

FRCCS 2024

Proceedings

French Regional
Conference on
Complex Systems

Montpellier, France
29-31 May

A methodological approach to map complex research systems to the Sustainable Development Goals: Analysis of CIRAD publications

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Abstract. This study proposes a methodology for mapping complex research systems to the Sustainable Development Goals (SDGs) using publications as an indicator of research activity. The approach is applied to analyse the research focus of CIRAD, a French agricultural research organisation, by mapping its publications to the SDGs. The article highlights the challenges associated with mapping publications to the SDGs, including the complexity of research systems, ambiguity in classifying the SDGs and data availability. The methodology uses advanced search functionalities and data extraction techniques from Agritrop databases, followed by visualisation tools such as Gephi to explore publication trends, collaboration networks and thematic priorities. The analysis reveals that CIRAD's research is aligned with several SDGs, with a primary focus on food security and nutrition (SDG 2), sustainable agriculture and rural development (SDGs 1 and 8), biodiversity conservation and environmental sustainability (SDGs 13 and 15) and gender equality and women's empowerment (SDG 5). This research offers valuable insights into the potential of mapping publications to understand the contribution of research institutions to the SDGs and guide evidence-based decision-making aligned with sustainable development.

Keywords: Sustainable Development Goals, Complex Research Systems, CIRAD.

1 Introduction

The United Nations' 2030 Agenda for Sustainable Development established 17 Sustainable Development Goals (SDGs) as a shared framework for tackling the biggest global

challenges. Achieving these ambitious SDGs requires mobilising and aligning complex social systems such as agriculture, energy, transport, and health. Research organisations play a significant role in generating knowledge, technologies and evidence-based solutions that can accelerate sustainable development. Assessing the orientation of large, decentralised research systems towards the SDGs remains a methodological challenge.

One approach is to use academic publications as tangible outputs that provide indicators of the focus and priorities of research institutions. Mapping scientific publications around themes associated with the SDGs provides a consistent basis for assessing how research activity aligns with the SDG framework. It also makes it possible to understand interconnections between the goals based on co-occurrences in publication mappings. Comparative analysis can also reveal variations in the focus of the SDGs between departments within the same institution. In this way, mapping research publications for the SDGs contributes to presenting guidelines and networks embedded within complex research systems.

This study presents a methodology for mapping research publications to the SDGs using the institutional repository of CIRAD, a French agricultural research organisation. The network analysis visually represents the connections between the SDGs based on CIRAD's publication mappings. A comparative analysis highlights the differences in emphasis on various SDGs between CIRAD departments. The methodology consists of a universally applicable approach to systematically track, assess, and strengthen the orientation of complex systems of research organisations towards the SDGs. Mapping scientific publications around the SDGs provides valuable insights into the structure and focus of multifaceted research activities. The technique can thus instrumentalise institutions in assessing their alignment with the sustainability goals and guiding their research activities.

2 CIRAD's contribution to the SDGs

By providing scientific and practical solutions to improve agricultural production and the management of natural resources, agronomic research is essential to address the interlinked issues of food security, environmental sustainability, and rural development, thus contributing significantly to the achievement of the United Nations Sustainable Development Goals. World Bank (2020).

CIRAD's contribution to the Sustainable Development Goals (SDGs) stands out, as it allows us to understand and evaluate the impact of its research and development activities at the international level. The SDGs provide a global framework for overcoming the world's most pressing obstacles, from eradicating poverty to protecting the environment and promoting gender equality.

2.1 The importance of agronomic research for sustainable development

Understanding agricultural systems and their interaction with the environment contributes to ensuring long-term sustainable food production and the well-being of local com-

munities. Agronomic research plays a strategic role in promoting sustainable development by addressing the main barriers related to food production, natural resource management and climate change mitigation.

Agronomic research focuses not only on increasing crop yields, but also on improving resource efficiency, reducing the use of pesticides, and promoting environmentally friendly agricultural practices. According to Kell et al (2009), agronomic research provides innovative solutions to increase the resilience of agricultural systems to climate and environmental issues.

With an active role in the fight against hunger and malnutrition around the world, agronomic research, according to the FAO (2021), has worked to ensure the food and nutritional security of the world's population by helping to improve agricultural productivity and access to quality food. Agronomic research contributes to the development of more nutritious and disease-resistant crops, as well as promoting agricultural practices that increase food availability in vulnerable areas.

Strategic in tackling the interrelated barriers of food security, environmental sustainability and rural development, agronomic research, by providing scientific and practical solutions to improve agricultural production and natural resource management, contributes significantly to achieving the United Nations Sustainable Development Goals.

The use of techniques to visualise CIRAD's contribution to the SDGs makes it possible to identify areas of competence and opportunities to improve research investments. According to Gunning et al (2020), mapping the contribution of research institutions to achieving the SDGs makes it possible to ensure effective strategic planning and to understand and evaluate the consequences of their research activities for the SDGs.

Using techniques to visualise CIRAD's contribution to the SDGs helps raise awareness among key stakeholders, such as policymakers, donors, and civil society, of the importance of investing in agricultural research and rural development. According to Rastoin and Chiffoleau (2016), data visualisation is a powerful tool for communicating the effectiveness of research activities in achieving the SDGs and mobilising public policies and financial support.

By visualising CIRAD's contribution to the SDGs, transparency, social responsibility and the effectiveness of its research and development activities can be improved. By providing a clear and accessible representation of the results of CIRAD's contribution to the implementation of the SDGs, greater collaboration, coordination, and funding can be promoted to tackle the problems associated with sustainable development worldwide.

2.2 Mapping publications by SDGs

Mapping publications for the Sustainable Development Goals (SDGs) presents a multifaceted challenge due to the inherent complexity of research systems and the broad scope of the SDGs themselves (Sachs, et al, 2019). In the context of analysing CIRAD's publications, several difficulties arise and must be addressed to ensure an accurate and meaningful mapping, Table 1, where we can highlight:

Table 1. Challenges in mapping SDG publications

Complexity and Interconnection of Research Systems	One of the main problems in mapping publications to the SDGs lies in the complexity and interconnectedness of research systems. Research often addresses multiple aspects of sustainable development simultaneously, making it difficult to categorise publications into distinct SDGs. For example, a study on agricultural practices can contribute to several SDGs, including zero hunger, sustainable agriculture, and climate action. Thus, determining the most relevant SDGs for a specific publication requires careful consideration of their various dimensions and outcomes.
Ambiguity and Subjectivity in the Classification of the SDGs	Categorising publications according to the SDGs can be subjective and open to interpretation. While some publications may clearly align with specific objectives, others may address multiple objectives or fall into a grey area where their relevance to the SDGs is less obvious. This ambiguity complicates the mapping process and can lead to inconsistencies in the classification, especially when different analysts assess the same publication. Standardising criteria for classifying the SDGs and providing clear guidelines can help mitigate this impasse.
Granularity and Details of Level	The SDGs cover a wide range of topics, from broad thematic areas to specific targets and indicators. Mapping publications to the SDGs requires finding a balance between granularity and comprehensiveness. At an important level, publications can align with general objectives such as poverty eradication or gender equality. However, to provide meaningful insights, it is often necessary to delve deeper into the targets and indicators associated with each goal. This level of detail increases the complexity of the mapping process and may require substantial resources and expertise.
Evolutionary nature of the SDGs	The SDGs are dynamic and subject to revision as global impasses and priorities evolve. New targets and indicators may be added, and existing ones may be modified to reflect emerging issues and knowledge gaps. As a result, mapping publications to the SDGs requires keeping up to date with changes in the SDG framework and ensuring that mapping methodologies remain relevant and adaptable over time. Continuous monitoring and refinement of mapping approaches are essential to

	capture the evolving relationship between research outputs and sustainable development priorities.
Data Availability and Quality	Effective mapping of publications to the SDGs depends on access to comprehensive and reliable data. However, data availability can vary between different research domains and geographical regions, presenting difficulties to the mapping process. In addition, the quality and consistency of data sources can influence the accuracy of SDG classification. Addressing data gaps and improving data quality are critical steps in improving the robustness of mapping methodologies and ensuring the credibility of mapping results.

Mapping publications to the SDGs presents several challenges that need to be overcome in order to facilitate meaningful analyses and decision-making. Dealing with the complexity of research systems, navigating ambiguity in the classification of the SDGs, balancing granularity with comprehensiveness, keeping up to date with evolving SDG frameworks, and ensuring data availability and quality are key considerations in devising methodological approaches to map complex research systems to the SDGs effectively. Despite these adversities, mapping efforts have enormous potential to advance our understanding of the contributions of research to sustainable development and guide public policy and evidence-based practice. World Bank Group (2019).

3 Theoretical Framework

The 17 Sustainable Development Goals (SDGs) were established by the United Nations (UN) in 2015 as a universal call to action to end poverty, protect the planet and ensure prosperity for all by the year 2030. Building on the Millennium Development Goals (MDGs) that preceded them, the SDGs represent a comprehensive and interconnected framework for tackling the world's most pressing issues. United Nations (2015).

Each of the 17 SDGs encompasses specific targets and indicators designed to address key aspects of sustainable development, including economic growth, social inclusion, and environmental sustainability. The goals cover a wide range of issues, from eradicating poverty and hunger to gender equality, climate action, peace, and justice.

3.1 Introduction to the 17 Sustainable Development Goals (SDGs)

The SDGs recognise that sustainable development must be holistic, addressing the interconnections between the social, economic, and environmental dimensions. They emphasise the importance of leaving no one behind, ensuring that progress is inclusive and reaches the most vulnerable and marginalised populations.

Achieving the SDGs requires collaboration and partnership between governments, civil society, the private sector, and other stakeholders at local, national, and global

levels. It requires innovative approaches, transformative policies and integrated solutions that address the root causes of poverty, inequality, and environmental degradation. The 17 SDGs are:



Fig. 1. The 17 SDGs

These goals are interconnected and mutually reinforcing, recognising that progress in one area often depends on progress in others. By addressing these interconnected obstacles in a coordinated way, the SDGs aim to create a more sustainable and equitable world for present and future generations. Le Blanc (2015).

The 17 Sustainable Development Goals represent a global commitment to building a better world for all. They provide a roadmap to address the most pressing issues facing humanity and offer an opportunity to create a future in which prosperity is shared. Achieving the SDGs requires collective action, political will, and a renewed commitment to leaving no-one behind.

3.2 Links between CIRAD's research activities and the SDGs

The Centre for International Cooperation in Agricultural Research for Development (CIRAD) works to tackle global complications related to agriculture, food security and sustainable development. Founded in 1984, CIRAD is at the forefront of carrying out research and promoting innovation to improve livelihoods, promote environmental sustainability and contribute to achieving the Sustainable Development Goals (SDGs) established by the United Nations.

The SDGs provide a comprehensive framework for overcoming the world's most pressing social, economic and environmental issues by 2030. CIRAD's research activities are aligned with several of these goals, reflecting its commitment to promoting sustainable development worldwide, Table 2.

Table 2. CIRAD's research activities and the SDGs

Objective 1 Eradication of Poverty	CIRAD's research focuses on improving agricultural productivity and rural livelihoods, especially in low-income countries. By developing innovative agricultural techniques, promoting inclusive value chains, and supporting small-scale farmers, CIRAD contributes to poverty reduction and economic empowerment among vulnerable communities.
Objective 2 Zero Hunger	CIRAD works to improve food and nutrition security by conducting research into sustainable agriculture, crop diversification and food systems. Through partnerships and capacity-building efforts, CIRAD helps to increase agricultural productivity, increase resilience to climate change and ensure access to food for all.
Objective 3 Health and Well-being	CIRAD's research into agroecology, sustainable livestock management and disease control contributes to improving human health and well-being. By promoting sustainable agricultural practices and reducing the use of pesticides and harmful chemicals, CIRAD helps to mitigate health risks and promote a healthier environment for farming communities.
Goal 5 Gender Equality	CIRAD is committed to promoting gender equality and empowering women in agriculture. Through research projects and training initiatives, CIRAD seeks to address gender disparities in access to resources, decision-making and agricultural productivity, thereby promoting more inclusive and equitable development outcomes.
Goal 13 Climate Action	CIRAD's research into climate-smart agriculture, agroforestry and sustainable land management contributes to climate change mitigation and adaptation. By developing resilient agricultural practices and promoting biodiversity conservation, CIRAD helps build adaptive capacity and reduce the vulnerability of farming communities to climate-related risks.
Objective 15 Terrestrial Life	Through efforts to promote agro-ecological practices and sustainable forest management, CIRAD helps protect and restore ecosystems, thus safeguarding biodiversity and ecosystem services vital to human well-being.

CIRAD's research activities are closely aligned with the Sustainable Development Goals, reflecting its commitment to promoting sustainable agriculture, food security and rural development worldwide. Through its interdisciplinary approach, collaborative partnerships, and innovative solutions, CIRAD contributes to advancing sustainable development and building a more resilient and equitable future for all.

4 Complex systems and the Sustainable Development Goals (SDGs)

Implementing the Sustainable Development Goals (SDGs) requires understanding and addressing the complexities inherent in socio-economic and environmental systems. The conceptualisation of complex systems provides a framework for understanding the interconnectedness, feedback loops and non-linear dynamics that characterise the impediments and opportunities associated with sustainable development. (Pradhan, 2017).

4.1 Conceptualising complex systems in the context of the SDGs

Complex systems theory emphasises the emergence of properties and behaviours at the system level that cannot be fully understood by analysing individual components in isolation. This holistic approach recognises the interdependence and interactions between various elements within a system, such as ecosystems, economies, and societies, and acknowledges their dynamic nature over time.

To formulate effective strategies and public policies to achieve the SDGs, it is necessary to understand the key concepts that underpin the conceptualisation of complex systems in the context of the SDGs. Table 3 summarises the main concepts:

Table 3. Key concepts of complex systems in the context of the SDGs

<p>Systems Thinking: Systems thinking involves examining the relationships and interdependencies between various components of a system to understand how they influence the system's behaviour and outcomes. By adopting a systems perspective, stakeholders can identify leverage points for intervention and design holistic solutions that address interconnected pathways.</p>
<p>Interdisciplinary Approaches: Addressing sustainable development challenges requires the integration of insights from various disciplines, including ecology, economics, sociology, and engineering. Interdisciplinary approaches allow for a more comprehensive understanding of complex systems by considering multiple perspectives and generating innovative solutions that transcend disciplinary boundaries.</p>
<p>Network Theory: Network theory provides a framework for analysing the structure and dynamics of interconnected systems, such as social networks, commercial networks, and ecological networks. By mapping relationships and flows of information, resources, and energy within and between systems, network theory helps to identify key actors, paths of influence and potential points of intervention to promote sustainability.</p>
<p>Resilience Theory: Resilience theory explores the capacity of systems to absorb disturbances, adapt to change and maintain functionality in the face of shocks and stresses. Understanding the resilience of socio-ecological systems is important for</p>

building adaptive capacity, improving sustainability, and promoting long-term resilience in the context of global issues such as climate change, biodiversity loss and social inequality.

Participatory Approaches: Involving stakeholders and local communities in decision-making processes is essential for understanding the complexities of socio-ecological systems, incorporating diverse perspectives, and promoting ownership and legitimacy of sustainable development initiatives. Participatory approaches facilitate the co-creation of knowledge, collaborative resolution of difficulties and empowerment of marginalised groups, thus contributing to more effective and equitable results.

By understanding the conceptualisation of complex systems, stakeholders can navigate the uncertainties and complexities inherent in sustainable development, promote synergies between the SDGs and advance transformative change towards a more equitable, resilient, and sustainable future (We-ber et al, 2021).

4.2 Interrelationships and interactions between the different SDGs

The Sustainable Development Goals (SDGs) represent a holistic framework, i.e., they address various dimensions of sustainable development in a comprehensive and integrated manner, Table 4, taking into account their environmental, social, economic, and institutional aspects in an interconnected way, implying:

Table 4 - Holistic framework of the SDGs

Multidimensional Approach: The 17 SDGs cover a wide range of critical issues, from poverty eradication, food security, health, education, gender equality, to natural resource management, climate action, peace, and justice.

Interconnectedness and indivisibility: The SDGs recognise that the challenges of sustainable development are intrinsically interconnected and indivisible. Progress in one area is linked to progress in others.

Balancing the Three Dimensions: These seek to balance the environmental, social, and economic dimensions of sustainable development in an integrated and mutually reinforcing way.

Universal Application: The SDGs are applicable to all countries, rich and poor, requiring national efforts and global co-operation.

Systemic Approach: Addresses challenges holistically, considering their root causes, interrelationships and impacts on multiple sectors and actors.

Inclusive Participation: Involves a wide range of stakeholders, including governments, civil society, the private sector, and local communities

The holistic framework of the SDGs, designed to address interconnected global issues, recognises the complexity and multiple facets of development challenges, promoting an integrated and comprehensive approach to achieving truly sustainable development in all its dimensions. (Soleimani et al, 2020). Interrelationships and interactions between the different Sustainable Development Goals (SDGs) are inherently influenced by the concept of complex systems where it becomes necessary to understand their interrelationships, Table 5, for the effective implementation and achievement of the sustainable development goals.

Table 5 - Interrelations and Interactions between ODs

Synergies: Many SDGs have synergistic relationships, where progress on one goal positively influences progress on others. For example, investing in education (SDG 4) not only contributes to the eradication of poverty (SDG 1), but also promotes gender equality (SDG 5) and improves economic growth (SDG 8). Recognising and taking advantage of these synergies can broaden the scope of interventions and accelerate progress towards multiple goals simultaneously.

Trade-offs: The pursuit of certain SDGs can lead to trade-offs or unintended consequences for other goals. For example, promoting economic growth (SDG 8) through industrialisation and infrastructure development can lead to increased carbon emissions and environmental degradation, undermining efforts to combat climate change (SDG 13) and protect biodiversity (SDG 15). Understanding and managing these trade-offs is important to ensure sustainable development outcomes and avoid negative consequences in interconnected systems.

Complex feedback loops: Interactions between SDGs can give rise to complex feedback loops, where changes in one goal trigger cascading effects in several goals and systems. For example, investments in renewable energy (SDG 7) can reduce greenhouse gas emissions (SDG 13), mitigating the effects of climate change and promoting environmental sustainability. This, in turn, can improve agricultural productivity (SDG 2) and food security (SDG 3), contributing to poverty reduction (SDG 1) and better health outcomes (SDG 3). Recognising these feedback loops is essential to designing holistic and integrated strategies that address interconnected contingencies effectively.

Context Dependence: The interrelationships between the SDGs can vary depending on contextual factors such as geography, socio-economic conditions, and governance structures. What constitutes a synergistic or conflicting relationship between goals in one context may differ in another. Therefore, contextual analyses and localised approaches are key to adapting interventions to specific circumstances and maximising positive synergies while minimising trade-offs.

Policy Integration: Given the complex interdependencies between the SDGs, integrated policy approaches that consider multiple goals simultaneously are relevant.

Isolated approaches that focus on individual goals in isolation are insufficient to address the interconnected nature of sustainable development pathways. Instead, policymakers need to adopt intersectoral and multisectoral strategies that promote coherence, coordination, and alignment across different policy domains.

By recognising and embracing the interrelationships and interactions between the SDGs in the context of complex systems, stakeholders can promote synergies, manage trade-offs, and design integrated strategies that move effectively and holistically towards the sustainable development goals.

5 Methodological approaches to addressing complex systems in SDG-related research

The research methodology offers a systematic and interdisciplinary approach to understanding and addressing complex systems in SDG-related research, thus contributing to the advancement of sustainable development goals and the promotion of global prosperity, equity, and environmental preservation.

The use of advanced search functionalities and data extraction techniques enables the identification and collection of relevant information from Agritrop databases, facilitating the accurate analysis of research trends, collaboration networks and thematic priorities within the SDG research domain. (Valdano et al, 2019).

The use of advanced visualisation tools, such as Cosma, Gephi, Cytoscape and Tableau, allows researchers to transform complex data sets into visually informative representations. These visualisations offer a clear and intuitive way to explore relationships, patterns, and trends within SDG-related scientific networks, facilitating the identification of key players, research clusters and emerging topics.

Through network analysis algorithms and advanced mapping methods, hidden insights can be identified, and the dynamics of scientific collaboration and knowledge exchange within the SDG research area can be understood. Centre for Complex Systems Modelling. (2018).

The clear and informative visual representations generated by this methodology empower stakeholders, policymakers, and funding agencies to make decisions underpinned by research priorities, resource allocation and intervention strategies related to the SDGs. By providing actionable insights derived from data-driven analyses, this methodology supports evidence-based decision-making processes aimed at promoting sustainable development agendas. United Nations Sustainable Development Solutions Network. (2019).

The methodology uses advanced search functionalities and data extraction techniques from Agritrop databases, followed by visualisation tools such as Gephi to explore publication trends, collaboration networks and thematic priorities.

5.1 Data Collection: Agritrop

In Data Collection, we utilised the Agritrop website (<https://agritrop.cirad.fr>) which provides access to a rich source of data covering various aspects of agricultural research and development.

This comprehensive dataset from the Agrotrop database allows us to explore SDG-related issues in depth, providing a holistic understanding of the interconnectedness of the Sustainable Development Goals. Using the Agritrop website as a comprehensive source of data related to our research we have processed and prepared the data to perform our network analyses.

In extracting the information from the Agritrop databases, we included the publications, organized by each Sustainable Development Goal (SDG). Using search and export functionalities of the data in Zorero, Reference manager (RIS) format, we retrieved datasets for all 17 Sustainable Development Goals (SDGs).

By creating a dashboard of the publications, we separated specific data based on keywords, abstracts, publication dates, authors and thematic areas aligned with the SDGs from the publications and keywords into an excel sheet. We have made a treatment to the keywords of lowercase transformation of all words, deletion of all spaces to establish the relationship between the keywords and the 17 Sustainable Development Goals (SDGs).

From this excel file we have processed the 45779 keywords to eliminate the repeated words and to be able to elaborate a table of unique keywords (5638). From these two excel tables we created the nodes table and the links table to perform our network analysis with the Gephi software.

This comprehensive dataset allows for an in-depth exploration of topics relevant to the SDGs, providing a holistic understanding of the interconnection of agricultural systems with the sustainable development goals. Data collection was carried out according to the methodological procedures presented in Table 6:

Table 6 - Data Collection Methodology

Database: the Agritrop website as a source of data related to agricultural research and development https://agritrop.cirad.fr/recherches_odd.html
Relevant information was extracted from Agritrop's databases, including publications, projects, and partnerships, focusing on topics relevant to the Sustainable Development Goals (SDGs).
Advanced search functionalities were applied in order to filter and retrieve specific data sets based on keywords, auto-res, publication dates and thematic areas aligned with the SDGs.
The integrity and quality of the data was guaranteed by cross-referencing information from Agritrop with other reliable sources and conducting data validation procedures.
Excel (dynamic graphics) was used for statistical analyses.

5.2 Visualisation and mapping methods and tools

The methodological procedure used visualisation techniques to represent and analyse the complex scientific networks related to the SDGs, derived from the data collected from Agritrop.

To visualise the relationships between researchers, institutions, and publications within the SDG research domain, we used the Gephi platform. Network analysis algorithms were used to identify key players, influential research topics and collaboration patterns within the SDG scientific community.

Implemented the integration of Gephi and gexf.js to enhance visualisation capabilities and generate interactive and dynamic visualisations of scientific networks related to the SDGs. Advanced mapping methods were used to geographically visualise the distribution of research activities, funding sources and impact metrics related to the SDGs in different regions and countries.

Social network analysis (SNA) (Avila-Toscano, 2018) has been used as a methodology to visualise the data. SNA uses networks and graph theory (Andrienko et al., 2020; Otte; Rousseau, 2002). The software used to create these visualisations was Gephi (Bastian; Heymann; Jacomy, 2009): <https://gephi.org>.

Gephi is a program for visualising, exploring, and understanding all types of graphs and networks (Cherven, 2015). It is free and is based on ARS. The spatialisation algorithms used were Atlas Force 2 and Atlas 2-3D. It was combined with a visualiser that allows graphics made with Gephi to be exported to the web, called gexf.js (Velt, 2011), which is available on Github: <https://github.com/raphv/gexf-js>.

The final visualisation is displayed as an interactive map, which can be manipulated by the user to analyse the results by applying different integrated filtering strategies.

6 Results and Discussion

CIRAD's research activities are closely aligned with the Sustainable Development Goals, addressing various dimensions of sustainable agriculture, rural development, environmental conservation, gender equality and technological innovation,

Table 6. CIRAD Research Activities and the SDGs

Food and Nutrition Security (SDG 2)	One of CIRAD's main areas of research revolves around increasing food and nutrition security, particularly in regions facing complications such as poverty, climate change and resource scarcity. Through innovative agricultural practices, crop diversification and sustainable farming techniques, CIRAD aims to improve agricultural productivity and guarantee access to nutritious food for all, thus contributing to SDG 2 - Zero Hunger.
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Sustainable Agriculture and Rural Development (SDG 1, 8)	CIRAD emphasises sustainable agricultural practices and rural development strategies to alleviate poverty (SDG 1) and promote inclusive economic growth (SDG 8) in rural communities. By empowering small-holder farmers, promoting value chains and fostering entrepreneurship, CIRAD strives to create resilient and prosperous rural economies.
Biodiversity Conservation and Environmental Sustainability (SDG 15, 13)	Biodiversity conservation and the preservation of natural ecosystems are integral components of CIRAD's research agenda. By studying agro-ecological systems, promoting agro-forestry, and advocating sustainable land management practices, CIRAD contributes to SDG 15 - Life on Land and SDG 13 - Climate Action, aiming to mitigate climate change and protect terrestrial ecosystems.
Gender Equality and Women's Empowerment (SDG 5)	CIRAD recognises the importance of gender equality and women's empowerment in agricultural development. Through gender-sensitive research initiatives, capacity-building programs, and inclusive policy interventions, CIRAD works to achieve SDG 5 - Gender Equality, ensuring equal opportunities for women in agriculture and rural livelihoods.
Innovation and Technology Transfer (SDG 9)	Promoting innovation and technology transfer is a key focus area for CIRAD to increase agricultural productivity, efficiency, and resilience. By facilitating the exchange of knowledge, fostering partnerships, and harnessing digital technologies, CIRAD contributes to SDG 9 - Industry, Innovation, and Infrastructure, boosting sustainable development through technological advancement.

By leveraging its expertise and partnerships, CIRAD continues to play a relevant role in advancing the global agenda for sustainable development and contributing to positive transformative change around the world.

6.1 Quantitative analysis of the distribution of publications by SDGs

Agritrop is a bibliographic database developed by the French agricultural research and education organization CIRAD (Centre de recherche agronomique pour le développement). It contains more than 1.5 million references covering a wide range of topics related to tropical and Mediterranean agriculture.

Table 7. Number of Publications per Sustainable Development Goal

SDGs	N° Publication	Unique Keywords	Keywords-Total
GOAL 1	87	399	1043

GOAL 2	367	865	3893
GOAL 3	307	1078	3332
GOAL 4	40	17	230
GOAL 5	125	47	1008
GOAL 6	54	26	434
GOAL 7	240	58	1833
GOAL 8	63	23	642
GOAL 9	57	16	553
GOAL 10	53	25	405
GOAL 11	386	70	2915
GOAL 12	293	66	2160
GOAL 13	2191	2796	17261
GOAL 14	42	22	399
GOAL 15	938	110	8941
GOAL 16	21	9	165
GOAL 17	43	11	565
Total	5307	5638	45779

Agritrop plays a crucial role in supporting research and knowledge dissemination aligned with the SDGs. The database's vast collection of references on various aspects of agriculture, food security, and rural development contributes to addressing critical challenges and promoting sustainable solutions.

The survey results provide an overview of CIRAD's main research areas related to the SDGs, highlighting the organisation's commitment to promoting agricultural sustainability, food security and socio-economic development in regions around the world, Table 7, Table 8, Figure 2, and Figure 3.

It can be seen that Goal 13 Climate Action and Goal 15 Life on Land, 2,191 and 938 respectively, represent 79% of CIRAD's publications in relation to the SDGs. Goal 16 Peace, Justice and Strong Institutions and Goal 17 Partnerships for the Goals have the lowest number of publications, with 21 and 43, respectively.

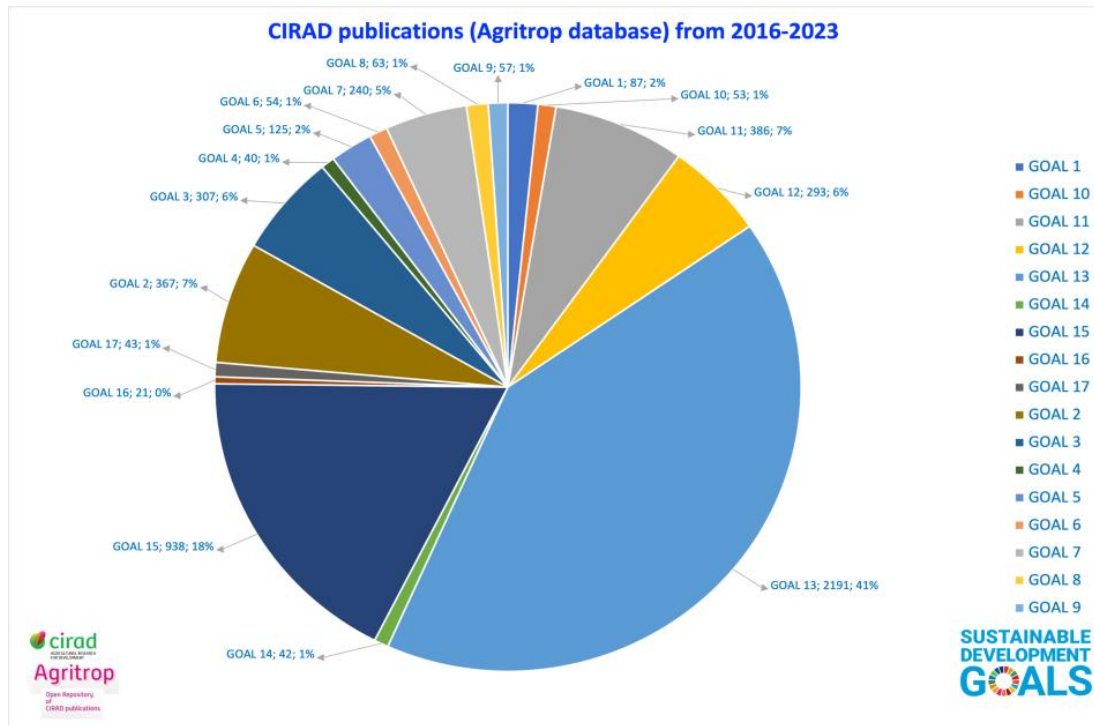


Fig. 2. CIRADS publications distribution for Goal

Table 8. CIRAD Publications Keyword Cloud

Word	TF-IDF	Weight
changement climatique	0.019	855
biodiversité	0.016	752
sécurité alimentaire	0.014	619
France	0.012	549
adaptation aux changements climatique	0.009	438
impact sur l'environnement	0.008	353
utilisation des terrer	0.007	327
gestion des ressources naturel	0.007	326
politique de développement	0.007	307
développement durable	0.007	299
forêt tropical	0.006	267
Brésil	0.006	255
services écosystémique	0.005	250
système de culture	0.005	242
agroécologie	0.005	241

Table 7. Distribution of CIRAD Publications

Number of Publications	5307
Number of total keywords	45779
Number of unique keywords	4487
Number of nodes	9812
Number edges	45598
Densidad	0,001
Centralidad de Eigenvector	0,1062
Modularidad	0,459

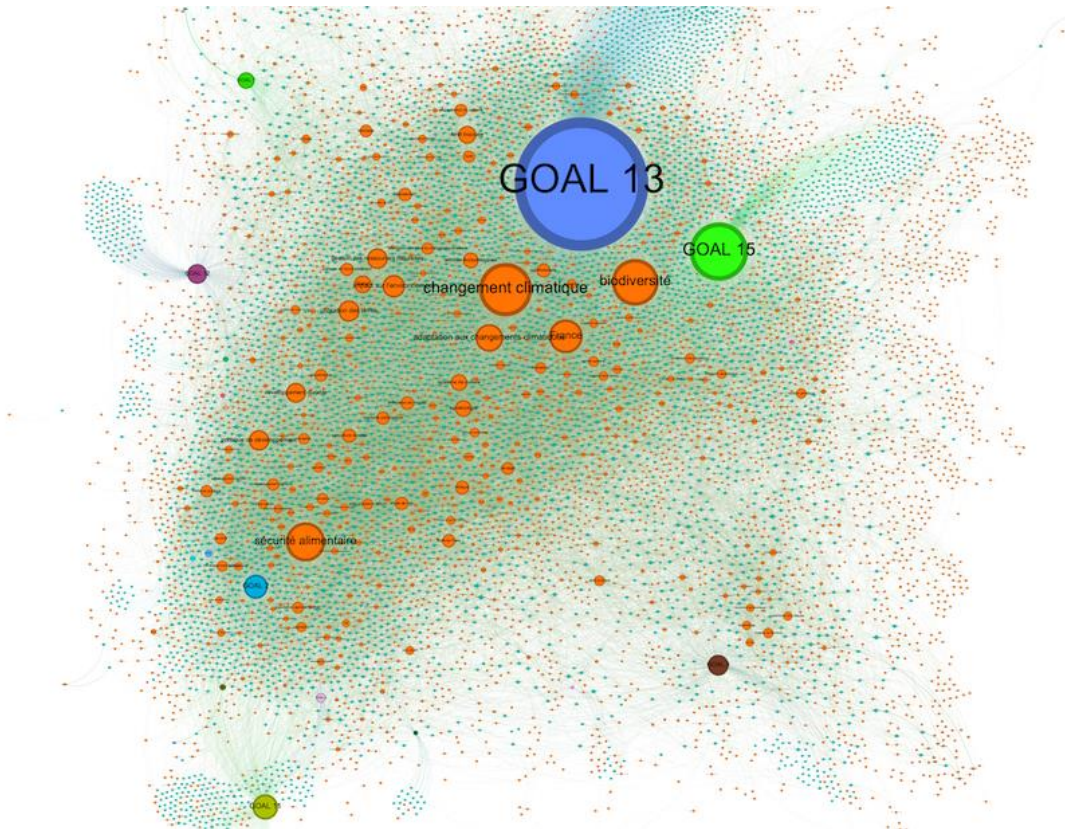


Fig. 4. Mapping of Cirad (Agritrop) publications 2016-2023. Interact Version : <https://metroteach.com/SDG/index.html>

Network Properties:

- Number of nodes: 9812
- Number of links: 48580
- Density: 0.001 (very sparsely connected)
- Eigenvector Centrality: 0.1062 (high value)
- Modularity: 0.459 (high modularity)

Interpretation of Properties:

- The extremely low density indicates that the network is extremely sparsely connected, meaning most nodes are not directly connected to each other.
- The high Eigenvector Centrality value suggests that influence is concentrated on a small number of key nodes.
- The high modularity indicates that the network is divided into distinct groups (modules) with stronger links within modules than between them. Fig. 6 and Fig. 7

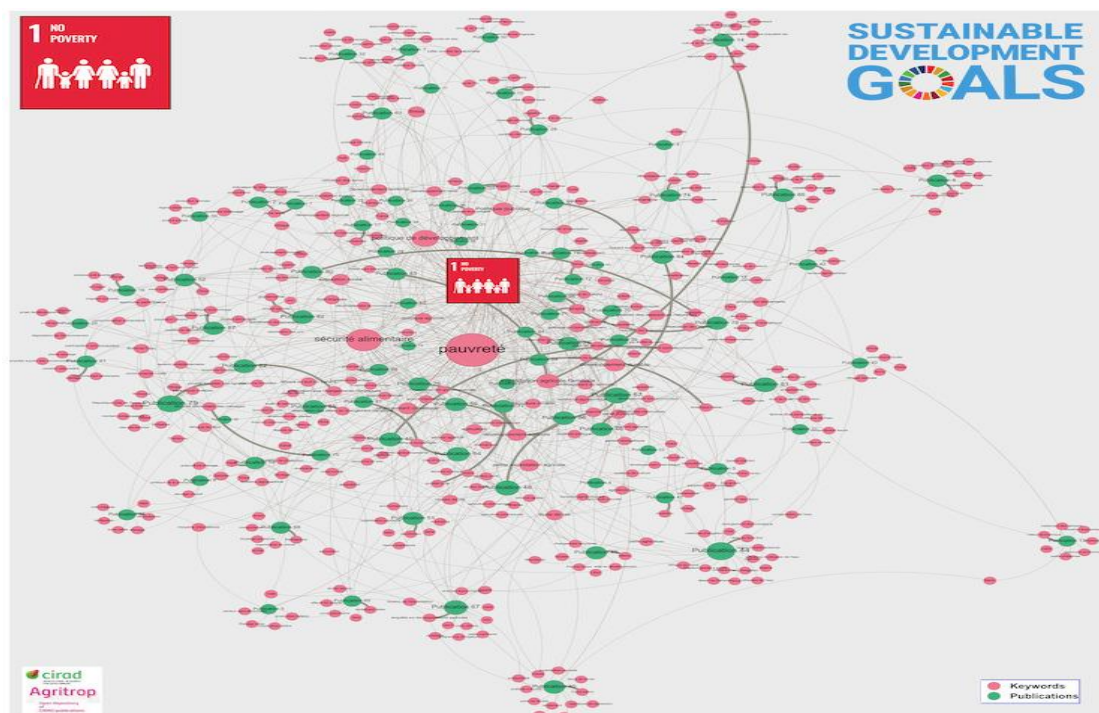


Fig. 5. Goal 1 - interactive tool allows you to explore CIRAD publications (<http://metroteach.com/SDG/index.html>)

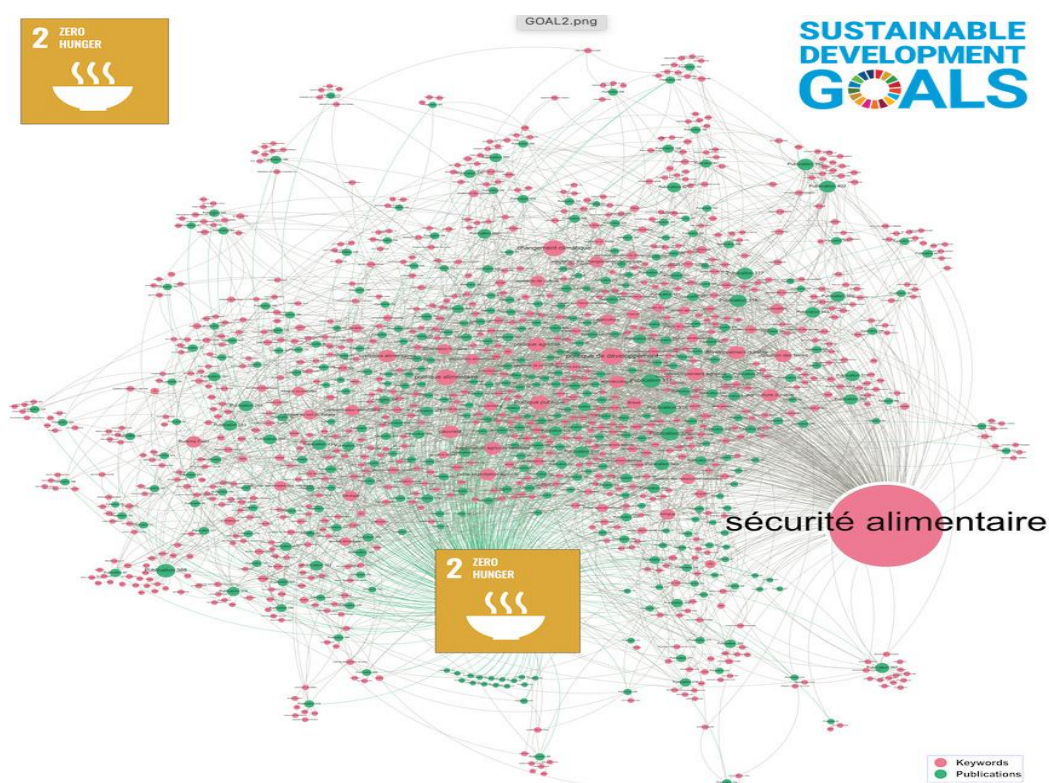


Fig. 6. Goal 2 - interactive tool allows you to explore CIRAD publications (<http://metroteach.com/SDG/index.html>)

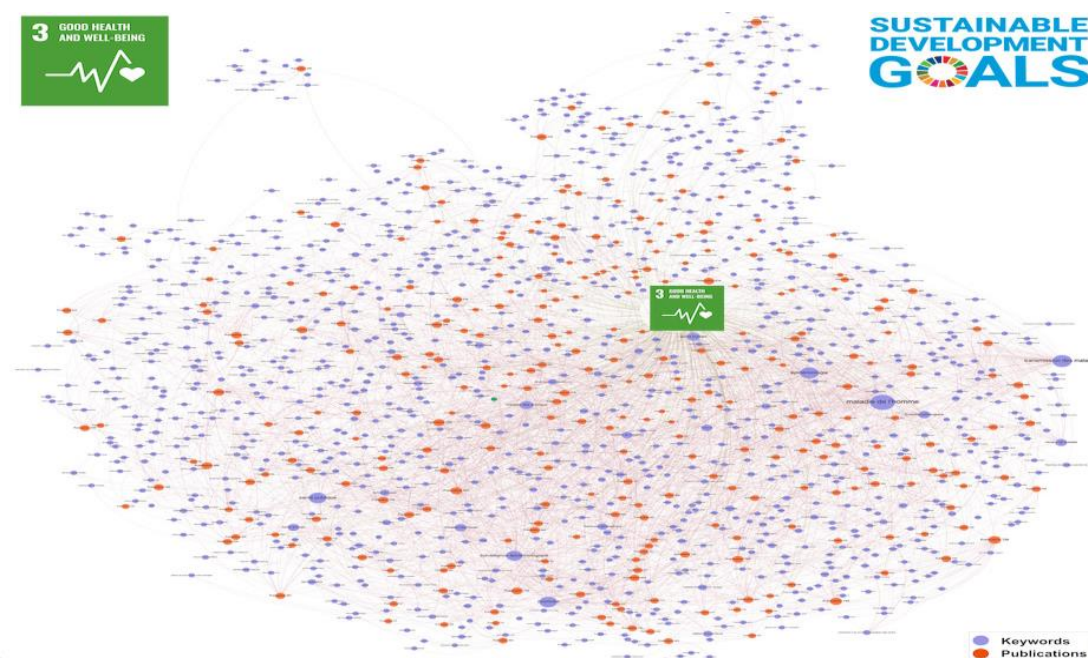


Fig. 7. Goal 3 - interactive tool allows you to explore CIRAD publications (<http://metroteach.com/SDG/index.html>)

7 Conclusion

The analysis of a Gephi network graph with 9812 nodes, 48580 links, a density of 0.001, an Eigenvector Centrality of 0.1062, and a modularity of 0.459 reveals a very sparsely connected network with a strong concentration of influence on a small number of key nodes. The network is also highly modular, suggesting the presence of distinct groups with stronger internal interactions.

The main conclusion of the research is to prove the importance of mapping publications for CIRAD and policymakers, considering complex systems within the SDGs. Publication mapping has significant value for both CIRAD and policymakers when considering complex systems within the SDGs, Table 7:

Table 7. Survey results.

BENEFITS FOR CIRAD
Identifying research gaps and opportunities: by mapping publications in different SDGs and research areas, CIRAD can identify areas where research is limited, highlighting potential areas for future focus and allocation of research resources. Overlaps or redundancies can occur, allowing for strategic collaboration and optimisation of resources. Emerging trends are developing, allowing CIRAD to anticipate future research directions and adapt its strategies.
Demonstrating the impact of research: mapping publications can help CIRAD visualise the breadth and depth of its research contributions to various SDGs. Track the reach and influence of its publications through citation analysis. Effectively communicate its research impact to stakeholders, including policymakers, donors, and the public.
Enhancing collaboration: mapping publications can reveal potential collaborators by identifying researchers working on similar topics within different disciplines or institutions. Facilitating connections and fostering interdisciplinary collaborations crucial to addressing the complex challenges of the SDGs.
BENEFITS FOR PUBLIC POLICY MAKERS
Inform evidence-based decision-making: mapping publications can help policymakers identify knowledge gaps and prioritise areas of research that require more investment to support policy development. Gain insights into emerging trends and anticipate future obstacles related to the SDGs. Evaluate the effectiveness of existing policies by analysing research on their implementation and results.
Monitor progress towards the SDGs: publication mapping can be used to track research efforts addressing different SDGs over time. Identify areas where considerable progress has been made through research breakthroughs. Highlight areas where additional efforts are needed to achieve the SDGs.

Facilitate international co-operation: mapping publications can identify research institutions and experts working on specific SDG targets globally. Promote knowledge sharing and collaboration between countries to address shared impediments

Considering the complex systems within the SDGs, mapping publications becomes even more relevant when considering the interconnected nature of the SDGs. By mapping publications on different SDGs, it is possible to identify synergies and potential conflicts between different SDGs, allowing for more holistic and integrated policy approaches as well as understanding the complex relationships between various SDG targets and the research efforts needed to achieve them. It is essential to promote transdisciplinary research that goes beyond disciplinary boundaries to address the interconnected dilemmas of the SDGs.

Acknowledge: Projeto FAPESP

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