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SOIL SCIENCE

Spatial and Scientometric study of the Brazilian scientific production on Antarctic soils and permafrost

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Abstract: This article carried out the first scientometric and spatial analysis of Brazilian scientific production on Antarctic soils and permafrost, based on all publications available from the Scopus and Web of Science databases. Information on co-authorship, citation, research topics, and sampling sites was used to understand the social and theoretical structure as well as the spatial dynamics of this research field in Brazil over the last 25 years. We highlight that Brazil is presently, the main country to study the soils and permafrost of Maritime Antarctica, in addition to having an international robust and prolific production, with high impact on the literature, and widely distributed throughout the studied region. It was also possible to identify potential future international partners, new research locations and strategic research themes.

Key words: Antarctica, Brazil, Scientific Production, Spatial Scientiometrics, Soil.

INTRODUCTION

The development of science and scientific activity can be analyzed through scientometrics, a branch of Information Science that deals with the quantitative and qualitative aspects of technical and scientific research activity, scientific communication, and science policy. Data and statistical information about science are not its end in themselves, but form the basis for analyzing the collective dimension and the dynamic process of knowledge construction (Callon et al. 1995).

Scientometric studies are conducted to understand developments and highlight emerging trends, as well as to assess the performance and influence of countries, regions, researchers, and research institutions in science as a whole (Roemer & Borchardt 2015) or in specific topics and areas, such as climate change (Haunschild et al. 2016).

Among the various scientometric methods and studies, we can mention those that use geographic information for their analysis. The burgeoning research field of "spatial scientometrics" in the last 20 years has spatialized bibliometric data to analyze the geographic distribution of scientific publications, authors, citations, etc. (Frenken et al. 2009), using geographic information softwares (Bornmann & Waltman 2011, Xuemei et al. 2014) to perform spatial analysis at various scales.

The combination of scientometric and spatial approaches contributes to the knowledge of sociology and geography of science. The avenues of inquiry are diverse, and important studies have been produced, including the classic precursor "The Distribution of World Science" by Frame et al. (1977) on the distribution of publications and authors across countries. In the modern spatial approach, we can highlight the studies by Ponds et al. (2007), Bornmann et al.

(2011), and Xuemei et al. (2011) that demonstrate spatial biases between organizations, countries, and study sites, respectively.

Studies such as those by Kim and Jung (2016) and Chignell et al. (2022) have already highlighted various spatial aspects of scientific activity on the Antarctic continent based on collaborative networks and research areas. With this background, in this article, a scientometric and spatial analysis of Brazilian scientific production on Antarctic soils based on information on co-authorship, citations, research topics, and sampling sites was carried out to understand the social and theoretical structure as well as the spatial dynamics of this research field in Brazil over the last 25 years.

MATERIALS AND METHODS

Data on citations, co-authorship, and geographic location were extracted from 85 publications from the Scopus and Web of Science databases. Therefore, two sets of search terms were compiled that articulate the main ideas/concepts that the subject addresses. The books "The soils of Antarctica" and "Cryopedology", both organized and authored by James Bockheim, were used to select the terms. The groups of words were labeled "Main Terms" and "Thematic Terms" as shown in Table I. The search for terms was limited to the title and keywords fields, since the terms placed in these sections are the main topics of the works. Only articles and book chapters were considered. After cleaning the data, we reached the 85 publications mentioned.

Table I. Sets of keywords used in data recovery.

Main Terms	Thematic Terms	
Antarctica Antarctic	Soil Cryosol Gelisol Pedology Cryogenic	Permafrost Active Layer Pedogeomorphology Soilscape

All the selected publications were authored or co-authored by authors affiliated with Brazilian institutions. Productivity aspects (publications and citations), co-authorship and keywords networks were analyzed. The data analysis applied its call "science mapping" approach, based on a visual representation of the structure of the research field in networks by distributing elements (publications, authors, journals, words, etc.) in different groupings (clusters). The network visualization is then used to create a spatial representation of the results analogous to geographic maps. Science mapping has a macro focus and attempts to find patterns in the literature, which is considered as a body of work (Cobo et al. 2011, Zupic & Čater 2015). The research networks were built using the VOSViwer 1.6.18 software.

Furthermore, the publications were classified by research topic, using the scientific structure of the Brazilian Soil Science Society as a reference. When necessary, other classes of topics were added. One or more topics were assigned to each document, depending on the case and the focus of the research, for example, if the article deals with biochemical aspects of soil, the topics "soil biology" and "soil chemistry" are assigned to it. For the final analysis, each topic was counted individually.

Our spatial approach is based on visualizing the occurrence of specific events. In this case, each event corresponds to the collection of a soil sample. For this purpose, geographic coordinates were manually extracted from the 85 publications mentioned. If coordinates and/or maps were available in the publications, all registered points were extracted. If only a textual indication of the area, physiographic element, or study region was present, only one point (in the central area of the locality) was given in the publication. Therefore, coordinates were not checked if the study location was unknown or if it

was not possible to access the publication. Only locations south of 60° South were considered (area of jurisdiction of the Antarctic Treaty).

Sample points were geoprocessed in ArcGIS Pro software and maps of point locations were created. We analyzed the spatial and temporal distribution patterns of the points. Additionally, we examined the temporal and spatial behavior of research topics and co-authorship subjects. In addition, we attempted to identify potential new research sites.

RESULTS AND DISCUSSIONS

Scientometric aspects

The publications cover a total period of 24 years, from 1998 to 2021. The analyzed scientific community consists of 287 authors with an average of 3.54 publications/year. With an average impact on the literature of 28.58 citations per document, distributed among 38 journals with an average of 3 authors per publication, the Brazilian research is among the most important among those that have Antarctic soils as an object of study (Table II).

A "zigzag" pattern was observed in the distribution of records over time, possibly related to the pace of scientific activity, where a year of lower productivity (fieldwork/research) is followed by a year of higher productivity (publications) (Figure 1). It can be seen that from 2013, the average number of publications has increased. The trend line of the data shows that publication productivity has generally increased over time.

The collection and analysis of data unveils the geopolitical nature of Antarctic soil science. Brazil's commitment to scientific development, as mandated by the Antarctic Treaty, has propelled it to its current standing as one of the leading countries in terms of productivity and impact on scientific literature. This treaty has fostered a continuous flow of resources, logistical support, and knowledge. It serves as a testament to the remarkable outcomes that can be achieved through long-term investments in research and exploration.

Brazil joined the Antarctic Treaty in 1975 and became a consultative member in 1983. Since then, Brazilian investment in Antarctic

Table II. Overview Publication information.

Description	Results
Total Documents	85
Av. publications per year	3,54
Av. citations per document	28,58
Publication Type	2
Journal Article	81
Book chapter	4
Authors	287
Av. documents per author	0,29
Av. authors per document	3,37
Partner countries	22
Institutions	89
Language	7
English	84
Portuguese	1
Journals	37
Av. citations per journal	58,91
Av. documents per journal	2,27

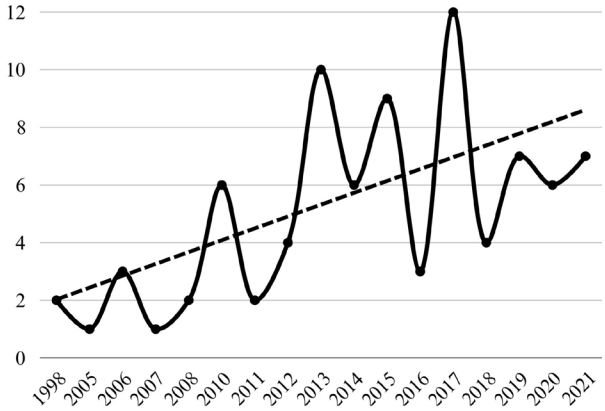

Figure 1. Graph of number of publications over time.

science, especially through the Brazilian Antarctic Program (PROANTAR), has been crucial in strengthening the country's geopolitical and scientific interests in Antarctica. This investment covers logistical aspects, scientific activities, and environmental issues, being crucial for Brazil's presence on the white continent. However, the lack of predictability in the allocation of resources for the program can affect the planning of scientific activities and logistical organization.

The resources allocated to PROANTAR are divided into several categories: science, environmental management, and logistical support. Despite variations in investments, there has been an increase in the number of Brazilian publications on Antarctic soils over time, indicating a growing interest and commitment to research in this area.

Based on data from the Institute of Applied Economic Research (IPEA) on investments in Antarctic science between 2008 and 2017 (Andrade et al. 2018), some interesting trends were observed. The amount invested decreased during the period analyzed. However, the number of Brazilian publications on Antarctic soils increased during the same time interval.

This suggests that despite the reduction in investment, research efficiency may have increased, allowing for more publications with fewer resources. However, it is important to note that other factors, mainly political and economic, can influence both research investment and the number of publications, and a more detailed analysis would be necessary to confirm this hypothesis.

The first studies on Antarctic soils conducted by Brazilian researchers were those of Kuzmann et al. (1998), who studied the soil mineralogy of King George Island, and Godoy et al. (1998), who analysed the concentrations of radioactive elements in the soils of the South Shetland archipelago. In 2002, the approval of the Criosolos Austrais project, sponsored by Professor Carlos Schaefer of the Federal University of Viçosa (UFV), created the nucleus of the future main research group on Antarctic soils in the country.

This project was the basis for the creation of the Núcleo Terrantar (NT), focused on the study of permafrost, soils and terrestrial ecosystems in Antarctica. The group has a considerable production and scientific contributions on the subject and is considered one of the most important in the world, involving researchers from all levels of education and institutions in the country. The increase in the number of publications in the second half of the 2000s is directly related to the work of this research group.

The increase in the number of publications is also due to advances in studies in soil biology, with emphasis on ecology, biogeography, and molecular biology. In general, Brazilian publications followed the trend of international research, in which the fields of biology, earth sciences, and human-soil relationships predominate in studies of Antarctic soils (Figure 2).

Knowledge of the biological and chemical aspects of the soil is fundamental to the performance of all other analyzes of the profile, ecosystem, or landscape under study and is therefore covered in most publications. The topics of genesis and morphology (GSM), pedometrics, and survey and classification (SSC) are predominant in Brazilian Antarctic soil research. Important publications in this area include (Michel et al. 2006, Simas et al. 2007, 2008), which studied the formation of cryosols, mainly ornithogenic, in maritime Antarctica, and (Moraes et al. 2017), which conducted a mapping of soil properties in the Keller Peninsula.

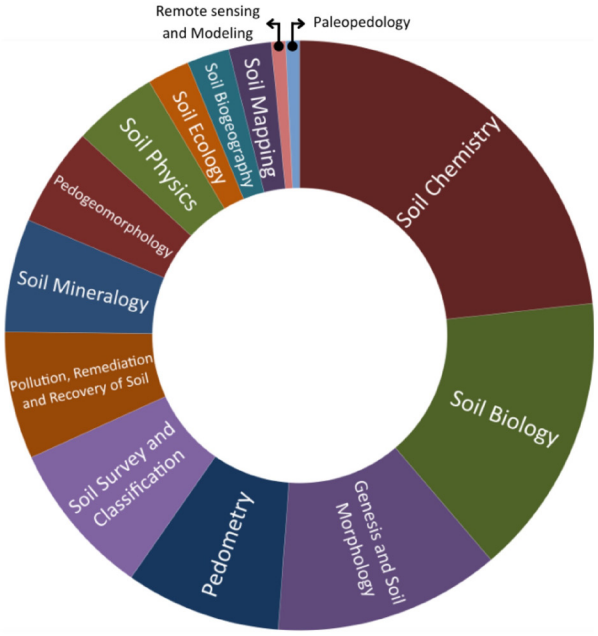

Figure 2. Proportion of research topics in publications.

Another group of papers focused on studies of Antarctic microbiology, with emphasis on the groups of fungi (Wentzel et al. 2019) and bacteria (Roesch et al. 2012). They examined not only the richness of biodiversity, but also bioprospecting (Godinho et al. 2015) and its potential use in bioremediation and mitigation of anthropogenic impacts on the Antarctic environment (Sampaio et al. 2017).

In one way or another, most work has also addressed the impacts of climate change in Antarctica, both by monitoring heat and water in the active soil and permafrost layer (Michel et al. 2012, Schaefer et al. 2017a) and by looking at the spatial patterns of colonization of ice-free areas by plants, lichens, and invertebrates (Almeida et al. 2014).

Soil science combines classical procedures with more modern instruments, emphasizing the importance of integrating both approaches to gain a comprehensive understanding of soil's basic concepts and their practical applications. The combination of traditional methods, such as field observations and soil sampling, with advanced technologies like molecular biology and remote sensing, allows researchers to explore the intricate complexities of soil ecosystems. By synergistically combining these approaches, scientists can uncover valuable insights into the soil's composition, microbial communities, nutrient dynamics, and their impacts on broader ecological processes.

Using the map to visualize the keywords (Figure 3), they can be viewed according to the frequency of their specific occurrence (circle size) and their connectivity (links between words), as well as the proximity between them, forming different clusters. The three main research areas are also shown here in green (biology), yellow (human-environment relations), and red (geosciences) and have strong interconnections between them.

The geoscience area stands out with terms such as "permafrost", "cryosol/gelisol", indicating a focus on permafrost monitoring issues alongside soil investigation, classification and genesis in an area closer to classical soil science. The ecosystem perspective of soil biology refers to the influence of biota on soil processes with particular emphasis on birds and plants. Terms such as "pollution," "anthropogenic impacts," and "bioremediation" indicate a branch of research that combines the preceding from an environmental perspective that is attentive to human impacts. The terms referring to maritime Antarctica, such as "Fildes Peninsula" and "King George Island", are due to the fact that most of the Brazilian studies on Antarctic soils took place there.

Geoderma (impact factor - FI of 7.422) and Geomorphology (FI of 4.406) emerged as the leading journals in terms of publishing articles related to Antarctic soil research, with 11 and 9 articles respectively (Figure 4). These journals are renowned for their focus on soil science and geomorphology, which aligns with

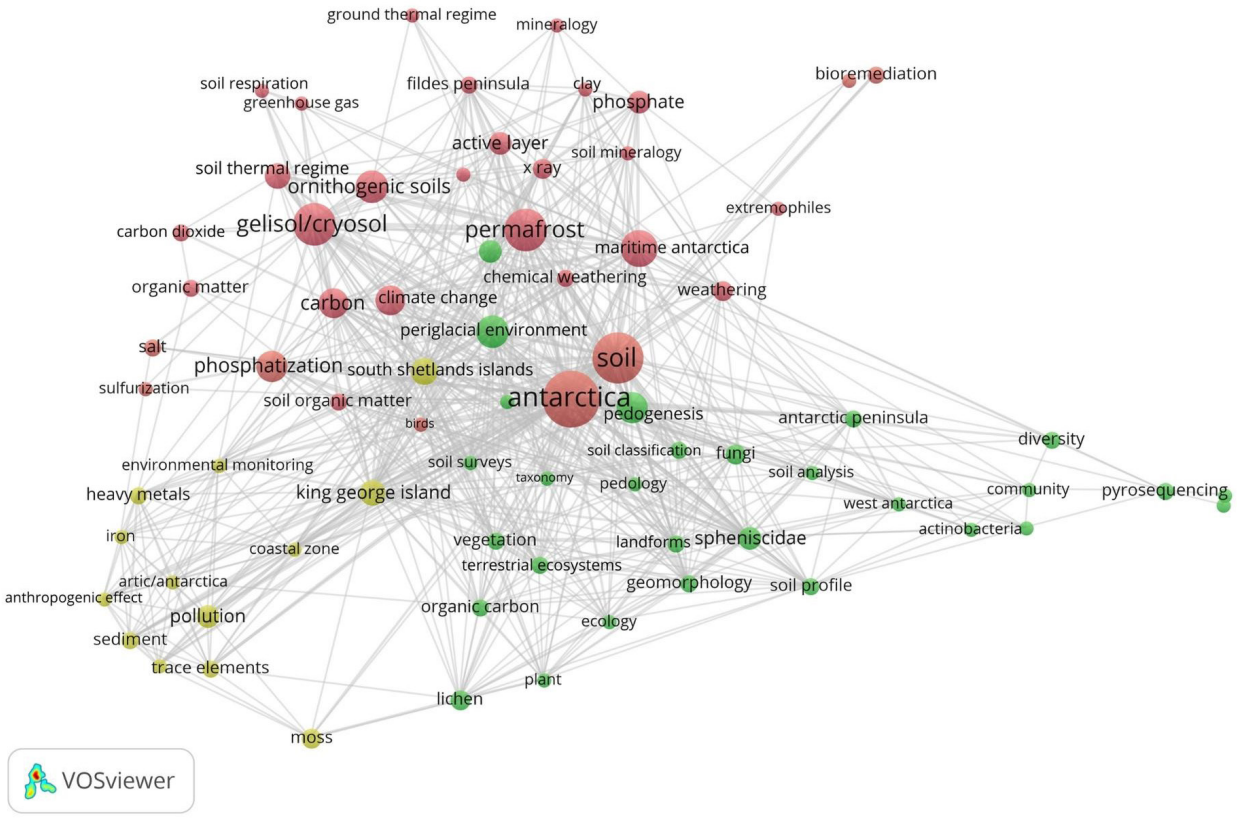

Figure 3. Keyword visualization network.

the predominant geoscience fields in Antarctic soil research. However, it is important to note that other journals, such as Antarctic Science (FI of 2.104) and Catena (FI of 6.367), also made notable contributions to the field. These journals demonstrate the interdisciplinary nature of Antarctic soil research, with a representation of biological and environmental sciences, showcasing the holistic approach taken in studying the unique Antarctic soil ecosystems. The diverse range of journals highlights the collaboration among researchers from various scientific disciplines working together to enhance our understanding of Antarctic landscape.

The main research groups were identified from the coauthorship networks of authors and institutions. The Núcleo Terrantar, based at the Federal University of Viçosa (UFV), is the most important group of Brazilian researchers working on Antarctic soils. Other highlights include the MicroPolar group coordinated by Prof. Luiz Rosa of Federal University of Minas Gerais (UFMG), the Microbial Molecular Ecology Laboratory founded by Prof. Alexandre Rosado of Federal University of Rio de Janeiro (UFRJ), both of which focus on Antarctic microbiota research, and the Nucleus for the Study of Antarctic Vegetation coordinated by Prof. Antonio Pereira of Federal University of Pampa Gaúcho (UniPampa), which specialises in terrestrial biodiversity (Figure 5).

The lead author, Prof. Schaefer, and the other authors are in orbit and are closely networked. Among the authors are Profs. Márcio Francelino (UFV), Felipe Simas (UFV), Elpídio Fernandes Filho (UFV), André Thomazini of Federal University of São João Del-Rei (UFSJ), and

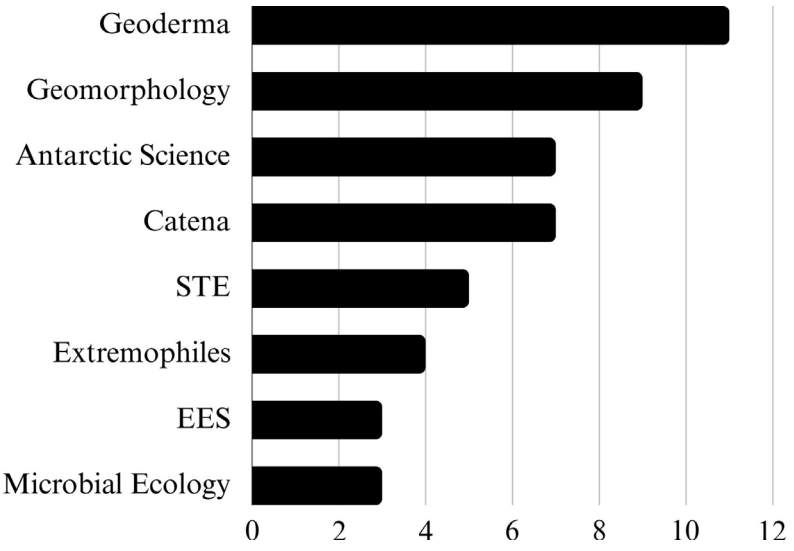

Figure 4. Graph with the main publishing journals. STE = Science of the Total Environment; EES = Environmental Earth Sciences.

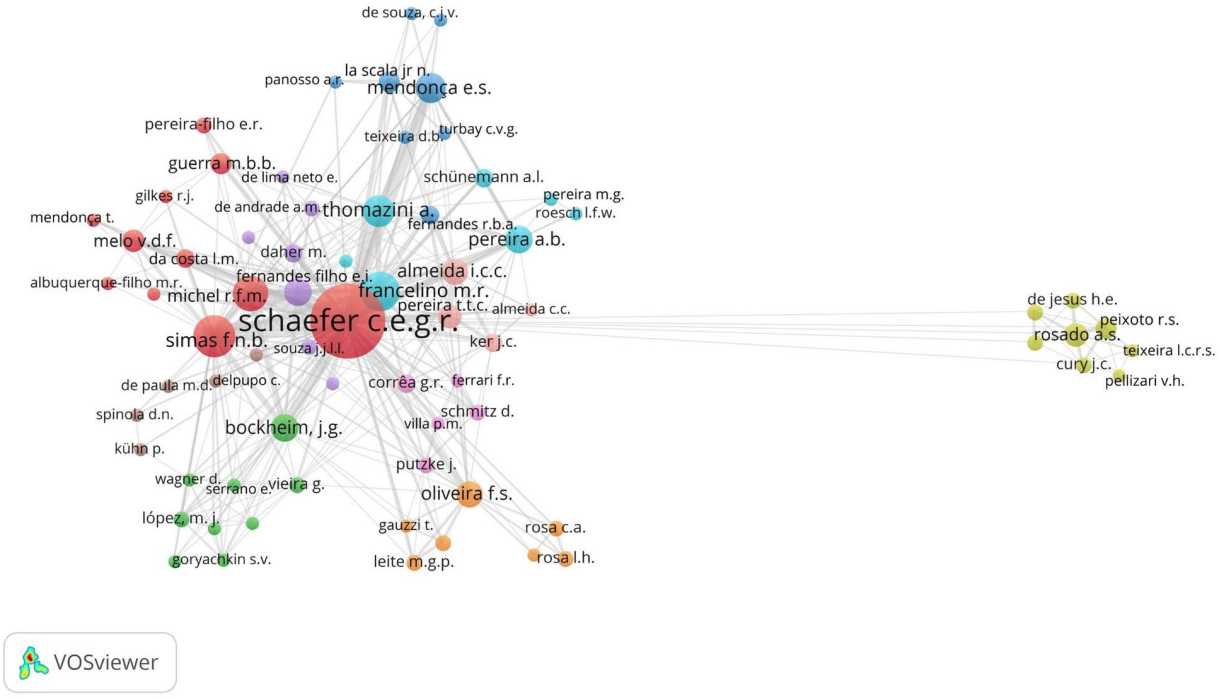

Figure 5. Network of researchers of Brazilian publications.

Roberto Michel of Santa Cruz State University (UESC), all collaborators of Núcleo Terrantar.

A large part of the production of Thomazini and Michel is due to UFV, as it relates to the period in which they completed their studies at that institution. This situation contributed to the fact that UFV accounted for most of the authors and publications (Figures 6 and 7) and became the central institution for scientific production on Antarctic soils.

The work of Federal University of Espírito Santo (UFES) and part of UFMG is also linked to Terrantar through Prof. Eduardo de Sá Mendonça (UFES) and Prof. Fábio Oliveira (UFMG). The group includes the Federal University of Rio Grande do

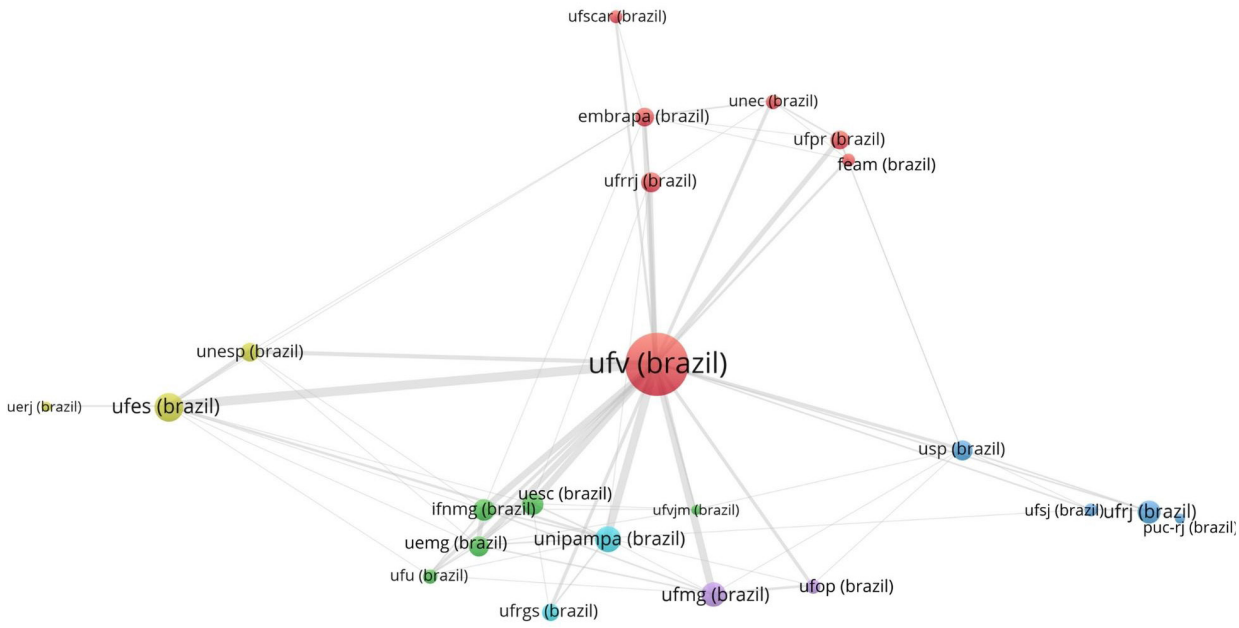

Figure 6. **Network of institutions of Brazilian publications.**

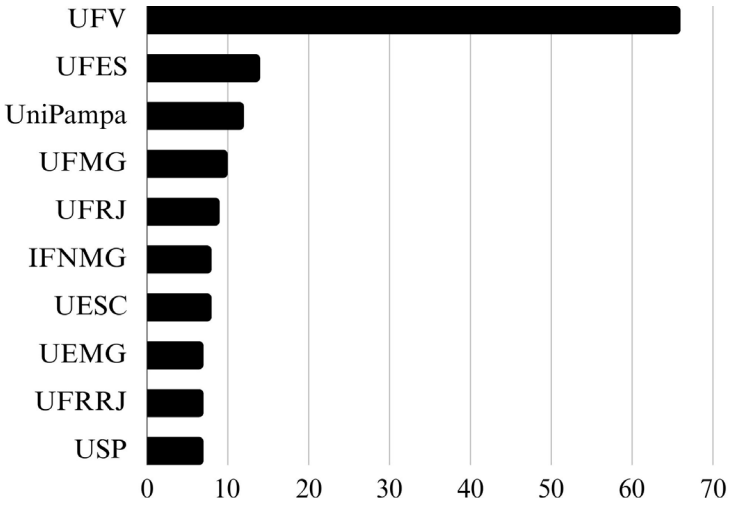

Figure 7. **Main institutions according to number of publications.**

Sul (UFRGS) and other institutions from Minas Gerais State (IFNMG and UEMG).

Brazilian researchers have established partnerships with institutions in more than 20 countries, with a focus on the United States, as evidenced by publications with Prof. James Bockheim, emeritus (Vieira et al. 2010, Michel et al. 2014a, Gjorup et al. 2020). Other important partners were Portugal (Vieira et al. 2014), Spain (Michel et al. 2014b), and Germany (Meier et al. 2019), important countries that for soils research in Maritime Antartica (Figure 8).

The number of citations of a publication is one of the measures of the importance of a text in the literature, i.e., the number of citations a publication has received from other publications in the databases consulted. The baseline values from Scopus were considered. The most frequently cited publications are shown in the graph in Figure 9.

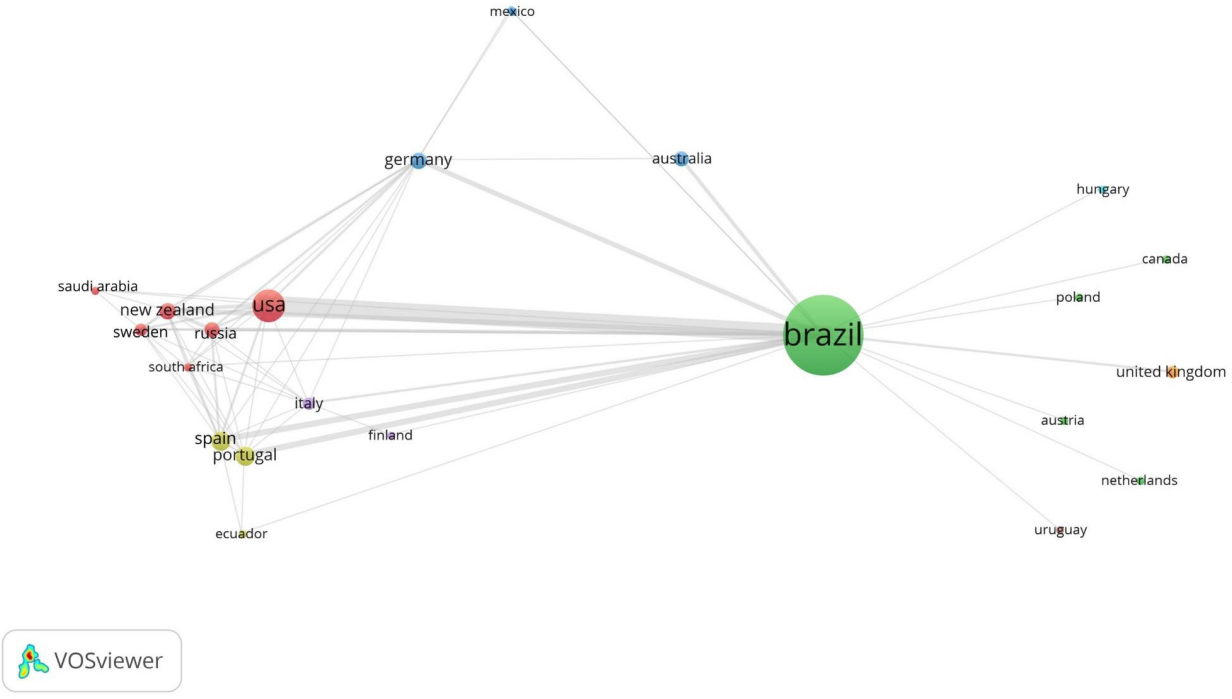

Figure 8. Network of countries of Brazilian publications.

The article with the greatest impact was that of Santos et al. (2005), who studied the chemistry of different soils in the Keller Peninsula, where the Brazilian Research Station is located. Then appears the article by Teixeira et al. (2010), who studied the DNA of the microbial community associated with the rhizospheres of Deschampsia antarctica Desv (Poaceae) and Colobanthus quitensis (Kunth) Bart I (Caryophyllaceae), the only two vascular plants native to Antarctic ecosystems. The other publications are discussed throughout this article.

The fact that the most cited publications deal with topics related to geosciences, biology, and environmental monitoring shows that Brazilian researchers publish important papers in the main areas of Antarctic soils research and are a global reference in this field.

Spatial aspects

In only 6 (7.05%) publications was it not possible to obtain information on the location of the studies, which allowed spatial analyzes to be performed with a considerable degree of data coverage. More than half of the cataloged points were exclusively Brazilian publications, indicating a high degree of autonomy and expertise of these researchers (Table II).

It is important to note that the 70 measurement points in the article "Thermal state of permafrost and active-layer monitoring in the antarctic: Advances during the international polar year 2007-2009" were not included in the following analyzes because it was a global initiative of the International Permafrost Association and this could bias the behavior and interpretation of the Brazilian research.

A broad spatial scope of the research was identified, as it was not limited to areas near the Brazilian scientific station Comandante Ferraz - EACF (Keller Peninsula, King George Island) (Figure 10).

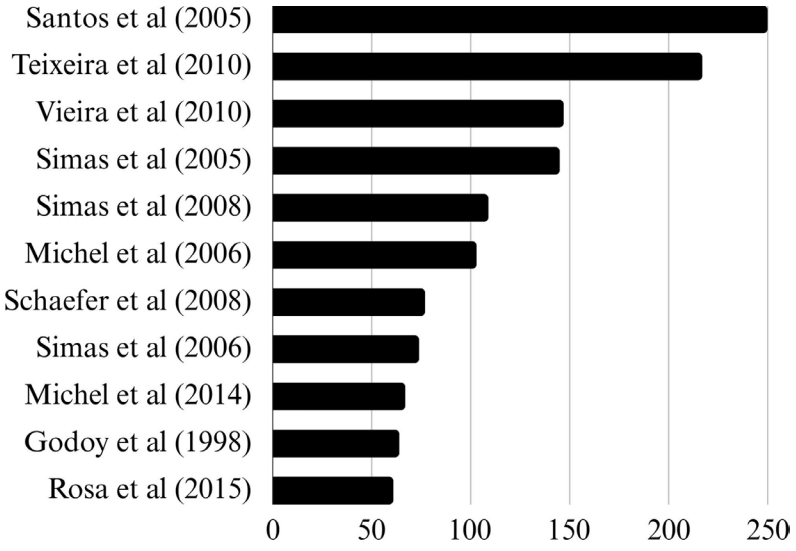

Figure 9. Publications with the greatest impact according to the number of citations.

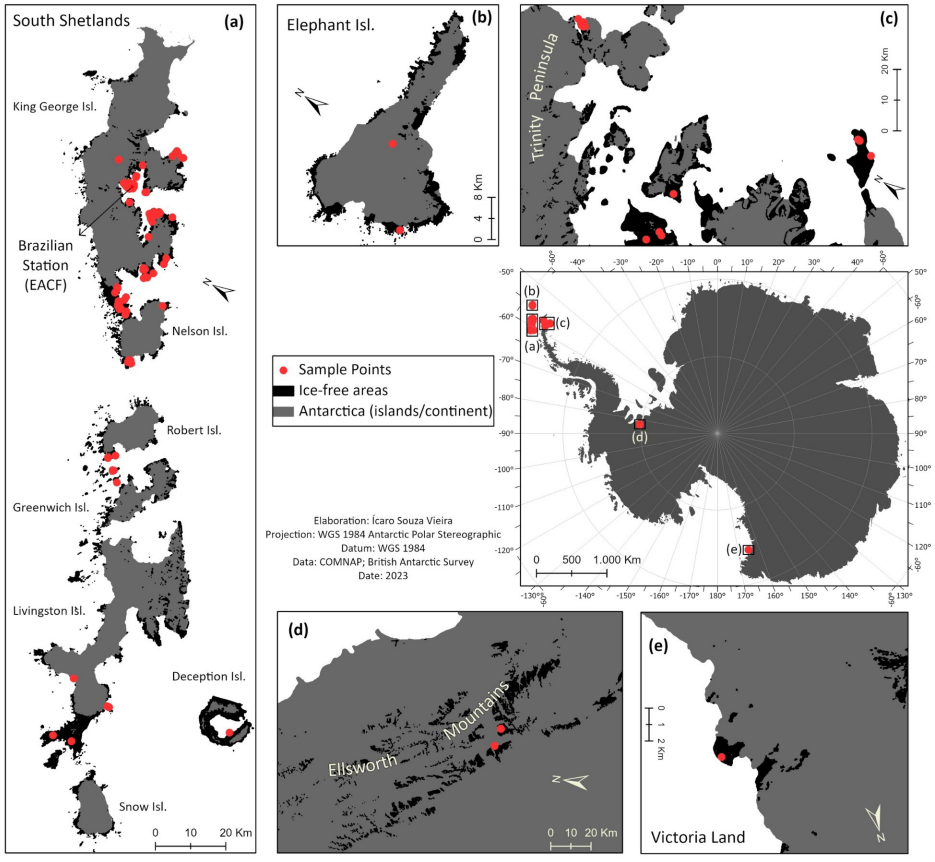

Figure 10. Map of the location points of Brazilian publications. South Shetlands (a); Elephant Island (b); Trinity Peninsula and nearby islands (c); Ellsworth Mountains (d); North of Victoria Land (e).

The Brazilian scientists' research intensively covers areas of Admiralty Bay, the South Shetland archipelago, Elephant Island, areas east of the Trinity Peninsula, and sites in the Ellsworth Mountains and Victoria Land in the Transantarctic Mountains.

By grouping the data from the year of publication according to the natural breaks method (Table III), it was found that soil

Table III. Location's points overview.

Pub. with location information	79
Pub. without location information	6
Total location points	301
Exclusive points (% of total)	54,48
Av. dist. to research station (km)	108,38
General Infrastructure	
Research Stations	1

chemistry is the topic or subtopic in which Brazilian researchers have more expertise than others (Oliveira et al. 2013), but also in research on soil genesis and morphology (Michel et al. 2006, Simas et al. 2007, 2008) and soil biology (Silva et al. 2020).

Although the older publication studied samples from Nelson Island, Elephant Island, and islands near Greenwich Island (Godoy et al. 1998), Brazilian research in the first decade focused on the ice-free areas of Admiralty Bay (Figure 11), focusing mainly on soil genesis, morphology, and mineralogy (Simas et al. 2006), but there are also early studies of bioremediation potential (Luz et al. 2006).

In the period from 2008 to 2011, research continued to focus on Baía do Almirantado, 90% of which involved exclusively researchers belonging to Brazilian institutions (Figure 12). They mainly studied pedogenesis under micromorphological (Schaefer et al. 2008) and pedogeomorphological (Francelino et al. 2011) approaches, in addition to studies on the effects of climate change on carbon mineralization (Carvalho et al. 2010) and comparison of analytical methods for cryosol chemistry (Guerra et al. 2010).

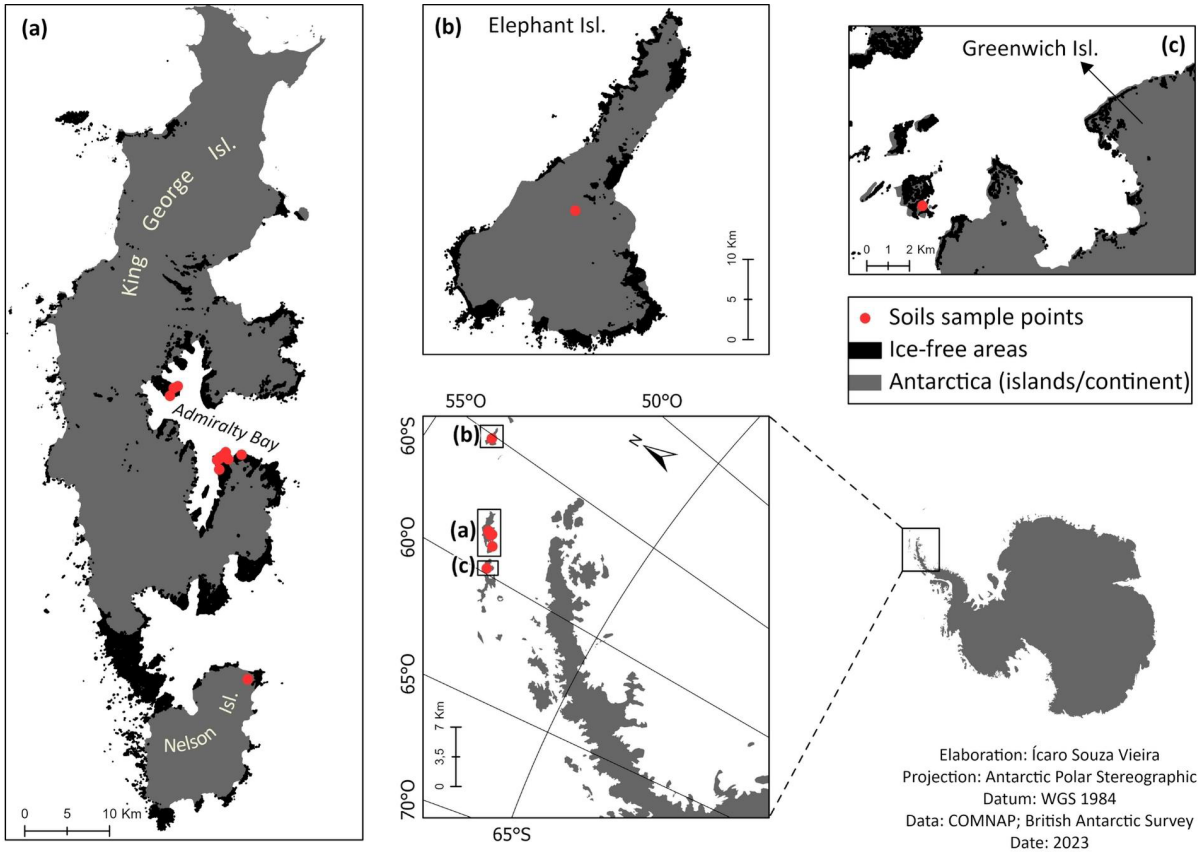

Figure 11. Map of location points in the 1998-2007 period. King George Island and Nelson Island (a); Elephant Island (b) and Greenwich Islands (c).

From 2012 to 2015 (Figure 13), research continued in Almirant Bay, particularly studies to quantify carbon dioxide emissions from soils in areas of glacial retreat (Thomazini et al. 2014, 2015) and to characterize the bacterial diversity of soils near the Brazilian station (Roesch et al. 2012).

Brazilian cryopedology has expertise in pedogeomorphological approaches to the study of the landscape. During this particular period, studies of soils and relief have been extended to other sites in the region, such as Fildes Peninsula (Michel et al. 2014a), Livingston Island (Moura et al. 2012), Hope Bay (Trinity Peninsula) (Pereira et al. 2013), and Potter Peninsula (Poelking et al. 2015).

Conducting studies in other regions of Antarctica has high added value in terms of autonomy and strategy in obtaining scientific knowledge. In this sense, the work on bioprospecting fungi in soils of the Ellsworth Mountains stands out (Godinho et al. 2015).

From 2016 to 2018 (Figure 14), the distribution pattern of points in the maritime Antarctic resembles the previous one, but in terms of thematic focus, research concentrated on monitoring the active layer on King George Island (Thomazini et al. 2016, Chaves et al. 2017) and on understanding biological activity in the soils of Trinity Peninsula (Schaefer et al. 2017b).

Studies that address bio-geo-chemical processes in the landscape, such as those by Pires et al. (2017) on the influence of nitrogen

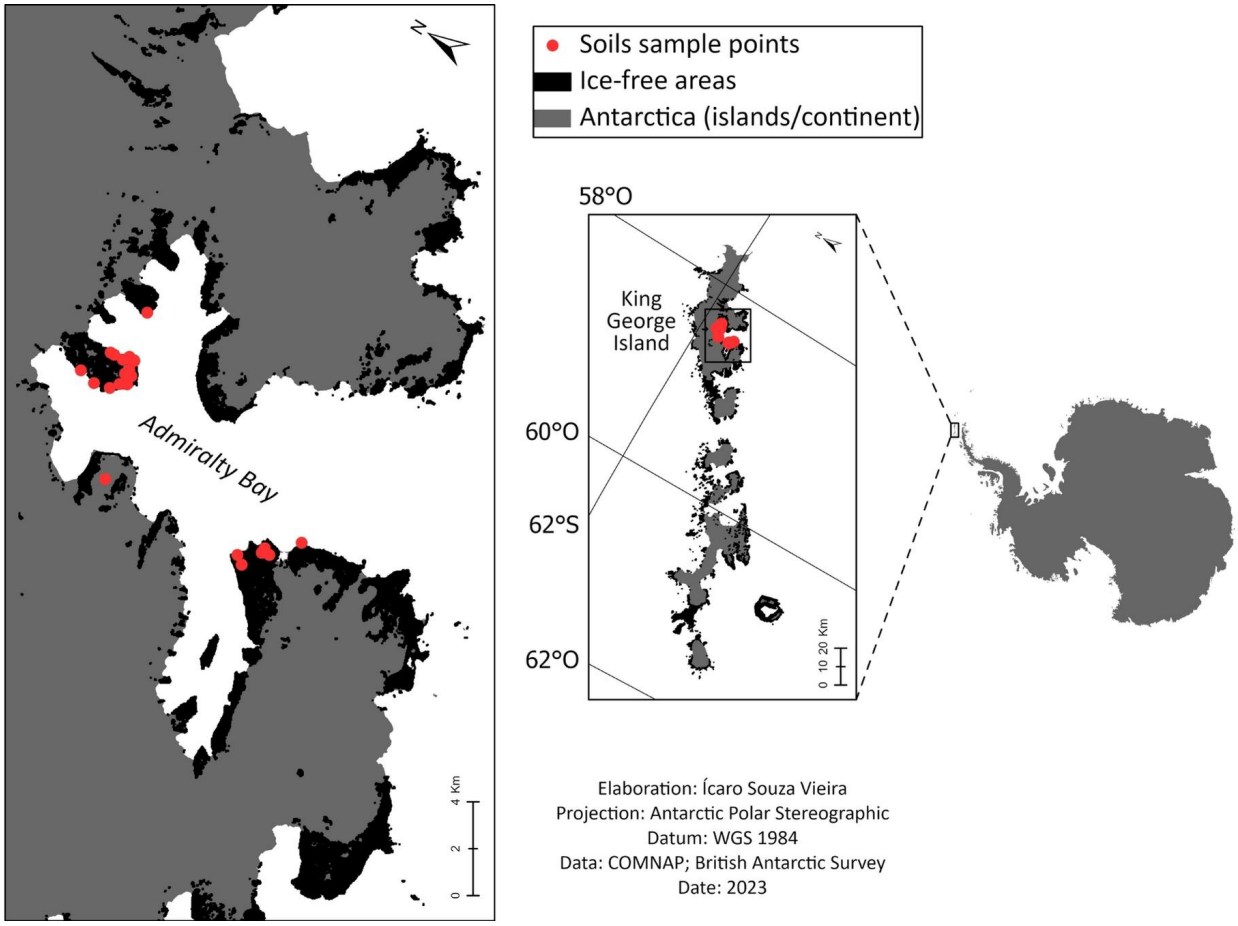

Figure 12. Map of location points in the 2008-2011 period.

and organic carbon on the emission of carbon dioxide in soils on the shores of Almirant Bay, and Thomazini et al. (2018), who investigated the structure of spatial variability of soil properties around the EACF, are worth highlighting.

In addition, soils in the valleys of the Ellsworth Mountains were studied using a pedogeomorphological approach (Delpupo et al. 2017, Schaefer et al. 2017a) and the ecology of the active layer at Edmonson Point in the Transantarctic Mountains in a partnership with Italian researchers (Papale et al. 2018).

In the most recent period from 2019 to 2021 (Figure 15), the focus has been on a more ecological view of soil from an ecosystem perspective based on "pedoenvironments" (Schmitz et al. 2020a) and "pedological landscapes" (Rodrigues et al. 2021) on Nelson Island and its relationships to vegetation on Elephant Island (Schmitz et al. 2020b). Biogeographic studies of Admiralty Bay (Ramos et al. 2019, Porto et al. 2020) and various islands of the South Shetlands (Silva et al. 2020) will also be conducted within this paradigm.

Research on soil elevation, classification, and formation from a landscape dynamics perspective is an integral part of Brazilian soil science and has led to notable work in recent years on Barrientos Island (Daher et al. 2019) and in the western part of maritime Antarctica, particularly in the James Ross Islands (Daher et al. 2019, Meier et al. 2019), Marambio (Gjorup et al. 2020), and Vega (Siqueira et al. 2021).

The spatiotemporal behavior of the research shows that over time Brazilian scientists have sought to expand the geographic scope of investigations both within the Antarctic Peninsula region and to other regions of the continent in their own initiatives, but also in

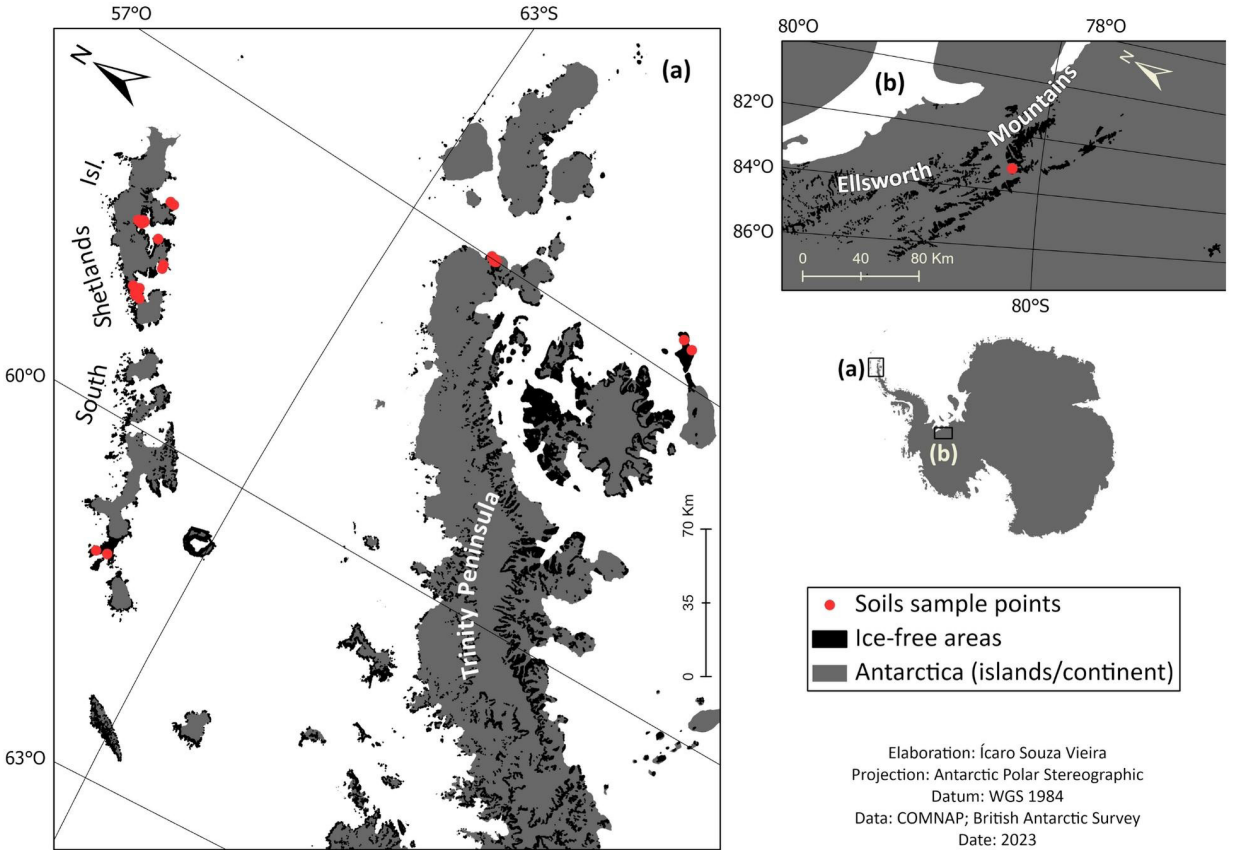

Figure 13. Map of location points in the 2012-2015 period. Northern Antarctic Peninsula (a); Ellsworth Mountains (b).

partnerships with other countries. The average distance between points and the Brazilian station was about 100 km, indicating maritime Antarctica as a focal region for Brazilian research.

Holistic approaches that integrate different landscape elements to understand their dynamics have emerged as a strong trend in Brazilian research on Antarctic soils. Studies related to bioprospecting and bioremediation of terrestrial ecosystems are also one of the research priorities.

Based on the analysis, it was found that there are many sites with potential for future research and consequent expansion of Brazilian knowledge on the pedological landscape of maritime Antarctica.

CONCLUSIONS

Despite possible limitations in the methods used, this study has shown that Brazilian studies make a significant contribution to the understanding of soils in Antarctica. By focusing the studies on data from only one country, it was possible to characterize the profile of Brazilian scientific production as productive, internationalized, and influential in the literature on Antarctic soils. This is a remarkable achievement that shows the tenacity of these scientists despite the budget and logistics difficulties of the Brazilian Antarctic Program (Gandra R.M., unpublished data, Andrade et al. 2018).

Moreover, the spatial extent of the research shows a remarkable knowledge produced and accumulated in Brazil on the subject, not only from a purely pedological point of view,

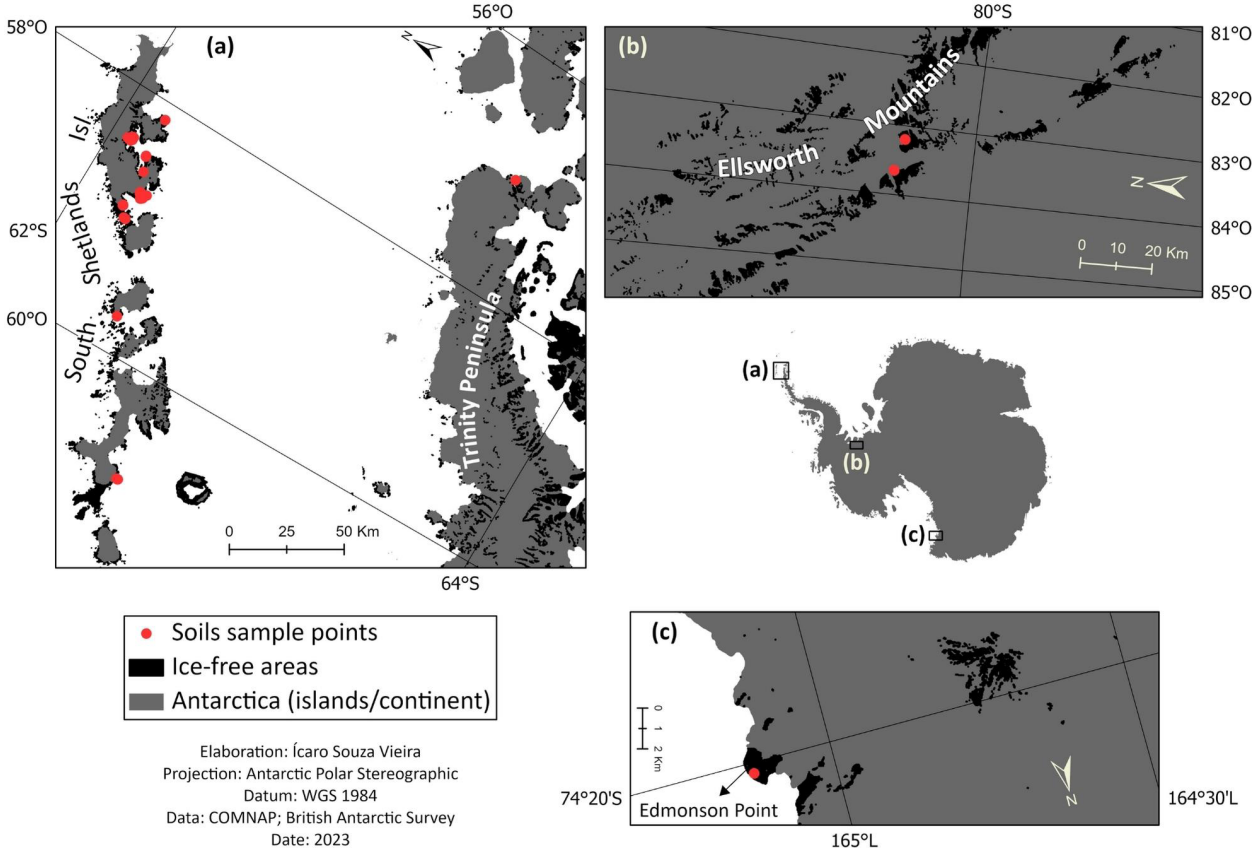

Figure 14. Map of location points in the 2016-2018 period. Northern Antarctic Peninsula (a); Ellsworth Mountains (b) and Edmonson Point in Victoria Land (c).

but also from geological, climatic, biological, anthropological, and geographical perspectives of maritime Antarctica and other regions of the continent. This knowledge is crucial not only for understanding the ongoing climate change, its impact on Antarctica and its influence on the Brazilian territory, but also for generating biotechnological patents that have enormous potential for applications in areas such as agriculture, food, pharmaceuticals, etc. However, it was possible to identify that many ice-free areas in Maritime Antarctica still lack research on soils, mainly in the southern and eastern portion of the Antarctic Peninsula.

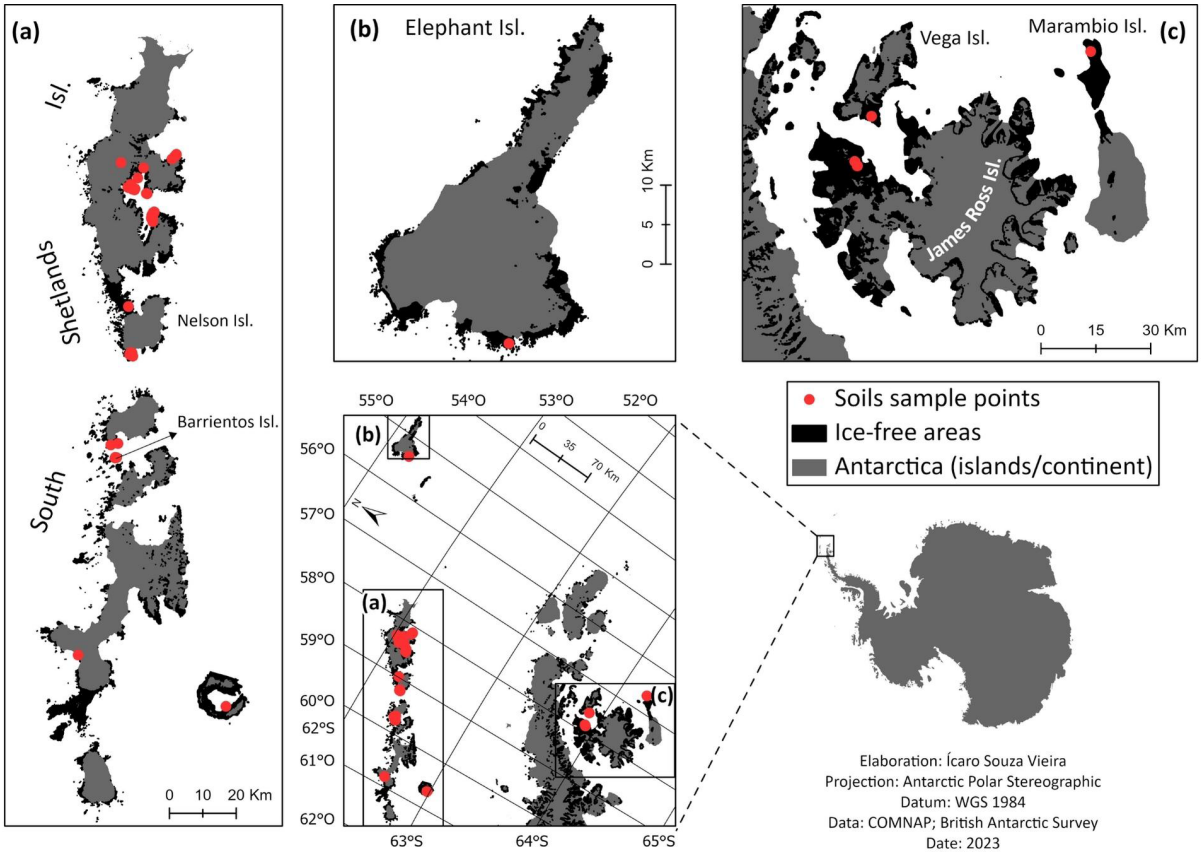

Figure 15. Map of location points in the 2019-2021 period. South Shetlands (a); Elephant Island (b); Islands east of the Trinity Peninsula (c).

Table IV. Publications and points by time periods.

Period	N. of pub.	N. of points	Exclusive pub.	Main Topics (frequency)
1998-2007	7	19	4	Soil Chemistry (3); GSM (2); PRR (2)
2008-2011	10	32	9	Soil Chemistry (6); Soil Biology (2); GSM (2)
2012-2015	28	54	15	Soil Chemistry (9); Soil Biology (6); GSM (4); Soil Physics (3)
2016-2018	21	68	13	Soil Chemistry (6); Pedometrics (5); Soil Biology (3); GSM (3); PRR (3); SSC (3)
2019-2021	19	52	15	Soil Chemistry (5); GSM (5); Soil Biology (5); SSC (4); Pedometrics (3)

SSC = Soil Survey and Classification; GSM = Genesis and Soil Morphology; PRR = Pollution, Remediation and Recovery of Soil. B

The research also call attention to the one of the key challenges faced by Brazilian Antarctic science: logistics. The accessibility to desired research areas remains a significant concern. In order to make progress, it is essential to contemplate the expansion of the logistics network. By addressing logistical limitations and improving access to remote locations, Brazilian scientists would have greater opportunities to explore new research sites, gather crucial data, and further enhance their contributions to the understanding of Antarctic environments and their multiscalar connections.

The world's most important research group on Antarctic soils (Núcleo Terrantar) is based in Brazil and makes important contributions in the areas of soil genesis, morphology and classification, pedogenomorphology, biogeochemistry and pedometrics. Other groups are making contributions in the topics of bioprospecting and bioremediation. These scientists face the challenge of strengthening research in areas and topics of increasing relevance in the current and future international scientific and environmental context. As the main country to study the Maritime Antarctic soils, Brazil has the potential to stand out in issues such as environmental monitoring and sustainable bioprospecting in the region and become an example for other countries.

The internationalization of scientific activities through various types of partnerships between countries brings benefits to the building of scientific knowledge and is a striking feature of Antarctic science as a whole (Brazil 1975). In this sense, another challenge is to maintain existing partnerships and establish new international partnerships with scientists from countries such as Russia, China, Germany, Australia, and South Korea.

In addition, the results of this study allowed us to look at the statistical and geographic behavior of scientific activity over time. This method can be applied at different spatial scales as long as there is sufficient data volume and coverage. The maps provided new insights into research priorities and the identification of new potential research sites.

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