

Geosciences research mapping for Portugal in the year 2023: standing and future challenges

Representação da investigação em geociências para Portugal no ano de 2023: posicionamento e futuros desafios

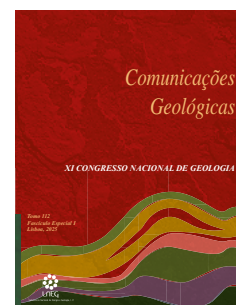
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Abstract: This study carries out a mapping of research topics in geosciences within the context of Portugal for the year 2023. The data for this analysis are sourced from 11 Research Centres and 4 other entities whose missions include research as their main objective. A bibliometric analysis is performed using the SCOPUS database for a sample of 103 researchers, with data collected in May 2023. A focus group is used, qualitatively assessing advanced or specialized knowledge about geoscience research in Portugal. Future constraints and challenges were highlighted, particularly with regard to changing research priorities and access to research funding. Guidelines for research in geosciences are presented from an ex-post point of view and in accordance with the instruments and research focuses in the European Union, namely those foreseen for Horizon 2030. The discussion raises ex-ante questions for the consolidation of geosciences in research centers and the expansion of knowledge to be produced by researchers.

Keywords: geosciences, research topics, bibliometrics, group of experts, Horizon 2030.

Resumo: Faz-se o levantamento dos tópicos de investigação em geociências em Portugal, tendo por referência o ano de 2023, recorrendo aos dados disponibilizados por 11 Centros de Investigação e 4 outras Entidades que, na sua missão, incorporam a investigação como objetivo. Realiza-se uma análise bibliométrica recorrendo à base de dados SCOPUS para uma amostra de 103 investigadores, com toma de dados a maio de 2023. Utilizando um grupo focal avalia-se qualitativamente o conhecimento avançado ou especializado sobre a investigação em geociências em Portugal, seus condicionamentos e desafios futuros, nomeadamente na mudança de focos de investigação e no acesso a financiamento. Apresentam-se os referenciais para a investigação em geociências a partir da visão ex-post e em função dos instrumentos e focos de investigação na União Europeia, nomeadamente os previstos para o Horizonte 2030. Na discussão suscitam-se questões ex-ante para a consolidação das geociências nos Centros de Investigação e a amplificação do conhecimento produzido pelos seus investigadores.

Palavras-chave: geociências, tópicos de investigação, bibliometria, grupo de especialistas, Horizonte 2030.

1. Introduction

The historical sciences of nature, in the sense of Potapova (1968), correspond to the understanding of the materials, processes and products of planetary evolution, as well as their multiple relationships, allowing the establishment of systemic interfaces. This consideration follows the meaning of geology by Thomas (1947), as a properly organized branch of natural knowledge, based on the observation, collection and correlation of information, which is sequential to the ancestral definition of Lyell (1830) in which the Geology is a science that arises from the comparison of past phenomena of change observed on the surface and within the Earth's crust. More recently, the consolidation of the systemic perspective of the planet, which allows identification of the different spheres of planetary organization, has made it possible to establish dynamic patterns for natural processes and to explore a holistic vision of the planet where the different branches of geosciences have expression (Mackenzie and Mackenzie, 1995; Orion, 2017). Different authors underline geology as the most logical starting point for understanding environmental issues (Montgomery, 2013), whether the approach highlights the role of materials, processes or territory. A line of thinking considers that geoscientists have a valuable conceptual, synoptic and temporal framework that allows them to assess the sustainable viability of life on Earth (Stewart and Gill, 2017; Vasconcelos and Orion, 2021; Peppoloni and Di Capua, 2021), and make accessible the knowledge of how Earth systems respond to disturbances (Howard *et al.*, 2009; Parr *et al.*, 2019; Tavares, 2020).

Research in geosciences is highlighted by Gerasimov (1970) as enabling the improvement of interrelationships between humanity and the environment, requiring a shift away from predominant research directions in favour of interdisciplinary approaches. Knowledge gains value when it can support decision making (Howard *et al.*, 2009).

Geosciences, like any other science, progress by addressing major questions and unresolved problems, both theoretically and methodologically (Sorkhabi, 2022). The creation of geoscientific knowledge and the interaction of its content with stakeholders is essential to affirm its relevance (Phillips, 2012).

Recent developments suggest that geoscience research has entered an era of big data with global coverage, comprehensive weather monitoring, and the observation of all elements (Zhou *et al.*, 2021). Many of the major questions in geosciences require multiple perspectives or methods, allowing understanding the evolution of our planet and how to provide vital resources and a safe environment for the world (Sorkhabi, 2022).

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The future of science and social needs will determine the value of long-term investment in research (Boyack, 2005; Klavans *et al.*, 2020), and it is pertinent to know whether investment in science produces prominence, achieves economic returns, or produces transnational linkages (Leydesdorff and Wagner 2008). Investments in R&I, both short and long term, strengthen and build resilience against future threats and disruptions, which include strengthening social and local innovation and bringing people with diverse backgrounds together for a common purpose (EU DGRI, 2023).

Based on theories of scientific change, scientific mapping offers a new and useful means of unravelling the historical development of fields of study (Hallinger and Kovačević, 2019). It is, therefore, about building metrics through scientific mapping with own methodologies and records (Ha *et al.*, 2020; Jurado de Los Santos *et al.*, 2020). The scientific mapping study typically consists of several components, namely a body of scientific literature, a set of scientometric and visual tools and indicators that can highlight significant patterns and trends, which can guide the interpretation of research patterns (Small *et al.*, 2014; Chen, 2017).

The main objective of this article is to describe geosciences research carried out in Portugal using the science mapping and a forum of experts. The discussion seeks to understand the constraints and envision the future.

2. Research mapping setting

Fundamental geoscience research aims to understand the global Earth system and to address problems of particular relevance to the welfare of the Earth's human population (IUGS, 2012). However, the geoscience discipline may have become too narrow to deal with complex environment and questions, requiring that Geoscientists acquire a stronger voice in policy spheres. On topics of global scientific debate, such as energy, clean water, cities or sustainable consumption, the geoscience community is often missing <https://www.geolocal.org.uk/futuregeosummit>. At the same time, the EU Agenda for R&I 2021-2027 (EU-DGRI, 2021) is based on three pillars, considering support for research focused on global challenges and Europe's industrial competitiveness. This encompassed support for research focused on social challenges, systematized in 6 themes: 1 – Health; 2 – Culture, Creativity and Inclusive Society; 3 – Civil Security for Society; 4 – Digital Transition, Industry and Space; 5 – Climate, Energy and Mobility; 6 – Food, Bioeconomy, Natural Resources, Agriculture and Environment. Support for research is presented in Missions and have goals for 2030, which are associated with: A – Adaptation to climate change, including social transformation; B – Combating Cancer; C – Healthy oceans, seas, coastal and inland waters; D – Smart cities and climate neutrality; E – Soils and food health (EU, 2021). In a complementary way. The Horizon Europe strategic plan 2025-2027 (EU-DGRI, 2023) explores 11 key areas for R&I. These aim to respond to deep dives into disruptive trends and contexts, exploring other potential disturbances or supporting future ecosystems dealing with resources and related technologies. Geosciences can also be seen as the science that include atmospheric and marine sciences, geography, geology, geophysics, among others, and use a spatio-temporal multiscale, and appeal to intense data integration (Zhou *et al.*, 2021).

Research in geosciences in Portugal is based on different research centres, recognized and funded by the Foundation for Science and Technology. These research units are structured in lines or areas, where integrated researchers and collaborators are distributed, with the first ones representing around 450 researchers dedicated to geosciences or geological topics. In addition to these structures, other public agencies which assume in their mission and objectives the carrying out of

research in geosciences are identified. Research centres have different configurations, are generically multi-thematic, where research in geosciences *sensu lato* can be dominant or a part individualized or scattered in lines or areas. The Research Centres that present more naturalistic, applied or technological development focuses in geosciences are the Dom Luiz Institute – IDL, the Geosciences Centre – CGEO, the Institute of Earth Sciences – ICT, the GeoBioSciences, GeoTechnologies and GeoEngineering – GEOBIOTEC, the Centre for Earth and Space Research – CITEUC, the Research Institute for Volcanology and Risk Assessment – IVAR, the Centre for Natural Resources and the Environment – CERENA, the Marine and Environmental Sciences Centre – MARE, the Hercules Laboratory – HERCULES LAB, the Marine and Environmental Research Centre – CIMA and the Centre for Environmental and Marine Studies – CESAM. The identified public agencies that carry out research in geosciences are the National Laboratory of Energy and Geology – LNEG, the Portuguese Institute for the Sea and Atmosphere – IPMA, the Portuguese Space Agency – AEP and the Portuguese Mining Company – EDM.

3. Material and methods

To assess the bias of research in geosciences, a science mapping methodology was used (Chen, 2017; Hallinger & Kovačević, 2019; Ha *et al.*, 2020). The description of the mission and objectives, as well as the lines or areas of research structuring, were collected from the web pages of each of the research centres or agencies. The information from the 15 research institutions was subject to content analysis, carried out using the MAXQDA 2022 program, applying the yEd Graph Editor for the graphical representation of the results and categories obtained. This was followed by a second phase of analysis with a more restricted sample (CGEO, CITEUC, GEOBIOTEC, ICT, IDL, IVAR), representing those where research in geosciences seems to be dominant.

In order to analyze the scientific production of a sample of researchers integrated in the research centres, a survey was carried out from the SCOPUS Database, in May 2023. The sample focused on the researchers integrated in the 11 research centres, starting from the central researcher in the organization of the Centre's members, and a secondary criterion the successive selection for a representativeness of 20%, adjusted to a minimum of 4 researchers per Centre, which resulted in a final sample of 103 researchers. These appear to represent around 22% of recognized researchers in geosciences in Portugal. For this group, a bibliometric analysis of the number of publications, the h-index, the number of citations and the number of co-authors was carried out. An analysis was also implemented of the journals most used for publication by the researchers, considering those in which there are at least 5 publications by the researcher. The topics that characterize the set of publications of each author were also mapped.

The Promoting Geosciences session that took place at the XI National Congress of Geology (July 2023) gathered a group of experts, who publicly and in the form of a focus group, presented a set of ex-ante issues for the consolidation of the research entities and the amplification of the knowledge produced by their researchers. The questions focused on: 1 – Recent developments in R&Di activities in Geosciences and the main research themes that will be consolidated in the next decade; 2 – Financing difficulties for R&Di activities in the Centres/Agencies and expectations/ways of reinforcing investment, national and non-national, for Geosciences; 3 – Mechanisms to better articulate research, development and innovation in Geosciences with the EU Horizon Europe 2025-2027 Plan, the Societal Challenges and the United Nations SDGs. After the interactions, a summary of the conclusions was carried out, valuing two axes of analysis: on the one hand the main threats and constraints, but also the potential and opportunities for geosciences research and development.

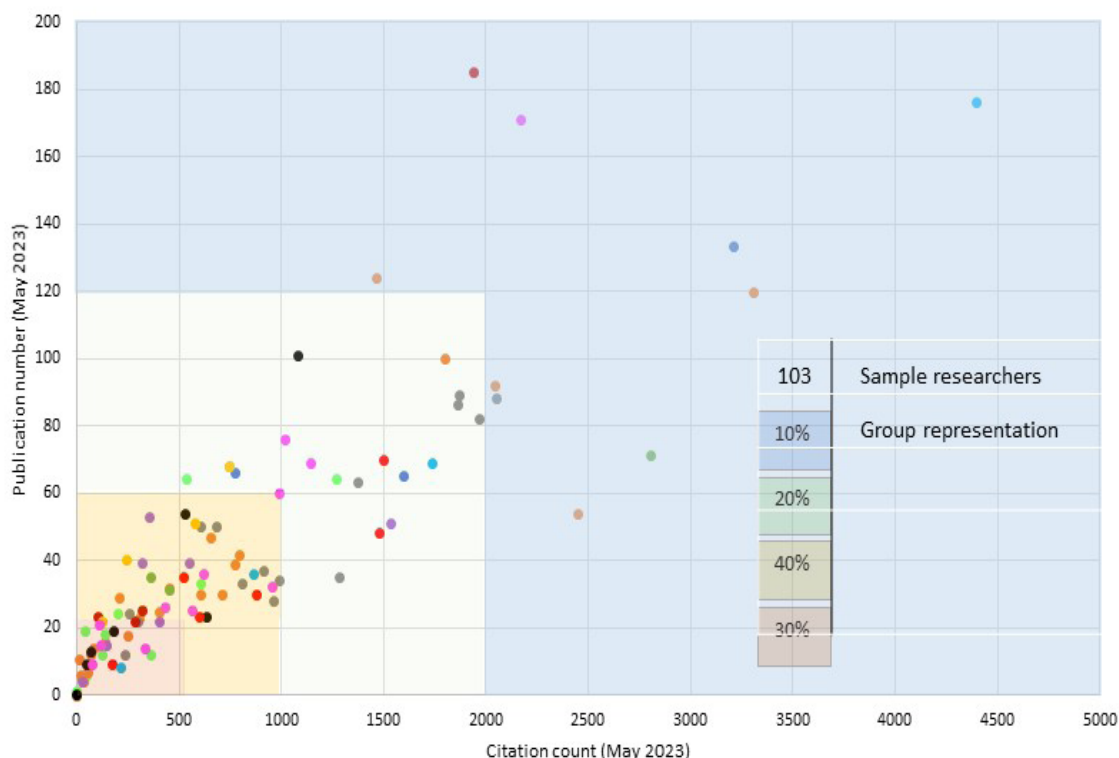


Figure 3. Number of publications and citations in the SCOPUS database (each color represents one of the 11 research centres).

Figura 3. Número de publicações e citações na base de dados SCOPUS (cada cor representa um dos 11 centros de pesquisa).

publication networks by co-authorship, it is possible to identify that there is a clear match with the number of citations, with a maximum value of 710 co-authorships. There is an average value of 109 co-authorships per researcher. When compared with an average number of 37 publications per researcher, it highlights a lower number of co-authors per publication, especially when compared to other research areas.

4.2. Geoscience advanced knowledge via a focus group

The results are now presented to the forum of experts, when faced with questions about the financing of research in geosciences, the notoriety of research for society in general and the future challenges for geosciences.

The experts' forum recognized the low notoriety of geosciences in various public dimensions: among political agents, research and development financiers, and the media. This low recognition can be considered structural and must be opposed through the participation of researchers and research institutions in projects and programs with social impact, as well as in challenges linked to the real economy.

The experts, individually or collectively, highlighted relevant topics to increase the importance of geosciences such as: the energy transition (sources and storage) and its relationship with climate change; waste management, risks and environmental remediation; resource management, particularly water resources; the protection and enhancement of coastal areas, marine environments and resources; the management of natural risks; the geoinformation in the access, organization and management of databases; the geological heritage and geoconservation.

To consolidate access to sources of financing, experts highlighted the need for alignment with societal challenges, namely the United

Nations SDGs, the increase in interpersonal and interinstitutional networks for research, development and innovation, as well as alignment with causes such as sustainability of mineral, water and energy resources.

It was highlighted that public recognition of the role of geosciences is crucial and must be promoted through the involvement of researchers in the value chains and circularity of resources. It was emphasized the internationalization in networks involving disruptive projects to respond to societal challenges and participate in the global energy paradigm changing. Only with these goals will it be possible to access funding resources for research and attract new professionals and researchers for geosciences.

Threats to the role of geosciences in today's society include the aging of academic professors, researchers and professionals in geology and applied areas, associated with precarious employment and the devaluation of working conditions. The lack of investment and renewal in research infrastructures is another major concern.

It was also highlighted that the media, stakeholders and other opinion leaders must be mobilized and made aware of the value of geosciences in a changing world. The hostile discourse regarding some areas of intervention must be overcome, valuing others such as the environment and geoheritage, as well as the role of geosciences in public policies and citizens' quality of life.

5. Discussion

The presence of geosciences in the multithematic or multidisciplinary research centres can be considered as imposed by the research system in Portugal, not being common to other areas of scientific research. When discussing if, in this format, geosciences have an aggregating role in research centres, a recognized role of complementarity, or whether it is

an association of instrumental convenience, the answer is not clear. If in some centres the aggregating role seems to be the present trend, a more detailed analysis makes it clear that other topics in the neighbourhood are taking edge (atmospheric sciences, energy, heritage or materials' conservation). In some cases, the presence of geosciences in multithematic conglomerates seems to result from an instrumental decision, based on higher education institutions. This assemblage should be used as an affirmation of the importance of geosciences and enabling researchers to establish networks and build bridges for research on topics for society, going beyond disciplinary dimensions and promoting new multidisciplinary challenges, or creating interdisciplinary scientific knowledge.

When trying to understand the organization of research centres into lines or thematic areas, the question arises whether these forms are organizational to federate researchers, descriptive of the scientific research carried out, or whether they are prospective for research and development projects? It is clearly the descriptive dimension that prevails in the different research centres and, on a second level, the role of bringing together researchers. The prospective dimension in the organization does not seem to be the structuring one. However, at the level of description of areas or lines, the ambition to call upon global and transversal science challenges (climatic change, heritage conservation, energy transition, resources exploitation, geospatial data information, among others) is often present.

In the bibliometric analysis of researchers' publications, there are standard-bearer researchers in each centre, who stands out above an average response. Citations of publications in Geosciences have impacts below the average of other scientific disciplines, resulting from the limited number of researchers' publications with more than 100 citations. This difference in comparison to other scientific disciplines (Parish *et al.*, 2018), also results from the global average of citations for the researcher sample being around 11 citations per publication.

When compared to other scientific areas, publications in geosciences have a greater citation longevity, with a drop-in citation time less evident than in areas such as biology, physics, chemistry or engineering.

The assessment of geoscience publication topics in relation to societal references and research paths shows three distinct trends: global problems using earth science methodologies; technological developments and models based on case studies; multidisciplinary approaches in which the signature of geosciences is barely evident.

The reduced notoriety of geosciences in the media and the apparent inability of professionals to get involved in societal challenges is not evident when analysing the areas and topics of research centres and the topics of the most used publications. What seems to be missing is to present objectives in which geosciences are fundamental and affirm that their researchers and professionals use ethical values and contribute to a safer, more sustainable world with a better quality of life.

6. Conclusions

Geoscience as other sciences is supposed to create a mirror of the real world, and the researchers' observations comprehensible and communicable to other humans (Suominen and Toivanen, 2016). The current biggest challenges geoscientists face are how earth systems respond to disturbances, changes in boundary conditions, or external inputs of matter and energy (Phillips, 2012). The question of whether investment in geosciences pays off in terms of prominence and reputation, economic returns or emergence of problem solving will provide answers for funding. As pointed out by Klavans *et al.* (2020), the future science and social needs will determine the long-term value of investment. Figure 4 presents the useful migration for research in geosciences, towards a strategy based on answering real world problems. Only this way, with an adaptation to the EU's funding focuses, will geosciences be able to inform public policies (European Commission, 2014, 2023). Eleven social challenges for geosciences are presented, which fit into the financing instruments, are recognized as social needs, are fundamental to public policies and, at the same time, the community of geoscientists seems to agree with their relevance.

This general analysis allows us to consider that the challenges facing geosciences will be crucial for researchers, academics and professionals. Young researchers and professionals from a global world will carry out essential research focused on solving real problems for future society, basically affirming geosciences on the right side of science. Perhaps one of the strengths of future geosciences is the ability to create interdisciplinary networks and forms of knowledge, in which research entities in Portugal have a consistent path.

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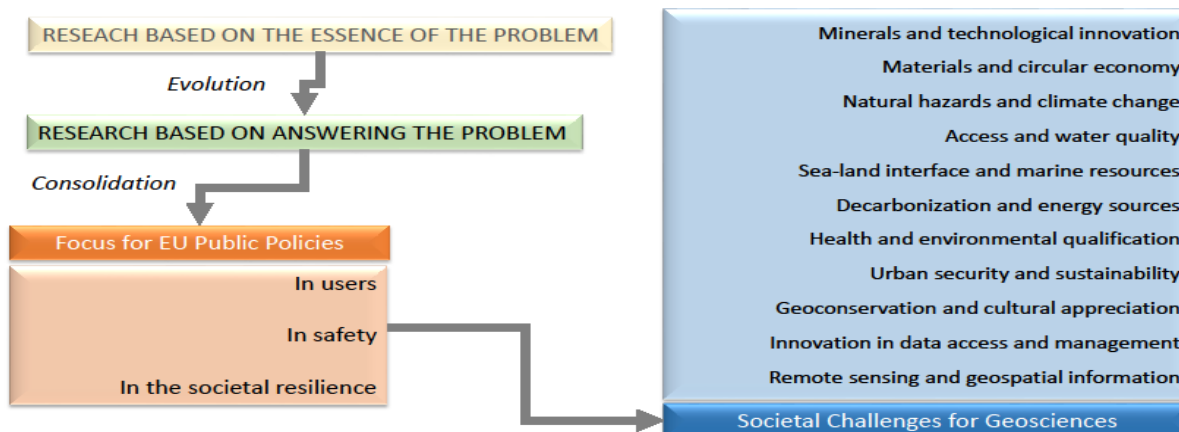


Figure 4. EU Research focus and societal research challengers for geosciences.

Figura 4. Focus de investigação na UE e desafios sociais para a investigação em geociências.

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