can use triad analysis to detect connections between different types of SDGs. In table 1 we show 10 different combinations of socio technical systems and transversal directions,[20] which allow us to look at SDGs nexus in research focused on sociotechnical systems, framework conditions and transversal directionalities, and the degree to which bridges are built between them (for more detail see (Ramirez et al., 2019). We suggest that triads representing research that combines sociotechnical systems, framework conditions and transversal directionalities are more likely to be able to open-up systems to new thinking about socio technical transformations. For example, combining knowledge about food production (sociotechnical systems) with knowledge about climate change and inequality (directionalities) could lead to new forms of production and consumption of food that help to address these challenges (pathways). Conservation agriculture (Beuchelt & Badstue, 2013; Feng, Krueger, & Oppenheimer, 2010) could be considered as an example of this, breaking disciplinary boundaries and becoming a promising avenue of research. In summary, our bibliometric approach aims to detect the connectivity between scientific research related to SDGs, so as to detect communities of knowledge that address SDGs, and to evaluate the diversity of triads revealing details about SDGs nexus within these research communities.

3.6. CLUSTER ANALYSIS

This technique is a Hierarchical Clustering based on a Correspondence Analysis (HCCA). This statistical analysis is a multivariate clustering (grouping) algorithm base on a dimensional reduction (variable simplification) that allows one to find groups of elements highly associated according to their composition in terms of a large set of variables (Lê, Josse & Husson, 2008). This method allowed us to simply the understanding of big cores of knowledge and to deploy an easy-to-handle set of coherent groups. For this, we ordered (Correspondence Analysis) the communities of knowledge detected in the previous subsection in terms of their SDG composition and creating groups (Hierarchical Cluster Analysis) or clusters of communities. Thereby, communities of knowledge in the same cluster are similar in terms of their SDG approach and share cognitive coherence. We merge the communities of WoS and SciELO to identify clusters of knowledge regardless the repository where the sources were registered.

[18]This methodology applies bibliographic coupling (BC) similarity between two bibliometric sources i and j to normalise the number of references that every bibliometric source has (Kessler, 1963), and Louvain modularity algorithm to find communities of bibliometric sources (knowledge communities) that share a large number of references (Duncan & Pascucci, 2017; Grauwin & Jensen, 2011). This approach also focuses on modularity maximisation that allows one to detect well defined communities (strong cognitive relationships). These networks are composed of nodes (bibliometric data sources), ties (shared bibliography) and attributes (e.g. relevance to one or more SDGs). We considered bibliographic coupling higher than 17.5%. As a result, a co-bibliography network was selected with 4,586 in WoS and 5,204 in SciELO (figure 1).
[19]Ramirez et al., 2019 also argues that "Triads also more resilient in a network structure since a break in one connection doesn't isolate other nodes as would be the case in dyads".
[20]We did not consider triads that combine framework conditions because this category is composed of just two SDGs and therefore less likely to build triads.

4. TRANSFORMATIVE INNOVATION INITIATIVES IN COLOMBIA

4.1. INTRODUCTION

This section presents a series of case studies that illustrate the potential for transformative innovation policy in Colombia. The initiatives described here engage with science, technology and innovation in a participative way, have the potential for systemic solutions and address different sustainable development goals. There is a considerable number of initiatives with transformative potential to be found in Colombia. In some of them, government agencies have played a prominent role. This is the case with A Ciencia Cierta and Ideas para el Cambio, programmes led by Colciencias that promote experimental spaces for knowledge sharing (Colciencias, 2019; MinCiencias, 2020b, 2020a). Similarly, the Ministry of Environment and Sustainable Development, in an effort to promote sustainable economies in the country has developed a portfolio of green businesses, where knowledge, capacity building and technology diffusion play a central role. Other more bottom-up examples are the activities and projects implemented by Simbiosis Corporation and La Cosmopolitana Foundation (http://www.fundacionlacosmopolitana.org/es/, 2019) as well as the innovations involved in the traditional production of veleño guava sweet and achiras in specific regions (Aristizábal Quintero, 2019).

In this chapter we focus on initiatives that have been the result of bottom-up and distributed efforts from communities, citizens, scientists and organisations, and operate under the radar of official STI policies. For these actors, innovation has a different meaning than in mainstream discourse: it is less about technical upgrading and technology breakthrough solutions, and more about new ways of organising, working and learning together, and producing and using knowledge in contexts and for purposes not considered before.

The following sections present and analyse four other distinctive experiences of innovation in Colombia that can be considered transformative. These case studies were selected because they align with some of the main challenges for Colombia in terms of the SDGs (socio-ecological systems, biodiversity, urban transformations, and integration of agricultural producers to value chains - SDGs 1, 3, 6, 8, 11, 12, 14 and 15). These cases show, in different ways, the interplay between local action, public policy and scientific knowledge in the process of opening up to new pathways of development. The first case identifies pathways of socio-ecological transitions, in which an alternative management of biodiversity towards a sustainable use of ecosystem services adapts to the changing Colombian context. The second initiative relates to the protection of the Bogotá wetlands by social movements. The third case describes social innovation and the Iza's polystyrene ban policy in Boyacá to reduce production and use of non-biodegradable materials. Finally, we include the experience of the adoption of speciality coffee by medium and small producers that represents change of socio-technical practices in agroindustry.

The methodological approach to these cases is based on transitions theory, and it is composed of secondary analysis and semi-structured interviews. A detailed account of these methods can be found in the Methods section at the end of this chapter.

4.2. CASE I. SOCIO-ECOLOGICAL TRANSITIONS TOWARDS SUSTAINABILITY AND ALTERNATIVE BIODIVERSITY MANAGEMENT IN COLOMBIA[21]

Colombia is one of the most bio-diverse countries in the world, and at the same time, one of the countries with the highest rates of deforestation and biodiversity loss. In this context, the work of the Alexander von Humboldt Biological Resources Research Institute (IAVH)[22] has been a keystone in the sustainable management of biodiversity in the country. The institute has developed an approach to socio–ecological systems based on the interaction with local communities, known as socio-ecological transitions towards sustainability (TSS).[23] This approach creates a vision for the sustainability of natural resources and land use in the country, which has the potential to influence priorities in science, the use of technology and the direction of innovation.

[21]The discussion and analysis of this case study draw upon the work of (Andrade-Pérez, Avella Rodríguez, Baptiste-Ballera, Bustamante Zamudio, Chaves, Corzo, Galvis-Hernández, Giraldo, et al., 2018), the information from the website (Andrade-Pérez, Avella Rodríguez, Baptiste-Ballera, Bustamante Zamudio, Chaves, Corzo, Galvis-Hernández, Giraldo, et al., 2018) and the information provided by interviewees.
[22]The IAVH is one of the most prominent biodiversity centres in Latin America.
[23]A socio-ecological system is defined as a type of social organisation that is associated with a certain nature system from which the society depends, colonises and exploits in different ways. Changes in these systems emerge from the particular interactions between society and natural resources, in which the former carries on the exploitation of the latter through processes of production and consumption. (Fischer-Kowalski & Haberl, 2007). This approach resonates with the socio-technical systems approach advanced in the sustainability transitions field on which this report is based.

4.2.1. BUILDING A BIODIVERSITY STRATEGY FOR COLOMBIA

The IAVH was created in the mid-1990s as an independent body to support the Ministry of Environment and Sustainable Development in the implementation of a biodiversity strategy, following a series of regulations in this domain, namely Law 164 (1994) that ratified the United Nations Agreement about Biological Diversity, and Law 99 for the creation of the Environmental National System and the National Policy of Biodiversity.

With an earlier, narrower, focus on biodiversity policy as minimisation of human intervention, this organisation has shifted to what is known today as TSS, through a process of interaction and learning-through-experience with local communities, scientists and national and international organisations. In 2018 The IAVH developed the TSS strategy in order to support the implementation of both the National Policy for the Integral Management of Biodiversity and its Ecosystem Services (PNGIBSE) –produced by the Ministry of Environment and Sustainable Development (MADS), the IAVH and the United Nations Development Programme (UNDP)— and the Biodiversity Action Plan 2016-2030 (MADS, 2012, 2016).[24]

The PNGIBSE is based on a dynamic understanding of the sustainable use of natural resources, as an interplay between the social, the natural and the territory through ecosystem services (MADS, 2012). This approach acknowledges the interdependent relationship between human beings and nature that shapes socio-ecological systems, and aims to formulate alternative paths to extractive regimes, fossil dependence and traditional conservation models. Central to this policy is the need to understand and recognise uncertainty, risks, perturbations and mutual dependency between the socio-economic and ecological systems as the context in which decision-making takes place. Therefore, the PNGIBSE approaches the management of biodiversity and ecosystems as a set of actions associated with knowledge, preservation, restoration, sustainable use and risk management that support the permanent adaptation of society (MADS, 2012).

Since its formulation, there has been some progress in the implementation of the PNGIBSE in terms of creation of programmes, regulations and strategies, monitoring systems, strategic plans and departments within ministries, as stated in the V Report of Biodiversity to the CDB (MADS & PNUD, 2015). However, further efforts are needed in the implementation of the PAB to meet the SDGs by 2030.

The TSS strategy was formulated to support the further implementation of the PNGIBSE. Leading its development approach, the IAVH has taken a transdisciplinary turn, integrating different disciplines and including the views, concerns and knowledge of a wider community. Biologists, ecologists and social scientists have taken part in the production of the TSS strategy, bringing together their experience in research with the knowledge of indigenous communities and social organisations. This provides a diversity of perspectives regarding land-use and ecosystem services. This strategy is already implemented by researchers in various projects in Colombian regions.

The TSS approach considers that protected areas and land are in constant change and need to be integrated into the social, economic and political dynamics. For example, the effects of massive forced migration of rural population due to conflict is a circumstance that must be accounted for in biodiversity management. Based on this understanding, the IAVH has proposed ten potential transitions, which are opportunities for change in different socio-ecological systems and dynamics, such as the sustainable reconversion of bovine farming in post-conflict rural areas (http://www.humboldt.org.co/transiciones/).

A sound and inclusive approach to biodiversity management is central to achieving desirable transformations through this transition, which can support the transformation of socio-technical systems such as clean water provision and agriculture. For this, different technologies and practices are required to monitor ecosystems and provide accurate diagnoses of the state and evolution of biodiversity, that can help us understand people's impact on nature and integrate these insights in processes of decision-making.

The leading principles of the TSS strategy show its transformative potential. They are strongly based on democratic principles of inclusion, social justice and democracy. The strategy has a strong territorial emphasis, acknowledging that local actors have strong agency and responsibility in the conservation of biodiversity, and that local communities contribute with unique and situated knowledge to the formulation of sustainable transitions. In addition, it acknowledges that it is necessary to invest

[24]The PNGIBSE and the PAB were formulated as a part of the commitment of Colombia with the Aichi Goals and the SDGs by 2030 and within the framework of the Convention on Biological Diversity (CBD). The Convention on Biological Diversity (CBD) is a multilateral treaty in which 196 parties have committed to the conservation of biodiversity, sustainable use of natural resources and fair sharing of benefits arising from genetic resources.

in science and technology, research and innovation and knowledge management as well as to integrate traditional and local knowledges that include place-based visions. Besides, the TSS strategy recommends the introduction of social dialogues and agendas on possible futures about the direction of social and ecological changes in the territory; to interpret how actors and their interests align and contradict the proposed transitions; to incorporate uncertainty in the environment and biodiversity management; to create scenarios for discussion and agreements between all actors and sectors; and to build agendas for adaptive interventions on the scientific and social basis of these transition (Andrade-Pérez, Avella Rodríguez, Baptiste-Ballera, Bustamante Zamudio, Chaves, Corzo, Galvis-Hernández, Giraldo R., et al., 2018; IAVH, 2019).

In a second stage, the IAVH is currently in the process of co-producing a more sophisticated version of the TSS strategy. Social organisations, governmental institutions, private sectors and several universities are committed in the provision of feedback on the transitions that are proposed. Social media tools also allow public audiences to make contributions to the document (see Humbold.org.co, 2019). It is important to note that this approach is still new and there is considerable room for shaping the design and implementation. Research and innovation agencies could play a more prominent role using the transformative innovation policy approach.

The case of IAVH and the development of the TSS strategy show that it is possible to create and implement knowledge production while closely working with local authorities, NGOs and communities, and maintaining a strong commitment to democratic principles. The IAVH show that knowledge-based organisations can provide more than knowledge, concepts, technical assistance and capacity building, they can also actively engage in processes of decision-making and local development without losing objectivity, technical capabilities, and capacity to produce socially relevant new knowledge.

4.3. CASE II. PLACE-BASED SOCIAL MOVEMENTS, LOCAL SCIENCE AND INCLUSIVE SOCIO-ECOLOGICAL SYSTEMS IN BOGOTÁ'S WETLANDS

Urban habitats play an important role in public health, environmental sustainability and wellbeing. Characteristically, the quality of urban habitats is both a symptom and a cause of social and economic exclusion, as they endure the – mostly negative – consequences of development. In low- and middle-income economies, the commitment to care for habitats rarely translate into effective policy implementation. In this sense, the movement for the protection of the wetlands in Bogota is an iconic case of how place-based social movements in alliance with and actors from the STI system can help bring about transformations in the practice of urban planning.

4.3.1. CONFLICT AND EXISTING FRAMINGS AROUND BOGOTÁ'S WETLANDS

Historically, urban development in the Bogotá area has expanded without any attention to the local wetland ecosystems. Lack of regulations, the promotion of uncontrolled urban development and a rapid increase in population due to internal forced migration from rural areas have created a tremendous stress over Bogotá's wetlands. For the inhabitants of these areas, this translated into unpleasant odours, pollution, droughts and an unhealthy environment. The situation worsened when, in 1980s and 1990s, vulnerable groups of migrants that were displaced by the armed conflict in rural areas established their neighbourhoods next to the wetlands. The public health crisis and lack of infrastructure in these areas as well as the serious flooding caused by a nearby river accelerated the deterioration of the wetlands.

This situation was the motivation for a series of social movements that emerged between the 1970s and 1980s, with the purpose of seeking formal and informal mechanisms to defend the wetlands. Through a long history of organisation, collaboration and resistance, this resulted in a court ruling and the Wetlands Decree 247 of 2007 that ordered a new set of management practices and the development of new and cleaner technologies for the protection and restoration of the wetlands.

This case shows how contrasting visions coexist in processes of transformative change (D. Palacio, Hurtado, & Garavito, 2003; D C Palacio, 2005, 2010, 2017; Dolly C. Palacio, 1992; Dolly Cristina Palacio, 2002). For the local authority DAMA,[25] the wetlands are strategic ecosystems that can provide environmental services and social welfare. For formal and informal construction companies, the wetlands provided opportunities for urban development, and were used as a landfill. The firm in charge of the Bogotá water supply (EEAB)[26] saw the wetlands as natural drainage areas. In contrast, the network of wetlands of the Savannah of Bogotá formed by community-based organisations, local schools, internationally funded NGOs and local environmental authorities, considered the wetlands as ecosystems that needed to be preserved and enjoyed.

4.3.2. CHANGING PRACTICES AROUND URBAN WETLANDS

The social movement around the wetland has been built, step by step, connecting the concerns of different communities. In fact, there has been a number of social movements operating around the wetlands, from residents'

[25]DAMA Departamento Técnico Administrativo de Medio Ambiente – Technical and Administrative Department of Environment, currently District Secretariat of Environment.
[26]EEAB Empresa de Acueducto de Bogotá – Aqueduct company of Bogotá.

concerns about odour and pollution to NGOs concerned about territorial management. The alliance between these different actors created a network[27] capable of creating and mobilising knowledge for local action and lobbying authorities. Scientists who engaged with this network were able to mobilise the existing resources (grants from Colciencias and other agencies) to create and communicate knowledge on the influence of the wetlands on public health and its role in the environmental sustainability of the city. For scientist and researchers engaged in this process this meant to integrate the concerns of social movements around the wetlands into their research agendas.

The participation of researchers to provide scientific evidence concerning the importance of the wetlands and the effects of water contamination on public health was a key driver of the success of this movement. The territorial embeddedness of multidisciplinary teams - social scientists and technical specialists - was also fundamental to build tailored solutions and to configure a new system. This shows that scientists can contribute to innovative solutions, open up policy processes, engage with priorities of civil society and have profound impacts in other social fields such as urban planning and public health. The case also highlights the importance of social movements as a signalling mechanism to policy makers working to meet the SDGs, highlighting areas of concern that need to be addressed and the importance of establishing local alliances including scientist and scholars to help overcome obstacles and barriers.

4.4. CASE III. SOCIAL INNOVATION AND THE IZA'S POLYSTYRENE BAN POLICY

The use of materials based on polystyrene and non-biodegradable products has been the centre of sustainability debates around the world. Colombia has not been absent of this debate, and a number of policy proposals seeking to promote sustainable production and consumption in the country have been developed. The ban of polystyrene in the municipality of Iza, announced in 2019, is an exceptional case of social innovation that has transformed the socio-technical regime of food packaging in this region. This case shows how the concerted actions of a variety of actors can overcome policy inertia through bottom-up solutions. The content of this chapter is based on the work of Marin (to be published).

4.4.1. NO MORE POLYSTYRENE! THE MOVEMENT OF THE DESSERT MAKERS

Iza is a small municipality located in the department of Boyáca. Iza is renowned for its local desserts which attracts a lot of tourists during the weekends. The production of these desserts is an important part of the local economy, mainly a women's activity in a region largely known for its cattle industry. In the middle of 2018, the success of Iza's desserts caused a crisis: more than 4,500 Expanded Polystyrene (EPS) containers were used per month (Rojas, 2019), which led to an overflow of the available landfills.

This crisis was the breaking point for the local authorities, mainly the municipality, to align with growing concerns from Iza's Dessert Vendors Association (Asociación de Productores de Iza -APAI) in the search for a solution. Seeking alternatives to EPS facilitated the creation of spaces for "experimentation processes" (with new packing materials. Starting from December 2018, the municipality of Iza and the APAI conducted experiments to test the use of different materials, engaging with tourists and other local inhabitants, raising awareness about plastic pollution and the opportunities found in the use of new materials. The results of this pilot experiment became the precedent for the implementation of a Polystyrene Ban Policy for Iza on February 2019 (Rojas, 2019).

What makes this case transformative is the bottom-up approach used by the community to reduce the massive use of EPS, based on local initiative and the engagement with a large variety of actors. The adoption of the new policy was accompanied by a transition period in which the city council held public meetings, inviting different users of the packaging systems to showcase their knowledge about the new changes. An essential component of this process was the ability of the city council to create financial and economic support strategies to facilitate a first stage of adoption of the policy. This new set of strategies shifted the existing market toward biodegradable packaging, incorporating local and regional suppliers who were previously EPS suppliers. Through this process, a social network of actors with common visions and strong links had been built around the policy and sustained the transition.

This initiative has been enthusiastically expanded to the regional level. So far, the change of the polystyrene regime in Iza has been replicated in two neighbouring towns. Promoters of sustainable modes of consumption have circulated the experiences of this social innovation, scaling it up to the whole region. This resulted in the banning single-use plastics for public procurement procedures in the department of Boyacá.

While strongly grained in the local level and in social organisations, the EPS ban from Iza did not include the participation of actors from the STI system, neither through grants nor through the expert advice. This may be seen as a missed opportunity, because there is plenty of scope for productive involvement. For example, the selection of a biodegradable solution was largely based on the knowledge of local actors and may be assessed further. The landfill management is a question yet to be solved.

It is important to note that this process has happened in the context in which the adoption of regulations at the national level for sustainable waste management regulations has been unsuccessful. While the Colombian government introduced a tax on plastic bag consumption in 2016, other

[27]In this case, a network does not refer to an institution or organisation, but to an informal arrangement of different actors that work together during a period of time.

agendas such as the implementation of technologies for waste management disposal (2018) and the ban on single-use plastic (2018) still sit in congress.

This project has not been immune to opposition and resistance from dominant actors. After March of 2019, when a new bill to ban single-use plastic was introduced to congress, incumbent actors such as large plastic producers strongly voiced their opposition to this change. However, more and more political parties, environmental institutions and grassroots movements support these changes, and we might expect that the transformation occurring in Iza can be replicated in many other areas of Colombia (Morales, 2019).

4.5. CASE IV. TRANSITION OF THE COFFEE SECTOR IN COLOMBIA: THE INTRODUCTION OF SPECIALTY COFFEES.

Given the important role of coffee production in Colombia, the development of speciality coffees represents one of the most important recent industrial transitions in the country. This movement emerged in response to the falling coffee prices. The transition resulted in a significant improvement of the social and environmental conditions in the areas of production. This transformation, driven by bottom-up initiatives, introduced new practices and routines (organisational, cultural, technical and normative) in the sector, and as a consequence, reshaped the relations between producers and other actors from the value chain.

4.5.1. FINDING A SUSTAINABLE PATH FOR COFFEE PRODUCTION IN COLOMBIA

The history of coffee production in Colombia has been marked by the relative stability of the commodity export model. The rigidity of policies and institutions during the 20th century contributed to sustain the position of Colombian coffee in the international markets, avoiding the introduction of innovations and alternative organisational forms that could disrupt the stability of the coffee regime.

The governance of the coffee industry has been defined by the Colombian Coffee Growers Federation (FNC) who mostly sets the priorities of the National Coffee Research Centre (Cenicafé). The R&D model of Cenicafé has been oriented mainly around improving the quality of Colombian coffee, increasing its productivity and transferring these research findings to producers.

Since the end of the 1980s, the coffee production regime has received economic, environmental and technical pressures that have forced the Colombian sector to open up to a more transformative innovation policy in the sector. Along with these pressures, the sector has seen a shift in consumer preferences for higher quality and differentiated coffee, attached to growing concerns about environmental and social conditions of production. These factors opened up an opportunity for speciality coffees which shifted the directionality of the sector to a focus on diversification, quality, and sustainability. The concerns about environmental sustainability and social conditions in the value chain traced a development route for producers, who aimed at reducing their poverty conditions and generate responsible production, thus aligning with SDG1 (No poverty), SDG2 (Food and agriculture), SDG3 (Health), SDG4 (Education) and SDG12 (Consumption and production).

On the producer side, coffee farmers organised themselves into local grassroots groups to demand more support from the government and changes in the hierarchical and highly centralised control of the FNC. This movement led to the reorganisation of the federation, which became more inclusive and with a greater willingness to work with other organisations, opening up opportunities for niches with the potential of being transformative.

Regarding policy, the Coffee Mission of 2013 introduced some pressure into the dominant regime to become more inclusive and involve actors from different sectors, partly resulting from the pressure of activists. The mission called for a reorientation of institutional arrangements, from a centralised model to a regional focus with more participation of local actors. Despite the call to reorient regional resources to research and technical assistance, Cenicafé still operates in a centralised and top down manner.

An initiative supporting regional STI policies in Colombia emerged in 2012 with the General System of Royalties (GSR). The GSR was a new STI fund whose projects were aligned with the priorities of regional development. It involved local and regional actors in the process of STI agenda-setting, and supported bottom-up initiatives and experimentation processes. By using the GSR, ten regions funded experiments and new research as well as innovation projects that involved smallholders in building new capacities that were crucial for speciality coffee. The projects also involved the FNC, regional committees and other local actors from outside the FNC. Other programmes included grants for entrepreneurs and women to start up their own business around speciality coffee.

What makes this case transformative is the systemic process of change in the direction of a more sustainable set of practices for the production of speciality coffees. The options created by these coffees led to a need for a partial upgrade in practices, technologies and knowledge in the coffee sector, and fostered a broad range of capabilities of smallholders. The production of value-added coffees required building up the knowledge of farmers around coffee attributes, experimentation, environmentally friendly production practices and export management. As a result, a greater empowerment of smallholders and a sense of ownership took place due to a redefinition of the interaction with their crops.

An element of transition in this case is the empowerment of bottom-up organisations and other actors in the value chain

(NGOs and women's groups), as well as the formation of horizontal networks amongst different actors in the sector that sidestepped dominant core agencies including the FNC. Smallholders capitalised collective action through associative organisations due to certification requirements and the necessity of a certain volume of production.

The initiative of speciality coffees generated several transformative changes. This case revealed changes in the production model that required different production processes and attention to agricultural and processing practices. There has also been a shift from a model of individual or family-based production to a model of associative production which embraced principles of social capital.

In terms of new competencies and cultural change, farmers not only acquired new technical knowledge and skills but also changed their perceptions about coffee and their willingness to experiment with their practices in order to improve its quality. To support this training process and to provide technical assistance there were coffee companies, exporters and certifiers. However, STI policy played a very small role in this important transition process. According to Arond et al., (2017), there have not been significant polices particularly directed to the development of speciality coffees. The main research projects and programmes explicitly oriented toward speciality coffee have arisen in the context of the GSR.

The potential of speciality coffees to become a niche and disrupt the coffee regime is not fully exploited because of the limited support provided to smallholders in areas related to the development, technical training and social sustainability. In general, instruments and policies oriented to these actors are limited in scope, and often smallholders are seen as passive beneficiaries instead of active innovation agents within the STI system.

4.6. CONCLUSION: POLICY EFFORTS TO SUPPORT DIRECTIONS TOWARDS SOCIO-TECHNICAL TRANSITIONS

From the cases presented in this chapter two key lessons and recommendations for transformative innovation policy can be drawn:

1. Promoting co-production of knowledge between a wide range of actors helps to close the gap between demand and supply of knowledge

The experiences show how important it is for the STI system to constantly promote interdisciplinary dialogues between natural sciences and social sciences as well as to open up spaces for co-production of knowledge amongst scholars, local and regional authorities, civil society, grassroots organisations and economic sectors. In addition to their own knowledge, the scientific community and STI policy makers need to mobilise other types of knowledge systems, values, demands and expectations from actors like farmers, social movements, and local and indigenous communities. These groups of people can contribute with forms of knowledge that are more place-based and that can help to close the gap between social demands and scientific research agendas.

2. Facilitate and support networks capable of developing and expanding transformative niches, especially at regional level.

Alliances between local movements and other forms of civil society action are important in areas where scientific knowledge needs to interact with other knowledge, share visions and ally with each other to alter research agendas, as happened in the experience of place-based social movements in Bogotá. Supporting a platform that brings together a vast variety of actors provides a space of collaborative work for residents, academics, students, lawyers and other specialists located in the vicinity of the local wetlands to resist anti-ecological practices and to re-frame the concept of socio-ecological systems.

4.7. METHODOLOGY (APPENDIX)

This section describes the methodology used for the analysis of the case studies in this report. The task of the analyst is to identify non-conventional ways of framing problems in a transformative context and how this could serve as a basis to build narratives and formulate key messages regarding pathways with alternative direction and patterns of transformative change.

4.7.1. ASSUMPTIONS

These case studies are based on transition theory. The objective here is to draw upon activities and/or framing of actions that open up the STI system to support transformations through the creation and reinforcement of transformative niches. Niches represent protected spaces where actors can experiment with different technologies, think about new innovation alternatives, make visible other proposals and listen to a diversity of perspectives regarding changes in socio-technical systems towards social and environmental sustainability. The cases we study were also based on interdisciplinary work in terms of research, and collaboration with civil society and local communities.

We assumed that different knowledge systems and views exist and that the co-production of knowledge with the participation of academic actors, civil society, public sector and private sector as well as the inclusion of historically marginalised communities (e.g. ethnic communities, farmers, women, youngsters) is important to promote transformative innovation. We also consider it necessary to include deliberative processes and controversies when building alternative frames. Different motivations and experiences coming from different agents representing different sectors of society can converge towards new pathways of sustainability.

4.7.2. METHODS FOR SELECTION OF CASE STUDIES AND INFORMATION COLLECTION

We identified projects, programmes and other initiatives that addressed the SDGs in Colombia highlighting, for example, the grand challenge of Peace, Justice and strong institutions (SDG 16). Some of these initiatives may have not been particularly visible within the STI system. Therefore, we explored social media (e.g. blogs, short videos, Twitter, Facebook, websites, etc.) in which participants of these community-based and grassroots initiatives were trying to garner further support and visibility. Subsequently, we conducted semi-structured interviews with the promoters, leaders and supporters of the two selected initiatives and looked for the potential of these projects to generate transformative change.

1) Description of alternative narratives of innovation

A critical element of the methodology, and what makes the cases transformative, is the identification and specification of fundamentally new approaches to problems (in normative terms, for example a democratisation of existing practices) or in terms of more socially or environmentally friendly ways of doing things. Against this background, we identified and described new narratives and new practices by showing the change of conditions, new thinking and participation of new agents and networks. We also identified the emergence of innovation policies that might result in alternative trajectories of sustainable and inclusive development and might impact or have the potential for destabilising current socio-technical regimes.

The following key topics guided the building of narratives and the formulation of questions during semi-structured interviews:

- Alignment with SDG goals: how this initiative is aligned with the SDG goals?
- Directionality and goals: is there directionality in the initiatives (e.g. equity and sustainability)? How was directionality defined?
- Inclusive patterns: what type of actors involved these initiatives? Are there grassroots organisations involved?
- Localisation: do local elements of space and place shape the emergence and consolidation of these initiatives? How?
- Linkages with the national STI: how do participants share knowledge with actors from the national and regional STI system? Does the STI system support this initiative? How technologies and innovations are generated in this programme/strategy? How are the concerns of the different groups (e.g. local communities, social organisations, etc) incorporated in interdisciplinary projects and materialised in technologies and practices (standards, routines)? How is the STI aligned with these concerns?
- Type and diversity of actors: who is involved and how diverse are the actors involved? What is the role of the traditional and scientific STI community, if any? Do actors experiment? How do experiments are defined?
- Changes in socio-technical systems: is the initiative generating changes in socio-technical systems (technological changes, changes in practices, policies, cultural meaning, values, standards, governance arrangements, industrial networks, infrastructure)? Does the initiative target system change?
- Leading approaches: what is the approach leading the initiative (e.g. bottom-up or top down)? who leads the initiative? how are resources mobilised? What types of activities are carried out?
- Challenges: who challenges the existing practices?
- Type of second order learning: how have knowledge generation and learning underpinned the emergence of these initiatives?
- Tensions and consensus: around what topics/areas are tensions and consensus/conflict?
- Legitimisation: how is it possible to make visible and legitimise initiatives with transformative potential in the STI system? Who legitimises these initiatives?
- Policy change: Have any policies supported, shielded, legitimised new initiative? if so, how has this been done?

2) Evaluation of transformative potential of initiatives

Based on the previous criteria, we drew conclusions about the extent to which an initiative has generated transformative change and its potential to constitute niches. We evaluated the presence of the following factors:

- Particular ways of understanding the meaning of innovation and the consideration of specific knowledge systems (not considered within the formal boundaries of the STI system)
- Existing opportunities for inclusive and sustainable pathways in which an initiative transforms lives and benefits local communities.
- Changes in second order learning and access to new skills and training opportunities.

- Changes in people's expectations, perceptions and commitments.
- Alteration of practices, norms and routines as well as development of local innovations.
- Building of horizontal networks and new collective relationships between actors.
- Participation of civil society or end-users in experimentation, research and technology development and consideration of these actors as innovation agents.
- Inclusion of transformative aspects of development agendas at national, regional, departmental, municipal and local level.
- Shift in policy thinking with the potential of developing a transformative innovation policy.

5. CONCLUSION: PROPOSAL FOR A NATIONAL PROGRAMME OF EXPERIMENTATION WITH A STRONG REGIONAL FOCUS

Colombia has been very active in the process of developing and adopting the United Nations 2030 Agenda and its seventeen Sustainable Development Goals (SDGs). These goals summarise the major economic, social and environmental challenges for Colombia and the world. To successfully address the SDGs, these should not be understood as individual targets or missions. Interactions and trade-offs between them are crucially important, for example between water, energy and food missions. Yet beyond the complexities of these interactions it is important not to lose sight of the deeper transformative ambition that these SDGs represent. SDG policy should focus on the underlying deeper transformational changes needed across all socio-technical systems in society, ranging from healthcare, food, energy, mobility, water and agriculture to education. The transformation of these systems involves technologies, knowledge, regulation, user preferences and cultural elements.

Science, technology and innovation (STI) policy can be a game changer for realising transformations, precisely because they are cross cutting various individual SDGs, as well offering a window for working on innovative and disruptive solutions. To play this role STI policy needs to put the SDGs at the heart of its activities. It integrates the concern for economic growth and competitiveness into a broader transformative frame.

In this report we have sought to articulate and define important knowledge clusters that can contribute to major transformations in socio-technical systems. In our analysis we advance a new bibliometric methodology that can identify such clusters[28]. For this methodology we have made a distinction between three types of SDGs: 1) SDGs that relate to socio-technical system areas such as healthcare, energy, food; 2) SDGs that relate to directionalities which should drive system change such as reduced inequality, poverty, climate change action, and 3) SDGs which relate to the participatory process and governance structures needed for transformative change (see figure 2).

Based on the bibliometric analysis we have identified twelve knowledge clusters (see table 2) that can contribute to a STI policy aimed at addressing SDGs. These twelve clusters can be further clustered in four key areas

1. Health, linking it to education, well-being, inequality, human rights;
2. Education, linking it to poverty and inequality, health, peace;
3. Climate Change in connection with conservation, agriculture and inequality
4. Food security in relation to climate change, agriculture and water management.

These areas can contribute to the work of the emblematic missions proposed by the Mision de Sabios clustered around three key challenges: Colombia Bio, Productive Colombia and Equity Colombia.

To realise missions and address the three key challenges knowledge production is not sufficient. Bottom-up implementation of missions is important to produce transformations that are better suited to the different regional contexts in Colombia. Scientific knowledge and capabilities are highly relevant for addressing challenges and SDGs, but we suggest they need to be integrated with local knowledge, actors and necessities to have maximum impact. Therefore, we propose to complement the mission-oriented approach with bottom-up principles from transformative innovation. This can be done by implementing the missions through experimentation (pilot projects at the local level) and nurture and evaluate these experiments as seedbeds for transformation. The experiments could be cases discussed in chapter 4, led by civil society, and small producers, as well as more high-tech projects led by business, and for example focused on digital transformation. For transformations to take place, it is important for individual projects to become connected and coordinated across regions. The new STI Ministry should take responsibility for making connections between various projects (and regions) coordinating various activities, organising learning across missions, and projects, and support training in transformative project management and formative evaluation on transformation. This can be done by creating a national programme of experimentation with a strong regional focus. Here the STI Ministry can work with several universities in Colombia who have begun to explore transformative innovation principles and with the Transformative Innovation Policy Consortium, of which Colombia is a member.

[28]Following a new method developed by Ramirez, M., Romero, O., Schot, J., & Arroyave, F. (2019). Mobilizing the Transformative Power of the Research System for Achieving the Sustainable Development Goals. SPRU Working Paper Serie.

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