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Alignment between United Nations Environmental Assembly Guidance and National Research Priorities

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Abstract: This study analyzes the alignment between (1) the scientific publications generated within a nation-state, and (2) the United Nations resolutions on climate change research and sustainable development guidelines to which that nation-state is a signatory. Starting with a characterization of Chile's modern scientific journal output using extensive scientometrics databases, this work contrasts the resulting Chilean analysis with United Nations (UN) resolutions generated at the fifth UN Environment Assembly held in Nairobi in March of 2022. Chile is an interesting choice because the most recent political election installed an environmentally progressive president who has described his administration as the "first ecological government in the history of Chile". Chile also held a constitutional referendum shortly after the presidential election that would have replaced the existing constitution from 1980 with a more progressive constitution designed to shift the country towards expanded social and environmental rights. The study covers different dimensions and scales, from the interaction of authors, institutions, and disciplines, to the current conditions regarding authors' gender and the co-author inertia existing in every niche of scientific publication in Chile. The results and recommendations presented in this paper are intended to assist in developing policies for improved scientific–technical knowledge management at the national level.

Keywords: climate change; science diplomacy; Sustainable Development Goals; United Nations; climate and society; big data analysis

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1. Introduction

During a UN Security Council meeting on 23 February 2021, climate change was described by a renowned expert as "the greatest threat modern humans have ever faced". The speaker, Dr. Ian Fry of Australia, called for greater global cooperation [1]. Subsequently, 14 resolutions were generated and published at the 5th United Nations Environment Assembly held in Nairobi [2–4] to help achieve the Sustainable Development Goals, the fundamental pillars developed to address the global climate challenge.

The UN Environment Assembly meets every two years and brings together all members of the United Nations. Reports, such as "Climate Change 2022: Impacts, Adaptation, and Vulnerability" or "The Heat is On: A world of climate promises not yet delivered" [5], discuss from a scientific point of view the inter-related global problems related to climate change.

This present study aims to describe and analyze the alignment between the scientific knowledge of a country, Chile, highly vulnerable to global warming in the short-to-medium term, and the international agreements signed by Chile to help the world address climate change. The techniques employed here include tools, such as text processing and network analysis, uniquely adapted for this work.

We choose Chile because its most recent election established, as the new president noted, "the first ecological government in the history of the country". Chile is located on a climate-critical continent holding both the Amazon rainforest and a dozen nations that still need a unified vision on climate [6]. In addition, the country recently began a second constitutional development process after the failure of the first constitutional referendum in mid-2022. That earlier effort had proposed a new constitution designed to enshrine a progressive social and environmental vision into law [7].

Scientific research contributes to the global understanding of complex and interdependent climate change issues. Such research can also inform the development of policies to alleviate or mitigate the climate emergency, but those studies have been relatively limited until well into this century [8]. Recently climate research has been upbraided for neglecting to analyze the most realistic scenarios, including those that seem feasibly catastrophic [9]. Despite criticism of scientific work on the climate crisis, countries, such as Chile, base their UN agreement participation and policy decisions on the results from global research publications [10]. However, scientific knowledge varies considerably between nations, and that variation correlates with national wealth and education levels [11,12]. Furthermore, research management at a nation-state level can be affected by factors that include poor governance in critical areas—often the result of elections rather than expert-driven policy choices [12]. Fundamentally, national decisions to act in priority directions, such as climate change prevention, develop with the country's overall structure of knowledge networks for data acquisition and interpretation.

1.1. Objectives of the Study

These study objectives have been designed to understand the points of approach and divergence between the scientific research published by Chilean authors (using existing information in scientific journals) and the objectives of the UN regarding climate change and sustainable development.

The goal of the study is to generate a multidimensional tool that allows for analysis at any scale, including globally. These early results show the potential of automated digital tools to inform leaders, policymakers, and stakeholders about gaps and misalignments between existing research initiatives within the nation, and the research required to help meet the international goals to which that nation is a signatory.

This work considered the 14 resolutions of the 5th United Nations Environment Assembly, held in Nairobi in March of 2022, as the point of comparison between the science developed by a country and the international agreements it has signed. These 14 resolutions focus on national actions favoring natural resource management to achieve the UN Sustainable Development Goals. That perspective is in keeping with the recommendations of the Intergovernmental Panel on Climate Change (IPCC AR6, WGIII Summary for Policymakers), which emphasizes nature-based solutions.

1.2. Significance of the Study

Climate change, or global warming, has been called the most significant problem humanity has ever faced [1]. Therefore, it is vital to know at the national level how well a country's scientific knowledge system (SKS) aligns with the 2022 guidelines provided by the UN.

The implications for national policies are relevant since, using the analysis presented here, it will be possible to evaluate where the state of the national SKS now resides concerning international expert advice on climate change and to suggest possible changes to improve that alignment. The generalizable characteristics of the current Latin American form of government, with a clear tendency towards internal presidential leadership and presidential diplomacy abroad [13], make it necessary to address this knowledge and information management problem in the political sphere. We will make some suggestions toward this point in the final section.

The differences between the two data pools analyzed in this work (UN documents and scientific information from national resources), will help both policy-makers and key actors decide where a greater alignment might be both desirable and achievable.

The questions guiding this research are as follows:

- When considering climate-based keywords in a country's scientific article output, what is the frequency of occurrence and evolution of their importance, and in which scientific sectors do those keywords appear?
- Using the 14 UNEP resolutions of March 2022 intended to help curb pollution and to protect and restore nature worldwide, is it possible to identify the frequency of keywords in the scientific publications related to those resolutions?
- Considering the Chilean SKS zones where climate change research is producing journal articles aligned to the 14 UN resolutions, is this output distributed according to geographical relevance?

A comprehensive study of the modern Chilean research landscape illuminates the state of Chilean science, its evolution over time, and its possible trends. The authors have also evaluated the social aspects of Chilean climate science, including leadership, gender, and funding. Along with this is an examination of the possible evolution of Chilean scientific collaboration through social inertia. The latter is analyzed at the individual and institutional levels and from the point of view of the scientific disciplines involved.

2. Methodology

The field of complex systems is, by definition, interdisciplinary, and seeks to unravel the information underlying the interaction of many non-linear elements of specific systems, such as those containing scientific knowledge. As the UN Director of the Bureau for Policy and Programme Support, Haoliang Hu wrote that [14], "It is important to add integrated approaches to the debate and analysis to understand interdependencies or emergent effects not obvious using traditional methods".

This research used an empirical point of view, but also used an inductive technique [15], collecting scientific data from the Agencia Nacional de Investigación y Desarrollo de Chile, or ANID (National Research and Development Agency, Chile), which reports to the Ministry of Science, Technology, Knowledge, and Innovation of Chile. The ANID database collects all Chilean scientific publications (defined as having at least one author affiliated with a Chilean institution) published between 2008 and 2022, as obtained from the following three databases: Web of Science, Scopus, and the SciELO-Chile collection [16]. These scientific publications contain the fundamental metadata required for analysis, including author, affiliation, journal, year, and discipline. Figure 1 shows a schematic of the metadata used in this work.

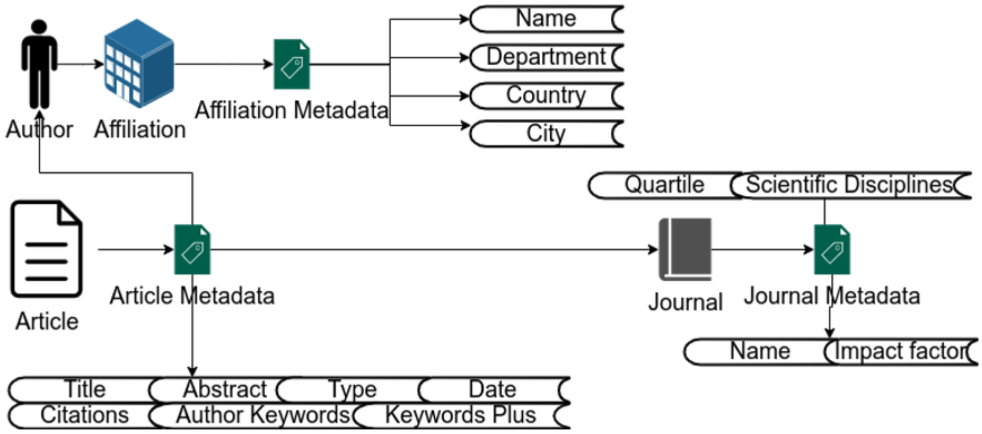

Figure 1. Schematic representation of the metadata of a scientific publication.

From an empirical point of view, the authors used methodologies from the field of complex systems [17–19], complex network theory [20], text processing, and others. For the construction of networks and the subsequent analysis, three types of networks were defined based on the entities (nodes) that compose them, namely authors, institutions, and disciplines. These networks are defined in this work as "undirected", so without direction in the relationships between pairs of nodes, and "weighted", where the frequency of relationship between nodes is considered. The relationship between a pair of nodes, whether authors, institutions, or disciplines, is defined by their joint appearance in the same publication.

After such analysis, it will be possible to construct metrics, such as co-author inertia, and complex objects, such as a scientific discipline network. It will then be possible to identify the key topics discussed in the knowledge network and their possible connections and relevant relationships with the information regarding climate change coming from the official documents of the United Nations.

2.1. The Data behind Scientific Production

Modern digital platforms have been used to acquire and classify information related to scientific output, including Dataciencia.cl in Chile. Scientific works (papers, books, patents) are compiled in databases, allowing them to be organized, and rankings are generated based on citations within their scientific disciplines.

One of the three essential platforms in this effort is the Web of Science (WoS) service [21], owned by Clarivate Analytics. It contains material from 1900 to the present and collects bibliographic references, citations, and relevant information, such as titles, abstracts, and keywords. The database classifications include natural sciences, engineering and technology, social sciences, agricultural and veterinary sciences, medical and health sciences, humanities and the arts, and more. They also provide a ranking of the journals based on citations within a given subject.

For the Web of Science, each published work is assigned at least 1 of more than 400 thematic categories, such as literature, romance, mathematics, applied mineralogy, optics, or linguistics [22], and the Web of Science Journal Citation Report collects close to 12,000 journals [21].

Before being accepted for inclusion on the Web of Science platform, journals undergo a prolonged evaluation. If they are found to be consistently acceptable, they are added to the Web of Science Core Collection used for this study. In addition, Clarivate publishes an annual Journal Citation Report with extensive citation statistics. This massive trove of scientific publication data allows a detailed statistical analysis of each journal and the categories to which a journal belongs.

The second valuable platform for measuring scientific activity is Scopus, the scientometric database of the publishing company Elsevier. Elsevier uses the services of a third company, SCimago Lab [23], to establish the rankings they publish, and Scopus analyzes approximately 35,000 scientific journals.

Finally, the SciELO (Scientific Electronic Library Online) database primarily comprises Latin American countries, including Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Mexico, Paraguay, Peru, Portugal, South Africa, Uruguay, and Venezuela. To these are added Spain and Portugal in Europe and South Africa on the African continent. While useful, SciELO is smaller than either Web of Science or Scopus [24]. Of the SciELO publications, most articles are in Spanish, some are in Portuguese, and 42% are in English. The SciELO database contains more than 1200 journals as of 2019 and has a publication rate of about 1200 articles per year [24]. In this work, the SciELO-Chile collection provided information unavailable in the Web of Science or Scopus databases.

The final metrics depend on the variables used. Usually, the number of citations a particular paper receives, the journal where it is published, and any third-party commentaries on the content help establish an index of impact. However, it is worth noting that this type of hierarchy in scientific production generates a dynamic that has not been without criticism. Indeed, works, such as those of Peter Weingart [25], warn of the possible "politicized" use of data that would lead scientific research to competitive submissions that seek to increase rankings rather than to answer relevant questions concerning scientific work. Furthermore, Reinhard Werner [26] said, "The focus on bibliometrics makes papers less useful". He continued by saying that recent research shows that highly-cited articles often contain relatively little new information and instead contain useful summary generalities rather than original work.

2.2. Assessing Scientific Output around Climate Change

Using computer programs specifically designed for textual analysis, researchers can analyze the scientific output of a given country in detail. For example, analysis of the Chilean data considered the following dimensions:

- Frequency of 69 keywords related to climate change;
- Scientific disciplines related to those keywords;
- Georeferencing of works devoted to those keywords;
- Relative importance of this scientific output considering the total scientific output of the country.

2.3. The Fourteen Resolutions Adopted by the UN Environment Assembly

The United Nations Environment Assembly

The United Nations Environment Assembly (UNEP) is the relevant environmental body of the United Nations and contains representatives from each member state. It is the highest-level global administrative entity contributing to the UN 2030 SDG agenda and functioning as a driver of government action [27].

As mentioned in the introduction, the United Nations Environment Assembly has met every two years since 2014 in Nairobi, Kenya. However, given the global pandemic, the fifth session took place in two parts; the first, held in February 2021, was only online and was called UNEA-5.1. The second part (UNEA-5.2) took place online and in-person in Nairobi from 28 February to 2 March 2022 (The Assembly was created in 2012, its predecessor being the 58-member Governing Council of the United Nations Environment Programme).

This fifth meeting was the first after the United Nations Climate Change Conference (COP26), adding to its importance. Indeed, COP26 was a milestone that tried to continue the idea of limiting the increase in global warming discussed in the "Paris Agreement" [28] and was relatively successful. Further agreements were established among members, including improved carbon credit trading and annual national reporting of the state of emission reduction commitments. However, as Alok Sharma mentioned, COP26 failed to move nations away from carbon-based energy [29].

The Assembly is highly relevant when a "triple planetary crisis" is recognized, namely pollution, climate change, and biodiversity loss [3]. The UNEA-5.1 successfully established a 2022–2025 strategy that accounts for the triple planetary crisis. That strategy also seeks to comply with the 2030 Agenda for Sustainable Development [30].

Meanwhile, months later, UNEA-5.2 set out to advance results that could lead to legally binding action on plastic pollution. That plastic pollution agreement passed and may mark a historic milestone. According to the Executive Director of the United Nations Environment Program (UNEP), Inger Andersen, the success in establishing an intergovernmental negotiating committee to end plastic pollution may be the most noteworthy achievement since the Paris Agreement in 2015 [31].

Other relevant topics negotiated during the Assembly include waste management, methods for addressing biodiversity, and implementing a circular economy. All parties accepted the following 14 resolutions [4]:

1. Resolution to End Plastic Pollution: Towards an international legally binding instrument;
2. Resolution on an Enhancing Circular Economy as a contribution to achieving sustainable consumption and production;

3. Resolution on Sustainable Lake Management;
4. Resolution on Nature-based Solutions for Supporting Sustainable Development;
5. Resolution on the environmental dimension of a sustainable, resilient, and inclusive post-COVID-19 recovery;
6. Resolution on Biodiversity and Health;
7. Resolution-Animal Welfare—Environment—Sustainable Development Nexus.
8. Resolution on Sustainable Nitrogen Management;
9. Resolution on Sustainable and Resilient Infrastructure;
10. Resolution on the Sound Management of Chemicals and Waste;
11. Resolution for a Science-Policy Panel to contribute further to the sound management of chemicals and waste and to prevent pollution;
12. Resolution on Environmental aspects of Minerals and Metals Management;
13. Resolution on the Future of the Global Environment Outlook;
14. Resolution of due regard to the principle of equitable geographical distribution, in accordance with paragraph 3 of article 101 of the Charter of the UN.

These resolutions have generated such a global resonance that some in the press have called it a 'historic' treaty [32,33].

While acknowledging how relevant and well-intentioned these resolutions are in addressing the climate problem (and, more generally, the triple crisis mentioned above), some reasonably significant points give pause. Among them are attempts by some countries, such as the United States, Cuba, and Saudi Arabia, to promote delayed dates for initiating plastic reduction.

Des Gasper [34] analyzes this situation and highlights that these problems can be significant when generating practical actions and solutions. However, he also stresses the importance of structural solutions, not just well-intentioned partnerships. Indeed, globalization and the interconnectedness of the international system make it necessary for proposals at the UN level to be acceptable across a broad swath of societal stakeholders.

Timeframes are also relevant. Hulme mentions several reasons for not considering fully-defined timeframes and considering extinction and panic scenarios that do not yet have a reliable scientific prediction percentage [35]. Nevertheless, considering the impact of delay is essential and connects with generating structural solutions on a larger scale. At the individual and collective level, representations of risk and fear associated with climate change have managed to capture attention but, at the same time, sometimes produce a "hopeless" or "despairing" response that leads to a society that views itself as impotent, disconnected from the problem, and unable to effect change [36].

In addition, it is essential to consider the United Nations' agenda for sustainable development (the SDGs). Seventeen goals were selected for achievement between 2015 and 2030 [37]. These goals are as follows:

1. End poverty;
2. Zero hunger;
3. Good health and well-being;
4. Quality education;
5. Gender equality;
6. Clean water and sanitation;
7. Affordable and clean energy;
8. Decent work and economic growth;
9. Industry innovation and infrastructure;
10. Reducing inequalities;
11. Sustainable cities and communities;
12. Responsible production and consumption;
13. Climate action;
14. Undersea life;
15. Terrestrial ecosystems;
16. Peace justice and strong institutions;

17. Partnership to achieve the goals.

Eleven of the fourteen resolutions adopted by the UN Environment Assembly were selected for this study, limiting the choices to those topics appropriate to big-data analysis and network theory. The other three are political actions less amenable to such analysis.

The keywords in this study emerged through inspection of the text of the UN Resolutions. Those keywords are listed in Table 1.

Table 1. Keywords associated with UN resolutions generated at the 5th UN Environment Assembly held in Nairobi in March 2022.

Resolution ID	Resolution Keyword
R1	Plastic pollution
R2	Circular economy
R3	Lake management
R4	Sustainable development
R5	COVID-19 recovery
R6	Biodiversity and health
R7	Animal welfare
R8	Nitrogen management
R9	Sustainable infrastructure
R10	Management of chemicals
R11	Minerals management

These keywords have been evaluated across the following dimensions:

- Relative importance considering the total scientific production within Chile;
- Impact of the related documents;
- Geographical distribution and institutions studying topics related to the resolutions;
- Social dynamics behind the authorship of these documents.

This analysis will quantitatively evaluate Chilean national alignment based on suggestions from the United Nations. That, in turn, will show Chilean alignment with the goals of the IPCC. Conversely, this analysis will provide suggestions to the government to align and optimize efforts to meet UNEA resolutions on climate change.

3. Chilean Scientific Output on Climate Change

Between 2008 and 2022, the authors identified 206,244 scientific publications from Chile. The year-over-year changes are in Figure 2 (black line).

As of November 2022, only a few current-year scientific publications have appeared in the relevant databases. That is not surprising, since there is a refractory time between the publication of a scientific work and its appearance in digital collections. Note, though, how the scientific publication slope has been consistent over more than a decade with very little change.

We also analyzed the frequency of the keywords related to climate change presented at least once in the title, abstract, or author (Figure 2, green line). Regular expressions were used in each search to increase sensitivity and to help ensure completeness.

Looking at Figure 2, it is apparent that the increase in scientific publications that began in late 2007 showed a remarkable increase in productivity around 2014, where the production rate of documents on climate change exceeds the total production rate of Chilean science (Figure 2, highlighted blue region).

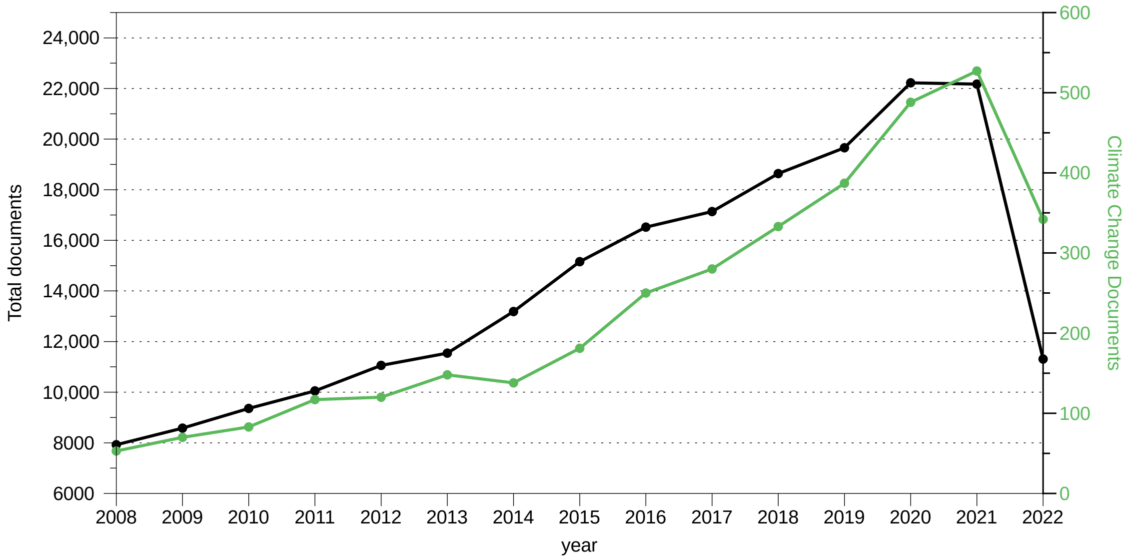

Figure 2. The number of scientific publications in Chile. The black line represents the total. The green line tracks Chilean studies with climate change keywords.

The analysis period presented here coincides with the Chilean economy's lowest GDP growth since the 1970s, well below the rate reached during the 1990s. In addition, during the most recent decade, state investment in research and development continued to be poor, staying close to 0.34% of GDP [10]. The period studied is also characterized by a series of political transformations. Those transformations included four changes in government, rapid ideological shifts between administrations, and profound instability [38]. However, there were still significant advances in environmental policies during this tumultuous period.

Between 1990–2018, public spending on environmental protection increased by an average of 8.3% per year [39]. By 2008, Chile had already signed international treaties, such as the 2005 Kyoto Protocol, and the National Environmental Commission (CONAMA) was already coordinating the country's environmental regulation. In 2010, CONAMA was restructured, becoming the Ministry of the Environment (MMA). That was also the year Chile joined the OECD, which obliges it to report environmental indicators periodically. In 2012, the Environmental Courts were created to resolve environmental disputes [40,41]. In 2015, Chile presented its first tentative nationally determined contribution (NDC) to the Paris Agreement, which, after ratification, became the official NDC of Chile. The same year, the National Institute of Human Rights (INDH) identified 118 socioenvironmental conflicts in Chile, concentrated in water, mining, and energy [42].

Notwithstanding, some authors [40,41,43] criticize the standardization of environmental norms or requirements of public policies that fail to incorporate the geographical and demographic diversity of the country. In addition, some territories of the country have lacked democratically defined frameworks for these issues, so work carried out there may not have engaged the participation of affected citizens and may not be directly comparable to studies in other regions.

Development of the Framework Law on Climate Change (LMCC) was initiated in 2020 and approved in 2022, providing a new legal structure around climate change strategies. The LMCC has also reinforced the existing institutional framework, incorporating new climate management instruments, such as the long-term climate strategy [40].

The emergence of the topic "climate change" in the Chilean scientific literature coincides with the 2007 appearance of the Fourth Assessment Report, produced by the working groups of the Intergovernmental Panel on Climate Change (IPCC). Their findings are presented as different "Themes", where Theme One provides a non-causal description of observed natural and human systems changes. Theme Two looks at possible causes of these changes. Theme Three refers to predictions of possible future scenarios concerning climate change. Mitigation and possible adaptations are analyzed in Theme 4, and a longer-term view of this is presented in Theme 5. Finally, Theme 6 brings together robust conclusions from the study [44].

At that time, there was significant uncertainty about how information from scientific studies might be incorporated into development plans and public policies. However, a precedent has now been established for moving research findings into policy statements through the collaborative participation of more than 70 Chilean state-funded organizations, including the Millennium Institutes and National Data Science Centers [16].

The results presented here show a correspondence between the increase in the rate of scientific production on climate change (around 2014–2015, Figure 2, green line) with the emergence of greater environmental awareness in Chile, both on the part of the government and also of the citizens.

The presence of the topic of "climate change" is still modest in the scientific literature of Chile. Preliminary results indicate that only 1.7% of all scientific papers reference the topic out of 3517 total scientific publications during the period studied. However, Chile is one of the countries in the region most committed to the climate problem. As evidence, Figure 3 shows the number of documents on climate change in the Web of Science database in proportion to the population of Latin American countries.

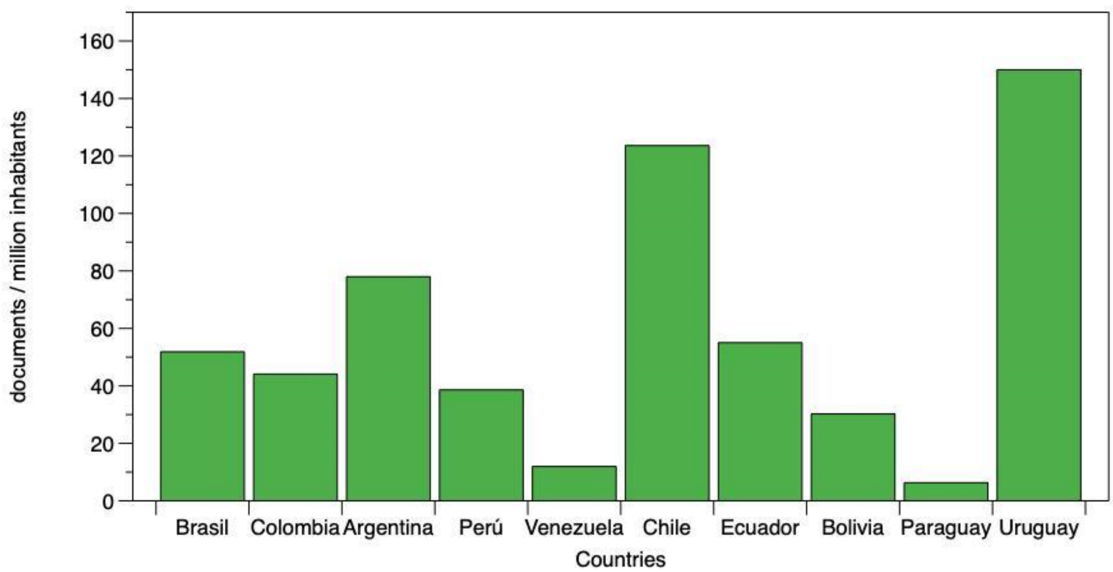

Figure 3. Papers with climate change keywords per million inhabitants in Latin America.

As shown in Figure 2, Uruguay, Chile, and Argentina display the top three values in their ratios between published papers with climate science keywords and their national populations.

This quantitative analysis allows us to compare several dimensions of the country's scientific publications, focusing on the frequency of occurrence of any keyword across scientific disciplines (Figure 4). The distribution in Figure 4 is shown in more detail in Table 2.

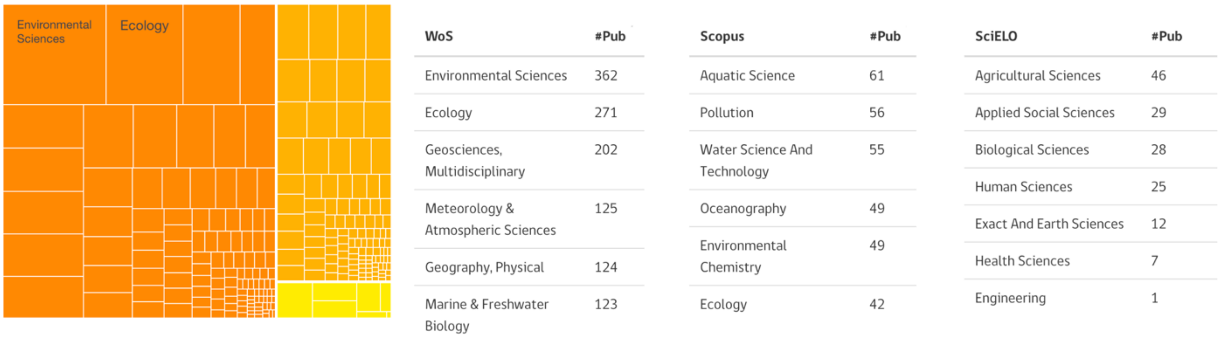

Figure 4. Climate change keywords across disciplines for the WoS (orange), Scopus (light orange), and SciELO-Chile collection (yellow) databases. Source [16].

Table 2. Important disciplines in climate change science. These are the first 10 WoS disciplines using the keyword "Climate change".

Discipline WoS	Percentage	Number of Documents
Environmental Sciences	12.18	362
Ecology	9.21	271
Geosciences, Multidisciplinary	6.73	202
Meteorology and Atmospheric Sciences	4.26	125
Geography, Physical	4.22	124
Marine and Freshwater Biology	4.15	123
Multidisciplinary Sciences	3.98	120
Environmental Studies	3.87	119
Plant Sciences	3.80	118
Water Resources	3.69	112

The environmental sciences discipline publishes the highest percentage of papers on climate change in Chile. However, its overall publication rate is much lower than the core scientific disciplines developed in Chile. For example, "Astronomy and Astrophysics" and "Physics Particles and Fields" represent about 25% of the total Chilean science literature [16]. Of the 4.65% of the total output that refers to the discipline of environmental sciences, only 15% relates to climate change. Chile might, therefore, consider top-down strategies for specific topics, especially those from the new global UN resolutions.

Scientific Disciplines System

It is crucial for the analysis in this work to demonstrate the contributions from the different disciplines of knowledge. Figure 5 shows the respective proportions of each higher OECD category of discipline. From this baseline, the authors created a network diagram with links connecting the various disciplines associated with the country's climate change publications (Figure 6).

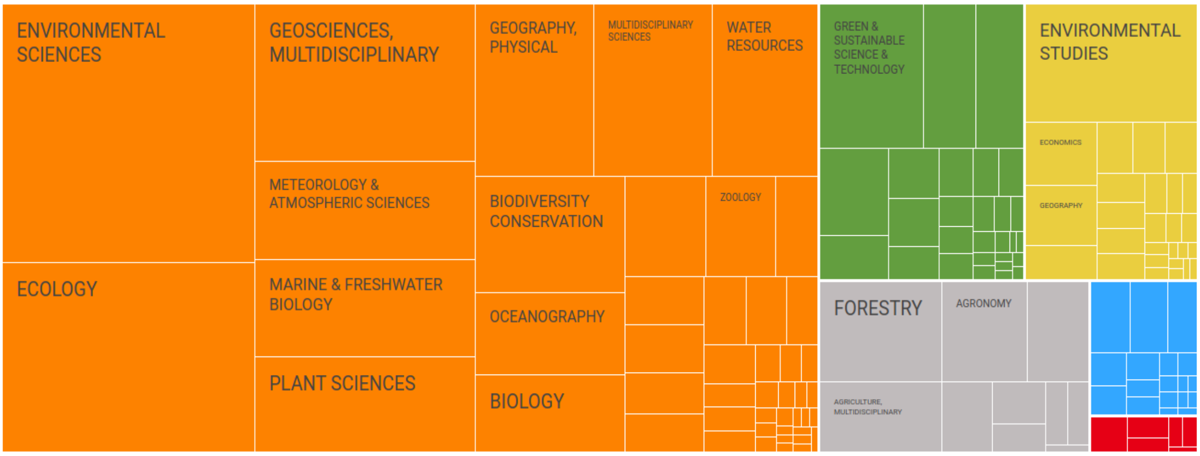

Figure 5. Chilean scientific documents (2008–2022) with climate change keywords according to WoS discipline categories. Colors—natural sciences (orange), engineering and technology (green), agricultural and veterinary Sciences (gray), medical and health sciences (blue), social sciences (yellow), and humanities and the arts (red). Source [16].

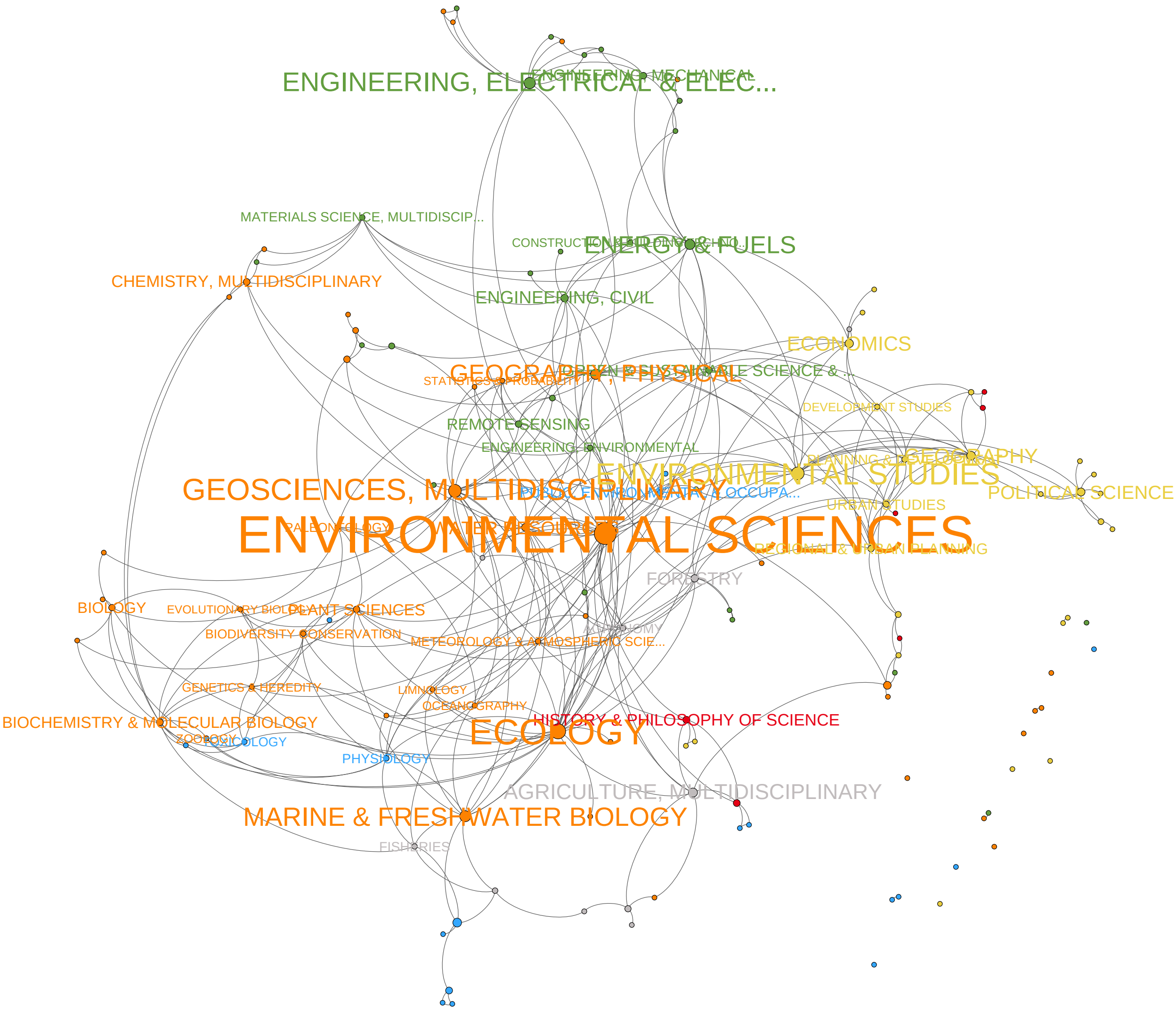

Figure 6. Network of scientific disciplines (WoS) related to climate change keywords. The color code is the same as in Figure 5. Note: the labels of those less relevant disciplines have been omitted.

These data show that most Chilean climate change studies are in the natural sciences, which accounts for 69% of Chile's total publications related to climate change, followed by engineering and technology with 11%. The other OECD disciplines contribute less than 20% of the whole; social sciences account for 9%, agricultural and veterinary sciences account for 8%, medical and health sciences account for 2% and, finally, humanities and the arts account for 1%.

Using network analysis of the whole dataset of scientific documents related to climate change, Figure 6 shows the connections that emerge from the co-occurrence of climate change terms in different disciplines.

The discipline network shows the presence of three large clusters (orange, yellow, and green), highlighting the natural sciences as the most central. Disciplines belonging to agricultural and veterinary sciences (gray) or medical and health sciences (light blue) appear to be mainly related to natural sciences, while the humanities and the arts (red) align with the social sciences (yellow).

Analyzing this network, its connections, and its interactions reveals that the natural sciences are closest to the other disciplines involved with questions from Chilean research on climate change.

4. Alignment between Scientific Production and the "14 Resolutions"

For each of the 11 resolutions (remember that of the 14 resolutions, 3 of them are measures involving general suggestions, such as the formation of expert panels, etc.), a 3-point review was carried out. First, we studied which disciplines are studying the specific subject of each resolution. Second, we analyzed which national institutions are leading this research type (geographical regions where relevant knowledge can be identified). Third, we analyzed the impact of the research.

4.1. Scientific Disciplines and Resolution

Each UNEA resolution could be reflected in a range of related disciplines. Thus, it could be expected find some variety in the impact sector of each discipline, whether it is social, natural sciences, or humanistic. This variety indicates the strength of Chilean national research in certain areas and can also reveal scientific sectors that could generate more relevant research. Table 3 summarizes the number of published papers for each resolution in each discipline in the Chilean SKS.

Table 3. Resolutions and disciplines. The table considers the 11 resolutions studied in this work (see Table 1) and shows the number of documents published related to each resolution corresponding to a given science discipline.

Discipline	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	Total
Environmental sciences	33	54	9	187	4	8	4	25	14	3	2	**343**
Green & sustainable science & technology	3	39	0	135	2	2	0	1	14	1	1	**198**
Environmental studies	3	23	2	131	1	2	0	2	11	0	1	**176**
Veterinary sciences	2	0	1	2	0	3	85	2	0	1	0	**96**
Engineering, environmental	4	26	1	35	0	0	0	2	4	1	1	**74**
Ecology	1	3	2	35	0	6	4	11	2	0	0	**64**
Agriculture, dairy & animal science	1	1	0	1	0	1	55	4	0	0	0	**63**
Marine & freshwater biology	15	1	3	21	0	0	4	6	2	0	0	**52**
Energy & fuels	0	9	0	34	1	0	0	0	5	0	0	**49**
Water resources	2	6	6	19	0	1	0	6	2	1	2	**45**
Agronomy	0	1	0	12	0	1	4	16	0	4	0	**38**
Fisheries	1	0	4	20	0	1	4	5	3	0	0	**38**
Agriculture, multidisciplinary	0	1	0	11	0	0	9	12	0	2	1	**36**

Table 3. *Cont.*

Discipline	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	Total
Public, environmental & occupational health	1	3	0	22	4	1	1	0	2	1	0	**35**
Multidisciplinary sciences	4	0	1	16	1	3	4	2	1	0	0	**32**
Economics	0	3	0	23	0	0	0	0	4	0	0	**30**
Plant sciences	0	2	0	9	0	3	1	14	0	1	0	**30**
Urban studies	0	1	0	23	0	1	0	0	3	0	0	**28**
Food science & technology	0	5	0	4	0	4	9	4	0	1	1	**28**
Geography	0	0	2	21	0	0	0	0	4	0	0	**27**
Engineering, civil	3	7	0	8	0	0	0	1	6	0	1	**26**
Biotechnology & applied microbiology	1	7	0	14	0	0	1	1	0	1	0	**25**
Soil science	0	1	1	4	0	2	0	15	0	0	0	**23**
Biology	2	0	2	9	1	3	3	1	0	0	1	**22**
Geosciences, multidisciplinary	1	0	2	12	0	1	0	1	2	0	2	**21**
Chemistry, multidisciplinary	2	6	1	6	1	0	0	1	0	1	1	**19**
Regional & urban planning	0	2	0	15	0	0	0	0	2	0	0	**19**
Management	0	5	0	13	0	0	0	0	0	0	0	**18**
Engineering, chemical	0	10	1	5	0	0	0	1	0	0	1	**18**
Construction & building technology	0	6	0	6	0	0	0	1	4	0	0	**17**
Oceanography	2	0	2	6	0	0	1	4	2	0	0	**17**
Geography, physical	0	0	1	13	0	0	0	0	3	0	0	**17**
Business	0	7	0	10	0	0	0	0	0	0	0	**17**
Zoology	1	0	2	0	0	1	12	1	0	0	0	**17**
Biodiversity conservation	0	1	1	7	1	4	1	2	0	0	0	**17**
Medicine, general & internal	0	0	0	11	1	1	1	2	1	0	0	**17**
Planning & development	0	2	0	13	0	0	0	0	1	0	0	**16**
Architecture	0	0	0	14	0	0	0	0	1	0	0	**15**
Biochemistry & molecular biology	0	2	0	7	1	2	0	0	0	2	1	**15**
Materials science, multidisciplinary	1	7	1	2	0	0	0	1	3	0	0	**15**
Microbiology	0	1	1	3	0	5	2	2	0	0	0	**14**
Development studies	0	0	0	13	0	0	0	0	1	0	0	**14**
Forestry	0	0	1	6	0	2	0	4	0	0	0	**13**
Meteorology & atmospheric sciences	1	1	1	8	0	0	0	1	0	0	0	**12**
Sociology	0	0	0	7	0	0	2	0	1	0	0	**10**
Operations research & management science	0	4	0	6	0	0	0	0	0	0	0	**10**

Table 3 is very sparse in transdisciplinary research, and some of the keywords used in specific resolutions have had no work associated with them for more than a decade. This analysis makes evident Chile's lack of scientific discussion concerning Resolution 5—COVID-19 Recovery, Resolution 6—Biodiversity, Resolution 10—Health, and Resolution 11—Management of Chemicals and Minerals Management.

4.2. Who Is Studying the Resolution Topics?

To identify which institutions are carrying out scientific work related to each resolution, the authors inspected data on the primary affiliations of each Chilean-identified author (Table 4).

Table 4. Studies related to each Resolution, with affiliations to Chilean universities. Note: Table shows only universities with more than ten documents in 2008–2022.

Institution	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	Total
Pontificia Universidad Católica de Chile	3	20	4	161	7	5	23	6	27	0	6	**262**
Universidad de Chile	9	14	4	114	9	7	33	19	10	3	5	**227**
Universidad Austral de Chile	5	5	9	50	0	7	68	20	2	2	0	**168**
Universidad de Concepción	15	14	7	79	3	8	7	18	8	4	1	**164**
Universidad Católica del Norte	19	11	1	50	1	4	0	3	3	0	1	**93**
Universidad Autónoma de Chile	2	18	2	59	1	0	1	0	5	0	0	**88**
Pontificia Universidad Católica de Valparaíso	3	10	2	30	3	4	2	7	7	1	1	**70**
Universidad Nacional Andrés Bello	6	6	1	32	2	5	10	2	3	0	0	**67**
Universidad de Talca	2	16	0	33	3	1	1	4	2	2	2	**66**
Universidad de la Frontera	1	5	4	30	2	2	7	10	1	2	0	**64**
Universidad de Santiago de Chile	1	18	3	25	3	0	4	2	1	0	0	**57**
Universidad del Bío Bío	3	7	2	33	0	0	0	1	3	2	1	**52**
Universidad Técnica Federico Santa María	0	5	1	25	0	1	1	2	4	1	0	**40**
Universidad Católica de la Santísima Concepción	7	3	0	18	2	3	0	4	2	0	0	**39**
Universidad Católica de Temuco	1	2	4	15	0	2	9	4	1	0	0	**38**
Universidad de Antofagasta	4	10	0	11	1	2	3	2	1	0	2	**36**
Universidad Adolfo Ibáñez	2	6	0	18	1	1	0	1	2	1	1	**33**
Universidad de Los Lagos	0	0	7	18	0	4	1	2	0	0	0	**32**
Universidad de Valparaíso	2	2	2	19	2	0	3	0	0	1	0	**31**
Universidad Diego Portales	0	2	0	21	0	0	1	2	2	0	0	**28**
Universidad Católica del Maule	2	3	0	14	1	0	3	4	0	1	0	**28**
Universidad Mayor	3	1	0	7	1	1	4	2	1	0	1	**21**
Universidad de la Serena	0	1	1	15	0	2	0	2	0	0	0	**21**
Universidad del Desarrollo	0	1	0	13	1	0	3	1	1	0	0	**20**
Universidad de Playa Ancha	3	2	0	12	2	0	1	0	0	0	0	**20**
Universidad Santo Tomás	5	1	1	6	0	1	2	2	0	0	0	**18**
Universidad de la República	1	0	0	7	2	2	6	0	0	0	0	**18**
Universidad de los Andes	0	2	3	8	0	1	0	0	1	0	0	**15**
Universidad de Tarapacá	1	1	0	11	1	0	1	0	0	0	0	**15**
Universidad Tecnológica Metropolitana	0	4	0	8	0	0	0	0	0	0	1	**13**
Universidad San Sebastián	2	2	0	8	0	1	0	0	0	0	0	**13**
Universidad de Magallanes	2	0	2	6	0	0	0	0	1	0	0	**11**
Universidad de Atacama	0	2	0	8	1	0	0	0	0	0	0	**11**

Table 4 shows only universities with more than 10 published papers between 2008 and 2022 and demonstrates a concentration of production in the 2 most prestigious universities in Chile, namely the Pontificia Universidad Católica de Chile and the Universidad de Chile, both located in Santiago, the capital.

4.3. Research Impact on UN's Resolutions

Although the number of scientific publications is a primary measure of a country's scientific output, their impact on the scientific community is another useful indicator. The impact metric, defined here as the number of citations a document has received, demonstrates the relevance of an article in other scientific publications and the relative differences between the topics of the 11 resolutions. Figure 7 is a "heatmap" showing the impact metrics for Chilean studies published in each resolution topic area.

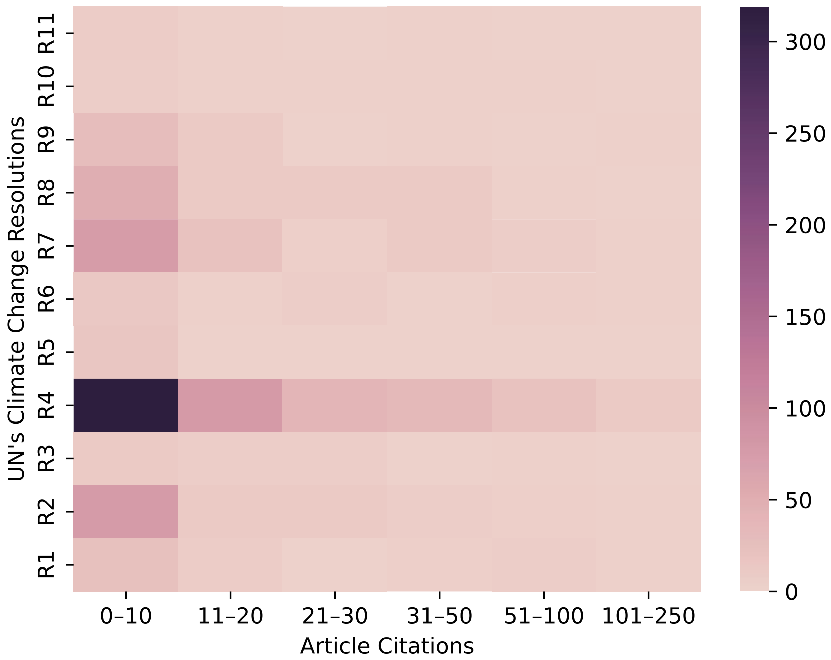

Figure 7. Impact on UNEA resolution research. This heatmap shows the number of citations for accumulated documents in each resolution theme.

As can be observed, scientific documents related to Resolution 4 (sustainable development) have the highest impact, followed by Resolution 7 (animal welfare), Resolution 2 (circular economy), and Resolution 8 (nitrogen management). Documents belonging to other resolutions have had no impact on the scientific community in this analysis.

5. Socio-Territorial Characterization of Chilean SKS on Climate Change

5.1. Geographical Distribution

Having completed the characterization of scientific production and its alignment with UN resolutions, the study analyzed the geographical characteristics of the Chilean scientific community working on these topics.

Chile is a longitudinally extended country, 4720 km long but less than 500 km wide at its widest point. It has historically been divided into 16 political regions, but that number was reduced to 13 in 2018, and all were renamed, complicating geospatial and demographic research continuity. Figure 8 shows the map of Chilean regions with associated climate change keywords in published studies.

The figure shows a focal point in Region XIII, or the Metropolitan Region, showing a concentration of national research in the city of Santiago de Chile, the capital of the country. Looking at Chilean universities, scientific publications related to the UN resolutions show the same pattern (Table 5). The institutions within Región Metropolitana, the capital city, comprise more than 40% of the published work.

Figure 8. Map of scientific production in relation to climate change. Source—DataCiencia, 2022.

Table 5. Percentage of the contribution of Chilean regions in documents related to UN Resolutions.

Region	%
Metropolitana	44.5
Bio-Bío	11.9
Los Ríos	9.4
Antofagasta	6.0
Araucanía	4.8
Valparaíso	4.3
Maule	3.1
Ñuble	1.3
Coquimbo	1.0
Tarapacá	0.7
Atacama	0.5
Magallanes	0.5

5.2. Social Inertia, Founding, Leadership, and Gender

The social threat posed by climate change often drives human attempts to restore the status quo and, thus, in some ways, to avoid what some researchers call "cultural trauma" [45]. Such attempts present themselves dynamically as inertia in the system, acting at personal, institutional, and societal levels [45].

Considering this, we studied a range of scales and dimensions to quantify this inertia in co-authorship relationships, comparing it to that observed in other topics. To compute "co-authorship inertia", we applied the methodology proposed by [46]. In this method, inertia can take values between zero and one. The inertia value is maximized when the authors collaborate with the same people over many years and close to zero when they always choose different research partners.

Figure 9 shows the inertia in authors (black line) and institutions (red line). In the case of the authors, inertia undergoes a period of increase in the first years of analysis (2008–2011) and then shows an apparent decrease. This effect does not occur in the case of institutions, showing strong fluctuations with significant inertia.

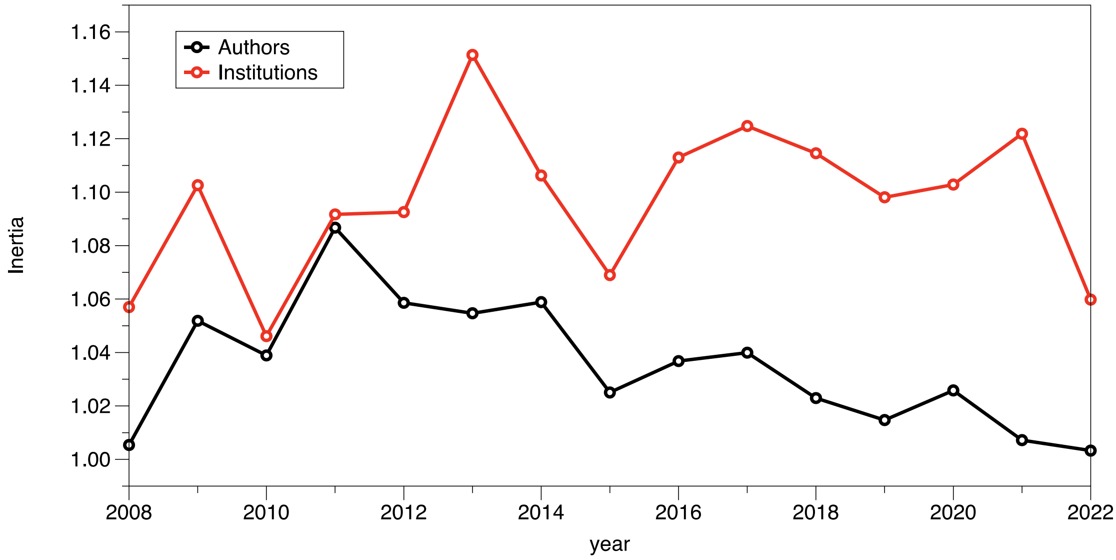

Figure 9. Co-authorship inertia for authors (black line) and institutions (red line) that are studying climate change (keywords).

Conversely, the average inertia of the authors, institutions, and disciplines associated with climate change shows lower inertia than the general average of their scientific peers. For example, Figure 10a demonstrates the contrast between co-authorship inertia in the study of climate change (green) and the average of a random sample of scientific co-authorship in the same period (red). Institutional results are similar (Figure 10b).

For both authors and institutions working on climate change, the inertia is less than that observed in the general scientific production of Chile. That lower inertia shows a more dynamic SKS for climate change than the prevailing system for studying other topics. The 2022 value of inertia in climate change co-authorship is also lower than that reported in [46], demonstrating improvement in the diversity of collaboration.

Disciplinary inertia is to be expected (Figure 10c). Climate change in Chile is being studied mainly in the field of natural sciences, as we see here where the disciplinary relationships for the study of climate change are fewer than in general scientific production.

This analysis of the Chilean SKS also enumerates authors identifiable as Chilean in climate change studies. A study was determined to have been led by Chile if the first author or corresponding author were attached to a Chilean institution. Figure 11 (red line) shows that the leadership of Chilean authors in publications about climate change has remained relatively constant during the last 14 years, with more than half of the authors of published studies bearing Chilean affiliations. The same occurs with the total number of Chilean authors, independently of their leadership (Figure 11, green line). Rising government interest can be seen in the percentage of climate research receiving Chilean state funding, reaching 50% in 2015 (Figure 11, black line).

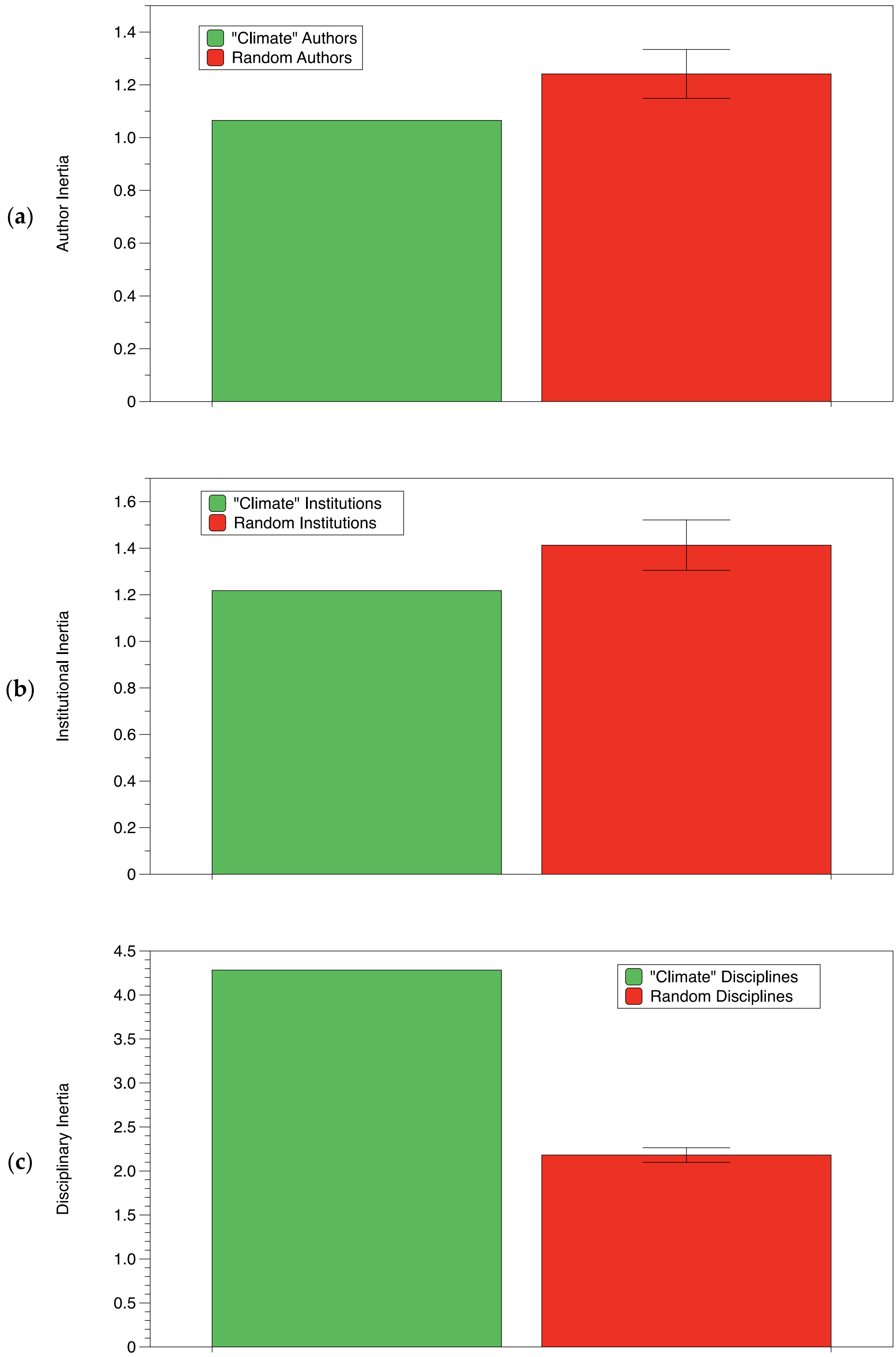

Figure 10. (**a**) Co-authorship inertia, (**b**) institution collaboration inertia, and (**c**) discipline collaboration inertia. Documents related to climate change (green) and three random samples of the same number of documents (red).

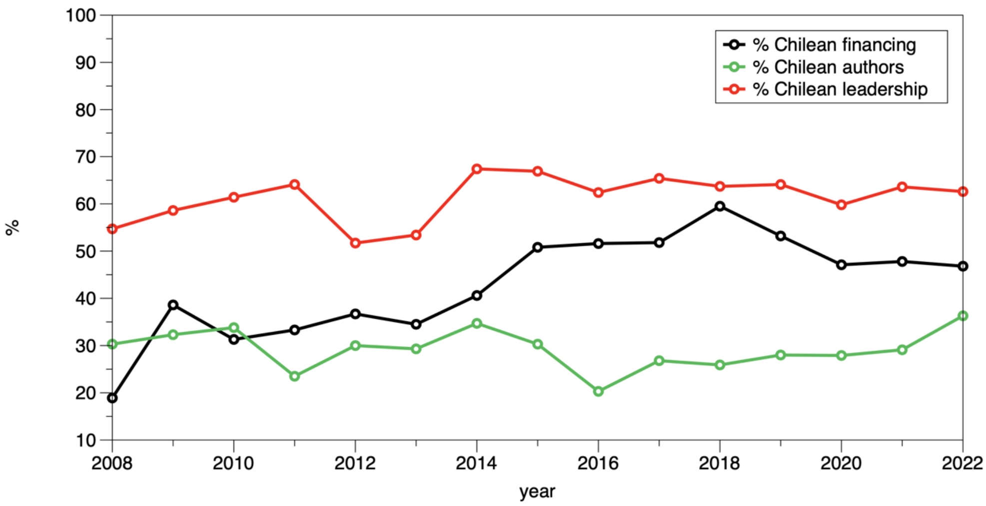

Figure 11. Percentage of Chilean leadership (red line), Chilean authors (green line), and documents financed by Chilean state funding (black line) for documents related to climate change.

An important aspect regarding the international collaboration of Chilean authors is what is shown in Figure 12. As can be seen, collaboration with foreign authors has also increased over time. The number of foreign authors has grown faster than the number of Chilean authors since 2014, showing that Chile is starting to become less siloed and more internationally collaborative in climate change research.

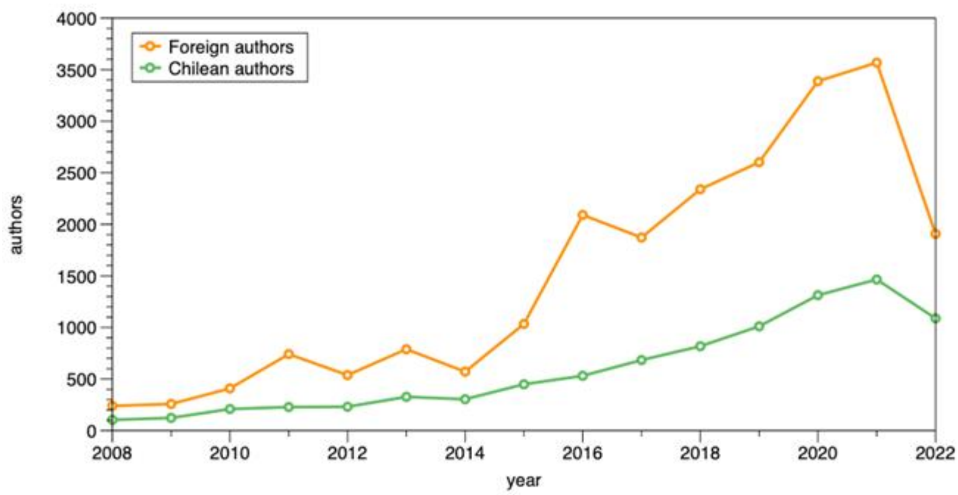

Figure 12. The number of foreign (orange) and Chilean (green) authors for documents on climate change produced in each year of the studied period.

Finally, regarding the gender of authors on climate change topics, Figure 13 shows a trend that reflects the overall gender proportions in the Chilean science community. In the last 14 years, the male-female ratio has shown significant fluctuations that describe a type of dampened periodic movement. During the beginning of the 2010s, these fluctuations were between 2 and 3, dampening with values close to 2.3 in recent years.

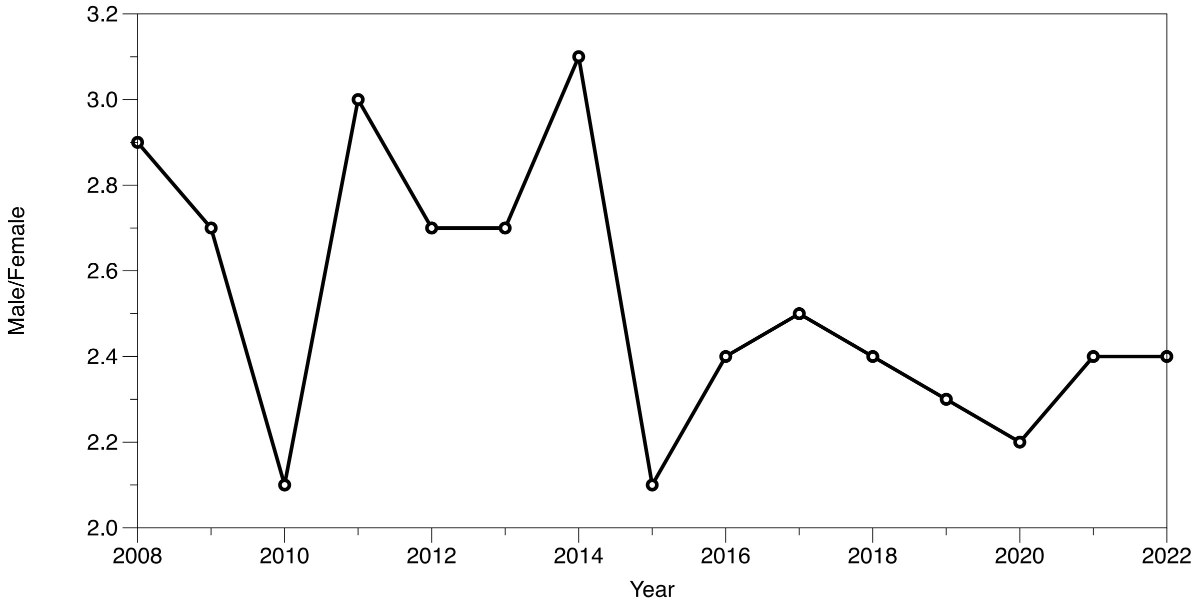

Figure 13. Male–female ratio of Chilean authors on climate change for documents on climate change produced in each year of the studied period.

6. Conclusions and Recommendations

6.1. Conclusions

Using different dimensions of analysis, this work characterizes the Chilean scientific work produced on climate change and details the volume, content, and discipline while considering regulations and resolutions adopted at the global level. Eleven of the fourteen resolutions from the fifth UN Environmental Assembly, held in Nairobi in March 2022, were studied in detail.

Analysis reveals that the Chilean scientific knowledge base still needs to be aligned with the resolutions of the UN Environment Assembly in 2022, a gap that would benefit from closure.

Chilean scientific studies on climate change are limited to relatively few relevant disciplines and lack adequate representation of Chile's varied geography. A disproportionate number of articles have been published from and about the region surrounding Chile's capital, Santiago, and relatively few articles address the broad swath of critical environmental issues faced by the biomes and microclimates elsewhere within the country. Furthermore, keyword analysis using the text of the UN resolutions shows that several relevant topics need more representation within Chilean environmental research.

Chile has become an interesting case study in environmental research for two reasons. The first is the change in government in 2022, where the incoming president defined his administration as "the first environmentalist government in Chile's history". The second occurred that same year when a vote on a proposed new constitution failed. That new document had taken an aggressive position on global warming, as well as on several other environmental and human security issues. It would have mandated profound changes in both social policy and environmental law, and the resulting constitution would have made Chile one of the most environmentally progressive nations in the world [7]. The vote on adoption failed, but the national conversation was lively and stimulated impassioned international debate.

The post-vote analysis within this report shows that positive changes have occurred in Chile's scientific output over the past several decades, improving steadily despite various government changes. The discussion stimulated by the constitutional referendum, plus the new administration's environmental emphasis, will likely have accelerated climate research agendas throughout the country. Given its stated priorities, the current government's incentives are likely to significantly increase the number of Chilean climate publications linked to the 2030 SDG agenda during this decade. That may improve Chile's domestically focused science and ensure more significant Chilean participation in international forums.

Climate change. Substantive scientific work on global warming began in Chile in early 2014, coinciding with a growing worldwide scientific interest in the subject [47]. However, this analysis shows that Chilean climate change studies to date primarily fall within the OECD's natural sciences classification. Unfortunately, Chile needs more interdisciplinary work on intersectional climate topics, such as social adaptation, urban planning, and public policy. That is where complex "wicked problems" appear as a natural consequence of ambitious UN resolutions designed to address existential threats to large swaths of humanity.

Moreover, Chile needs to publish more on climate change topics, regardless of the OECD classification. A mere 1.7% of all Chilean scientific publications during the study period concerned any topic related to global warming. While there might be several reasons, it is evident that Chile needs more domestic incentives and increased research funding around climate research.

Despite this low percentage, it is important to note that Chile's political, social, and scientific attention to climate change still puts this country among those most concerned about the problem in the Latin American region. Chile can, and should, serve as a model for the countries of the continent, where environmental degradation of the Amazon rainforest, for example, has consequences for every living being on earth.

This research also shows that publications about climate change too frequently appear from within the capital city of Santiago and that the remainder of the country publishes very little on the topic. Fortunately, some exceptional institutions have begun showing climate leadership despite their remote location, demonstrating that the impact of the 2030 SDG agenda is not homogeneous on the SKS, and that regional interest might be readily enhanced if adequately encouraged. In addition, cultural and ethnic groups throughout Chile have been differentially affected by global warming, and members of those groups hold positions within academic centers throughout the country. They need to be heard.

The UN resolutions in Nairobi 2022. Results included here show that the sustainable development goals, the most frequent UN environmental subject cited globally, have less than 0.1% percent representation in the Chilean scientific arena. Biodiversity and ecological health, two related UN resolution topics, have even less. We also note that most research teams in Chile work in relative isolation. Enhancing inter-institutional research collaboration would likely generate publication benefits in both quality and quantity and should be encouraged and incentivized.

This analysis also highlights the impact of existing Chilean studies on the research performed in response to UN resolutions. Figure 6 shows that only a few Chilean scientific documents (perhaps 20 throughout this study window) have had any recognized global impact as assessed by subsequent citations. As one indicator of significance, only a single Chilean study out of all the articles evaluated had more than 200 subsequent citations. Relatedly, despite having a state university in almost every region, climate change research is pursued in only a few institutions, most within the capital city. Academic leadership outreach may be one place to start enhancing the pursuit of global warming research elsewhere in the country (see Figure 7 and Table 5).

The reporting here also reflects the climate burden of current Chilean economics. National economic data [48] demonstrate the relevance of Chile's products (particularly copper mining, coastal fishing, and fruit harvesting) to climate change and sustainable development discussions. Chile's economic livelihood rests on extracting organic and inorganic natural resources. Though mining and food production are each essential for the success of modern humanity, there are opportunities to embrace a more complex, less fragile economy. Extractive economies are necessarily limited by their finite natural resources, so transitioning responsibly from resource extraction to alternatives seems politically, economically, and socially wise. Similarly, increasing Chilean scientific capacity around climate change and sustainable development is itself an economic opportunity to bring international research funds into Chile.

Social aspects of the Chilean SKS. Research on climate systems appears more amenable to collaboration than other topics identified in this research. Climate is a relatively new field of study with less academic inertia than most. Other Chilean research boundaries, still visible around gender studies and several siloed scientific disciplines, are likely to require new policies that encourage, promote, and possibly mandate collaboration and a systems-thinking approach. Such process improvements will likely have wide-ranging benefits throughout the Chilean educational system and might extend to the national climate conversation.

Finally, the data included here show a steady 2.3:1 ratio of men to women studying climate phenomena in recent years. It is also apparent that participation by women in climate science is lower than in the overall Chilean scientific work product. Ordinarily, women represent more than a third of all science authors in Chile [16], so the climate research gender gap is significant. Unfortunately, the reason for the gap is not readily apparent and requires further study. However, the result suggests the need to encourage the involvement of women via public or institutional policies in the study of climate change, not only to encourage gender equity but also because solid research shows that multiple-gender scientific teams perform better than single-gender teams [49].

6.2. Recommendations

Recommendations from this study are in the Results and Conclusions above, and in Section 6.2 below, and ongoing discussions stimulated by this work may eventually lead to changes in legislation, policy, and law. Those changes may better align internal Chilean research guidance documents with UN resolutions, the SDGs, and the global effort toward a more just, responsible, and humane world.

6.2.1. Our Suggestions

- Given the current characteristics of the Chilean state, this analysis suggests that collaboration between ministries is now essential, particularly between the Ministry of the Environment, the Ministry of Foreign Affairs, and the Ministry of Science, Technology, Knowledge, and Innovation (MSTKI). Such collaboration may require policies and procedures that do not currently exist. It may be desirable to create a standing committee comprised of members from those ministries to assess the state of UN resolution alignment with climate research in Chile;
- The Chilean scientific community needs an incentive system to encourage shifting a substantial fraction of its work toward the 2030 SDG framework and the UNEA resolutions. A domestic focus on climate research will also provide helpful—and perhaps profitable—results within the Chilean economy, aligning with the country's desire to prepare for an uncertain future;
- International cooperation related to these issues and encouraging the country to develop scientific and technological competence around climate threats will position Chile well for an inevitable future of scarcity and change;
- It is necessary to generate a long-term scientific management plan for national and global discussions of climate change and sustainable development;
- Local is key. It is important to develop a science policy that stipulates research agendas linked to local problems related to sustainable development and climate change. That local impact will have a positive knock-on effect on other issues from the 2030 SDG agenda, since complex local problems are affected by multiple kinds of systems, including natural, cultural, ethnic, social, linguistic, financial, educational, technological, and more.

6.2.2. Addressing the Generation of Research Dominantly from the Capital City

- Enhancing educational infrastructure within the regional colleges would encourage climate research with local relevance. That enhancement would encourage expansion in science, engineering, and innovation derived from local perspectives across the length and breadth of the nation;
- Addressing regional problems with international peer/partner validation will generate knowledge about local and regional problems, which will help inform Chile's public policy decisions;
- The superb astronomical research performed in Chilean observatories has led to an understandable weighting of scientific publications toward that specialty (a kind of "scientific extractivism"). The analysis within this paper suggests that the country should build on its observatory expertise in data storage, data analysis, computational power, mathematical modeling, and other tools necessary for astronomers. Enhancing these existing strengths will facilitate transdisciplinary research on the climate of Chile. All science is interdependent, and since global warming will eventually affect astronomical observation, Chilean society can prepare for that future by encouraging collaboration now.

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