Journal on Interactive Systems, 2024, 15:1 doi: 10.5753/jis.2024.3824

Eleven years of WCAMA (2013 – 2023): A Comprehensive Descriptive and Meta-Scientific Analysis

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Received: 08 November 2023 • **Accepted:** 02 August 2024 • **Published:** 06 September 2024

Abstract: CSBC is the biggest scientific event dedicated to computing in Latin America, integrating Brazilian computing and driving the area in the country. In one of its satellite events, WCAMA combines computing with the management of the environment and natural resources, an essential theme for Brazil. The analysis of the last eleven years of WCAMA (2013 – 2023) exposes a relevance in the theme of beekeeping, it also notes a limited number of broad collaborations, with the most prolific authors in a low number of collaborations. Several collaborations transcend national universities, involving environmental institutes or international institutions.

Keywords: WCAMA, Meta-science, Natural Resources, Ecoinformatics, Social Network Analysis, Brazilian Computing

1 Introduction

In 2023, the Workshop on Computing Applied to the Environmental Management and Natural Resources (*Workshop de Computação Aplicada à Gestão do Meio Ambiente e Recursos Naturais* – WCAMA) reaches its fourteenth edition, and both presents itself and exposes the relevance of its related area:

> "The Workshop on Computing Applied to the Environmental Management and Natural Resources (WCAMA) aims to promote integration between the areas of Computing (methodologies, techniques and tools) and Ecology (definition of policies and environmental management). Natural resource management is a complex and extremely dynamic activity, which requires integration between actors from the social, political and technological areas to be carried out effectively. Structuring viable national and international environmental policies is essential in this context. The diverse fields within Computing can provide detailed insights into these policies, assist in their implementation and maintenance, and monitor their consequences and effects. The term Ecoinformatics [...] has been widely used by the scientific community, and seeks to use computational methods to manage and study data from the areas of ecology, natural environment and resources, as well as develop and simulate models of environmental phenomena." [1]

The intersection of environmental management and natural resources dates long and crosses the international and Brazilian scenery. On the international scenery, as already pointed out by WCAMA, we have academic-scientific movements such as *ecoinformatics* [Recknagel and Michener, 2018] or *Green IT* [Velte *et al*., 2008], maturing since the beginning of the 21st century. It is possible to position WCAMA as a potential, fruitful, and pioneering national academic-scientific space to debate, discuss, and communicate research on this topic, given the abundance and richness of the Brazilian environment and natural resources known worldwide (and recognized).

In alignment with sustainable advancement and the notion that natural issues are urgent or crucial, the Brazilian Computing Society (SBC) launched the document "Digital Technologies for the Environment. SBC Manifesto" [Clua *et al*., 2022] pointing out that the sustainability of our planet is everyone's duty, extending the epistemic phenomena central to WCAMA to everyone. Part of those actions requires quality research, development, and science, which WCAMA has managed for over ten years. In addition to its publications, WCAMA involves researchers, research or development institutions, and their respective qualities and properties.

In issue number 50, from July 2023, of the Brazilian Computing Society magazine, *Computação Brasil*, WCAMA is one of the main objects in an article. Authored by Marilton Sanchotene de Aguiar, Diana F. Adamatti and Raquel de Miranda Barbosa, some meta-scientific and technological data are mapped through publications and data from the event, presented as follows:

> "As natural resource management is a complex and dynamic activity, it requires integration between actors in the social, political, and technological fields to be effectively developed and implemented. In this scenario, WCAMA seeks to discuss from a computing point of view the development of methodologies and tools for managing the environment and natural resources, working towards efficiently handling: a) management and communication between large volumes of data; b) the development of techniques for analyzing this data; and, c) optimization, control and integration of generated data.

[1] `https://csbc.sbc.org.br/2023/wcama/` [our translation] [access 04-04-2023]

> The workshop covers all areas of research and applications in methodologies, techniques, and computational tools applied to the management of the environment and natural resources, including, among others: priority areas for conservation; biodiversity; environmental education; management of natural and renewable resources; species distribution modeling; modeling of land use and cover change; environmental monitoring; global environmental changes; soil, noise and environmental pollution; environmental sanitation and waste treatment; health and environment; and, sustainability." [our translation] [de Aguiar *et al*., 2023]

In the traditional scientific context, the advancement of science is mostly anchored in formal scientific publications and communications [Agassi, 2008]. We present a materialist vision through other variables [Latour, 1987; Lefèvre, 2005], with a meta-scientific emphasis [Ioannidis *et al*., 2015; Ioannidis, 2018] and an analytical-descriptive approach [Marconi and Lakatos, 2017; Wazlawick, 2014]. Here, we consider that the intersection between computing, environmental management, and natural resources is developed by other factors and dimensions, overflowing only its publications, namely authorship, gender, institution/affiliation, institutional geolocation, language, and abstracts + keywords.

This work presents a meta-scientific research [Ioannidis *et al*., 2015; Ioannidis, 2018] on WCAMA. Self-examination of one's network or community is valuable to understanding the elements surrounding and making up the research applied to particular topics. As an objective, we **present a descriptive analysis based on Social Network Analysis (SNA) and statistics on data and metadata from the last decade of WCAMA, through its publications, involving diverse available, possible, and valid data**. This research category permits the absence of research questions or hypotheses [Marconi and Lakatos, 2017], with an emphasis on the information and knowledge generated; we expose the panorama of a decade of WCAMA as a meta-scientific contribution describing the scenario of environmental management and natural resources and computing in Brazil.

Similar works analyze Brazilian academic-scientific communities and spaces meta-scientifically [Ioannidis, 2018], such as [Lobato *et al*., 2021] and [Digiampietri *et al*., 2017] about the *Brazilian Social Network Analysis and Mining* (BraSNAM) workshop. The examination of oneself, involving formal and structured analyses, evaluations, and perceptions; allows network(s) or community(ies) to mature, make evidence-based decisions, and identify themselves objectively [Ioannidis *et al*., 2015]. To the best of our knowledge, this is an unprecedented work with this approach to Brazilian environmental management, natural resources, and computing, specifically, WCAMA.

Section 2 exposes the method, materials, and essential information; Section 3 presents the results; and Section 4 provides final considerations.

2 Method, resources, data sources and concepts

Data were collected for analysis from the *CSBCSet* [Filho *et al*., 2023], a dataset representing publications from 2013 to 2022 in the Congress of the Brazilian Computing Society (CSBC). We start with the attributes: Year, Event, Edition, Author, Gender, Institution 1, UF Inst. 1, Institution 2, UF Inst. 2, Language, filtering by "WCAMA" event.

The methodology is explained below in depth, in Section 2.3. In each analysis, e.g., quantitative or statistical, we detail the procedures in the specific moment accordingly and conducted methods and approaches in SNA [Tabassum *et al*., 2018]. We treated WCAMA as a whole and analyzed each year separately. For better visualization, we made the resulting artifacts available online in Section 5, also containing the specific WCAMA dataset metadata between 2013 and 2022, complementing Filho *et al*. [2023]'s work.

2.1 Ethical aspects

Carvalho *et al*. [2023d] present similar discussions, given the same nature and research protocols. When conducting our research, we faced an ethical dilemma regarding whether to keep the authors' identities anonymous [Latour, 1987; Lefèvre, 2005]. Our analysis of WCAMA emphasized the crucial role played by the authors in implementing, supporting, and managing the event. Any publications outside 2013 and 2023 are beyond our scope.

From a moral standpoint, there are no specific justifications or basis for anonymity according to the governmental and institutional guidelines governing ethics in Brazilian research [Brasil, 2016] or in general ethical research inquiries [ANPEd, 2019; Bos, 2020; London, 2022]. The data we utilized is openly and publicly available on SBC SOL. Our focus is on promoting the core activities and highlighting the materialistic value of academic-scientific work without involving sensitive, potentially harmful, or personally identifiable information. This study falls under the category of secondary research, explicitly addressing meta-scientific data. It is customary in this type of research to discuss authorship, such as identifying the most productive authors in a particular research topic.

Importantly, we refrain from making moral judgments or assigning value to individual analyses, as our initial intention is to provide a descriptive census. For example, if an author has the highest number of WCAMA authorships, it is an objective and factual observation. We intentionally avoid making statements like "this is the best author" as this would introduce subjective value judgments, which are not within the scope of this study.

Furthermore, interested authors, particularly those pursuing an academic-scientific career, can use this data or information to their advantage, such as for career promotion. However, we extensively debated the potential material and tangible negative consequences from an ethical standpoint, disregarding moralistic idealism based on relativistic ethics (e.g., personal preferences or dislikes). Despite careful consideration, we could not identify justifications significant enough to warrant anonymity, disclosing the names associated with the available open data. Given the values and nature of academic-scientific work [London, 2022; Bos, 2020; Latour, 1987], pursuing supposed "privacy" or "confidentiality" despite rational justifications may raise moral concerns.

In the format of a question, we expand on some of the possible ethical or moral sticking points we raised in discus-

sions. *"Considering that this work exposes people's names, should it have been submitted, assessed, and approved by a Research Ethics Committee?"* No. The data is public and openly available on the SBC SOL platform; it is exempt from consideration by the CEP system. The exemption occurs through Article 1, items II and III [Brasil, 2016].

"Can the content exposed here arouse negative emotions or feelings in the people involved in the analyzed and structured information?" The content exposed here, the analyzed and structured information, is objective and factual data from reality. They represent the professional and specialized practice of the people involved, who are conscious, rational, and with a sense of responsibility when agreeing to the terms of publication and related dynamics. None of the data exposed deals with subjectivity, private experiences, or intimacies. Despite the real risk, although probabilistic small, of someone feeling sadness, resentment, and hurt, among others, when perceiving what is present in this work, these phenomena are beyond our reach and responsibility. On the other hand, within our reach and responsibility, we make significant efforts to present valid, true, and effective knowledge. The knowledge exposed here can also awaken positive phenomena, such as joy, satisfaction, and self-worth, which also cannot be discarded when it comes to ethical assessment.

"The people identified in this work did not expect their data to be used this way." By agreeing and accepting the publication terms that culminated in the publication and dissemination of these scientific communications, people, consciously, rationally, and with a sense of responsibility, granted their data for public exposure, allowing other analyses and scientific studies to be carried out. What we did, intending a meta-scientific advance related to WCAMA and with the best intentions possible, was to organize, structure, combine, concatenate, and share this data. It also allows others to carry out other relevant analyses, studies, or interpretations. Therefore, we highlight and positively value WCAMA researchers. Based on the principle that occupation and academic-scientific work are valuable, valued, and positive for society [Bos, 2020], exposing it objectively and facts is a reason for self-worth. It is a scientific source of appreciation for the work of professional researchers [Lefèvre, 2005].

Are we seeking neutrality? No. No scientific communication is ethically neutral [Babbie, 2021], regardless of whether we anonymize the names of the authors or not. Scientific communication must be oriented towards objectivity, moral advancement [Vázquez, 2018], and research ethical requirements, e.g., avoiding damage and harm to those involved [Brasil, 2016]. During the several rounds of discussions on this aspect, we analyzed many potential biases, both positive and negative. Ultimately, based on the arguments in this section, we decided to opt for non-anonymization. Our choice for non-anonymization was not neutral and was rationally and consciously deliberate considering all the positive potential, as opposed to the negligible negative. For example, when we mention that researchers can use the data presented here as a structured, published, and validated academic-scientific basis for career promotion or memorial; build new research ties and connections; perceive gaps or academic-scientific spaces to be explored; perceive potential institutions for connection or affiliation, among others.

2.2 Graphs and Social Networks Concepts

In order to gain a comprehensive understanding of the various aspects of WCAMA, we utilize social network theories to characterize and model complex interactive systems [Barabási *et al*., 2002]. Within the WCAMA community, researchers from diverse institutions interact with one another. A co-authorship social network can represent these interactions, where authors who have collaborated on publications figure as nodes in a graph [Brandão and Moro, 2017]. The graph's edges depict the co-authorship relationships, as illustrated in Figure 1. Nodes with similar colors may indicate shared characteristics, such as researchers affiliated with the same institution. Analyzing social networks enables the investigation of distinct behaviors and characteristics within academic communities [Barabási *et al*., 2002; Brandão and Moro, 2017].

A common way to represent a social network is by using graph theory. A *graph* is a mathematical representation of a network. We can define a graph G as an ordered pair (V, E) between a set of nodes V and a set of edges E. In the case of this study, G is an undirected graph, which means that an edge e from E does not inform which direction it must follow. G can also have weight i, which means the sum of $e_{nm1}, e_{nm2}, ..., e_{nmi}$ existing edges between a pair of nodes n, m from V.

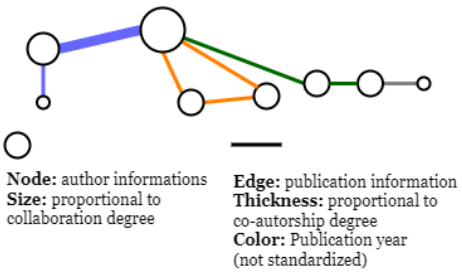


Figure 1. A social network model.

Studying academic interactions can assist researchers in finding collaborators or exploring citation relationships [Kong *et al*., 2019]. Examining academic and social networks to uncover innovation systems' structure, evolution, and dynamics offers a different dimensional perspective [Dahesh *et al*., 2020].

Throughout this work, several definitions and concepts from SNA are pertinent [Tabassum *et al*., 2018; HabibAgahi *et al*., 2022]. For example, the *giant component* refers to a sub-graph within the leading network that contains the largest number of interconnected nodes, providing insights into the network's cohesion or fragmentation. The *degree* of a node n is the number of edges connected to it and can be represented as:

$$k_n = \sum_{\iota=1}^{\mu} A_{n\iota} \tag{1}$$

where $A_{n\iota}$ is the matrix representation of graph G that has μ nodes. The clustering coefficient represents the likelihood

of a node n forming connections within its community, reflecting the tendency of its neighbors to connect. We can define the clustering coefficient C_n for a node n as:

$$C_n = \frac{2L_n}{k_n(k_n - 1)} \tag{2}$$

Where k_n represents the degree of n, and L_i is the number of links between the neighbors of n. Such as, C_n will be 0 if none of the neighbors link to each other or 1 if the adjacency nodes of n are all connected.

The diameter refers to the shortest path between two nodes with the greatest distance in the network. Density measures the proportion of existing connections to the total possible connections in the network. Lastly, a clique signifies a complete sub-graph within the network where all nodes are interconnected.

In this study, we represent the authors through graphs and their collaboration through the papers collected. As represented by Figure 1, we represent each instance from the author's group as a node, and we represent as edges each paper produced by a group of authors. The authorship, gender, and institutions analysis in sections 3.3, 3.4 and 3.6 represents the results after using the data as a graph or tabular. Since each author is a node in the graph, most authorship analyses use the node degree in equation 1.

For gender analysis, we apply for each edition of WCAMA the equation:

$$\text{Articles per Gender} \sum_{year=2013}^{2023} n_{gender} \tag{3}$$

Where n is a node from the author's graph, and *gender* is the biological gender of an author, which can be three different values. Analogously, we apply the sum operator for each author's institution to get the total number of papers per institution in WCAMA history. In this case, specifically, we change the representation of the node, using institutions as nodes and edges still the articles. In this scenario, we explore the collaborations between institutions and use the degree metric to count the number of works by institution. We can still use the sum operator to get the total number of publications per institution like the following equation:

$$\text{Articles per Institution} = \sum_{year=2013}^{2023} k_n \tag{4}$$

Where *n* is a node that represents an institution, and k_n is the degree for node *n*.

2.3 Research method step-by-step

From this point on, we will detail the method used in this work in depth. Filho *et al*. [2023] presents similar content, already dedicated to this specific database.

2.3.1 Collect stage

During the **collect stage**, we extracted the data from the SBC OpenLib (SBC SOL) [2], the SBC open library. When data is available, data scraping automatically extracts the authors names, affiliations, abstracts, keywords, year of publication, and event edition. Data between 2013 and 2022 was extracted from Filho *et al*. [2023], and 2023 data was extracted from the library directly. For the automated scraping task, we use the Web Scraper [3] system.

2.3.2 Storing stage

After collecting the raw data, we separated only the metadata and relevant data for this present work, excluding the rest, e.g., there is no use for "document access address" data.

For the **storing stage**, we store this raw data in the Google Sheets [4] system, allowing for a group, concurrent, and real-time practice.

2.3.3 Preprocess stage

Following storage, we initiate the **preprocess stage**. This stage began with a data treatment that resolved any ambiguities in the names of the authors, separated the institutions for authors who had multiple affiliations, corrected the names and affiliations of the institutions, deleted the excessive spacing between keywords, and divided the year edition of the event into distinct columns. Subsequently, we translated all abstracts and keywords into English. We then included the authors' gender and the institutions' geolocation by Federative Units (FU) [Wikipedia contributors, 2023], which represent the states of Brazil, to the table, enriching it with data acquired from the primary ones.

We employed the same methodology as in Lobato *et al*. [2021] to deduce the gender of the researchers via an external association system, and we employed an online database [5] that included the acronyms of the institutions and the corresponding FUs where they are located to deduce the geolocation. The "-" character is used to indicate null or uncertain results. Next, to lessen the influence on the outcome, a treatment is applied to rectify null or unknowns having quantitative relevance, detailed in the respective section.

For the wordcloud preparation, we extracted the data in English, which is available at SBC SOL. We grouped terms by semantic and syntactic similarity, e.g., plurals, we removed stopwords or terms without significance for this analysis, e.g., connective verbs or numerals.

Table 1 exposes the metadata and a data example after extracting, separating, and processing.

2.3.4 Build a social network stage

The preprocessed data is then used to create a co-authorship social network, **build a social network**, using WCAMA's publications and their authors. The nodes provide authors details, including their name, gender, affiliations, and institutions. Conversely, publication-related details like year and language are included on the edges. The studies carried out in this paper use all of these data, illustrated by Figure 1.

[2] `https://sol.sbc.org.br/index.php/wcama/issue/archive` [accessed 04-04-2023]

[3] `https://webscraper.io/` [accessed 04-04-2023]

[4] `https://www.google.com/sheets/about/` [accessed 04-04-2023]

[5] `https://gist.github.com/alexandremcosta/c9361cc23722a5aa1133` [accessed 04-04-2023]

Table 1. Data breakdown and structured metadata

Field name	Format	Example	Description
Year	Integer	2022	Publication year
Event	String	WCAMA	Name of the event in which the article was published
Edition	Integer	13	Issue number in which the paper was published
Title	String	"Abordagem iWater: uma Contribuição ao Monitoramento da Barragem Santa Bárbara no Cenário da IoT"	Paper complete title
Author	String	"Gerson Andrade"	Author's name
Gender	String	"M"	Author's gender [F XOR M]
Institution 1	String	"UCPel"	Author's first affiliation
UF Inst. 1	String	"RS"	Federative Unit from author's first affiliation [LIST WITH 27 UF]
Institution 2	String	"-"	Author's second affiliation
UF Inst. 2	String	"-"	Federative Unit from author's second affiliation (if any) [LIST WITH 27 UF]
Language	String	"pt-br"	Publication language [en XOR pt-br XOR esp]
Abstract	String	"No Brasil, o monitoramento de barragens [...]" (excerpt from paper)	Paper abstract
Keywords	String	"Monitoramento remoto, barragens, IoT, middleware, LoRaWAN"	Paper keywords (if any)

For the structuring and development of the graphs presented in this work, we used the systems NetworkX and Gephi [6]. The first is for formalizing and organizing data in a format suitable for creating a graph, and the second is for the graph's graphical representation.

2.3.5 Analyze stage

We depict and detail the **analyze stage** in Section 3. These eleven years of WCAMA network behavior were analyzed graphically or quantitatively using metrics and graphs produced by the SNA analyses. Both the entire WCAMA and each year are covered in the analysis, depending on the circumstances. We made the generated artifacts publicly available online in order to better visualize the produced surplus information (Section 5).

In addition to the graphs, the word cloud (Figure 2) was generated using an wordcloud system [7]; line or bar graphs were generated using the Microsoft Excel system [8]; the heat map of collaborations (Figure 5) was generated using Matplotlib library systems in Python [9].

2.3.6 Consolidate and disseminate stage

In the **consolidate and disseminate stage**, we made openly available online the treated and processed data [Filho *et al*., 2023] for reproducibility, access, and possible future work. The WCAMA dedicated dataset is in the external supplementary online material (Section 5).

3 Analysis results and discussions

This section presents the analysis combining data and information about WCAMA, between 2013 - 2023, excluding communications such as opening, prefaces, and coordination messages, among others.

In this section we will analyze and discuss each extracted dimension, respectively, presenting the data and concatenating information in sub-sections for abstracts + keywords (Section 3.2); authority and author numbers; publication languages; authors gender; institutions or affiliations; institutions or affiliations regions. For suitable content, through SNA we generate graphs and specific analyses.

3.1 First step, an early treatment

Unlike other work carried out in this same category [Carvalho *et al*., 2023b,c], including the analysis of other CSBC workshops [Carvalho *et al*., 2023d], WCAMA presents a single atypical work.

Mazzega *et al*. [2013] is a work with twenty-one authors, an exorbitant number of authors compared to the normal behavior of this aspect in other Computing publications [Carvalho *et al*., 2023d]. All authors are from universities located in France [10], in their identification we were only able to accurately validate the last names, and scientific participation in the event was summarized in this work, in just one edition. For example, we were unable to verify the authors' gender, of the 24 occurrences of unidentified gender in 2013 authorships, 21 are these authors (Table 4).

As our secondary intention is to build an overview of Brazilian science in Computing, this work loses significant value because it does not present any Brazilian authorship and because it does not present a scientific line of work continued in the respective WCAMA. This for all 21 authors, with no recurrence of participation by any. If they had participated in any previous edition, the database and available information limit us to confirming this.

Furthermore, this work specifically resulted in some negative effects for the analysis. The algorithms and heuristics of SNA and graph development gave this work an excessively high value, both in terms of degree and general rel-

[6] `https://networkx.org/` – `https://gephi.org/` [accessed 04-04-2023]

[7] `https://www.wordclouds.com/` [accessed 04-04-2023]

[8] `https://en.wikipedia.org/wiki/Microsoft_Excel` [accessed 04-04-2023]

[9] `https://matplotlib.org/` [accessed 04-04-2023]

[10] We conducted external research on one of the authors, specifically the first author, identified in the publication as P. Mazzega and secondarily affiliated to University of Brasília (UnB). We traced it back to Pierre Mazzega, and validated the publication data. This affiliation is indicated as secondary by the author, the first being the University of Toulouse, in France. Furthermore, his participation in the event, considering formal scientific communication, is isolated to this 2013 work only, with no recurrence afterwards.

evance. With 21 authors combined, it represents the giant component of WCAMA for many years after its publication (2013). Only in 2019 did the configuration of collaborations and partnerships surpass this component.

Despite being a relevant work, accepted, in collaboration with 21 authors, its an atypical object, without constructive characteristics for the analysis of this work and with negative consequences for it, so we decided to exclude it from the analysis in specific scopes outside its year of publication, 2013. It is represented in the complete graph (Figure 6) and in the 2013 giant component (Figure 10). However, do not represent the giant component of 2014, as it should be if it were included without treatment.

3.2 Abstracts and keywords analysis

To better understand the content of publications, we analyze their abstracts and keywords. After translating the keywords into English and removing irrelevant terms, we created a word cloud, as shown in Figure 2. We had access to keywords from 2019 to 2022, but as the abstract word cloud was similar to the keyword cloud, we focused on the abstract word cloud, which is more comprehensive and reliable.

In the case of this specific study, this analysis is divided into two parts: the consolidation of the most frequently occurring terms in WCAMA's work in these eleven years of analysis; the analysis of terms by year, thinking about their evolution and relevance, by position of occurrence, in each specific year.

Some other *workshops* at CSBC present word clouds containing terms related to their epistemic nature. For example, in the Workshop on Teaching about Computing (Workshop *sobre Educação em Computação* – WEI), the most expressive terms are teaching, students, and similar. In WCAMA, several generic terms appear, such as development, tool, monitoring, system, or analysis. We found the relevant term "environmental" often without association with natural resources, without significant relevance of other high-level terms associated with the workshop main topics, such as "nature", "ecology", or similar.

Furthermore, as an unusual difference, one notices that one of the most consistent, recurring, and usual research topics is "bees", i.e., WCAMA is an event that presents a substantial amount of research on bees and beekeeping in a total of 13 publications that deal primarily with beekeeping and bees, led by UFC, with first authorship in 10 of these publications. This is an expressive semantic result, realizing the contemporary threats to bees, a proportionally significant amount of publications from the event seek to solve this problem, which involves humanity, various ecosystems, and Brazil [Braga *et al.*, 2019; Leocádio *et al.*, 2021; Ícaro Rodrigues *et al.*, 2022]. Other terms are associated with this topic, such as "monitoring", with specific works focusing on monitoring bees.

As a complement, we use the approach proposed by Nolasco and Oliveira [2016] for general topic modeling of WCAMA abstracts. The result indicated an interpretation similar to wordcloud, in order of relevance: 1. digital agriculture, bees, colony; 2. neural networks, artificial neural, meteorological; 3. water resources, climate, species; 4. technological tool, machine learning, computer vision; 5. internet of things, sensors, environmental monitoring.

Figure 2. WCAMA's abstract wordcloud (2014 – 2023)

Analyzing this dimension with the analysis of authorship and authors in Section 3.3, mainly through Figure 7, we find some groups or components of a higher degree oriented to specific topics. Guided respectively by their most quantitatively significant authors, these are: **Danielo G. Gomes**, bees; **Marilton Sanchonete de Aguiar and Diana F. Adamatti**, water resources and educational games; **Fabrício Farias**, sustainability and Internet of Things (IoT); **Willington Pavan and Carlos Amaral Hölbig**, climate, temperature, agriculture; **Hugo Figueirêdo and Cláudio Baptista**, environmental management and domain-oriented information systems (natural resources and environment); **Paulo de Souza, Gustavo Pessin and Alen Vieira**, bees and water resources; **Helvécio L. Neto, Adriano Almeida and Alan Calheiros**, climate and temperature, many works involving Artificial Intelligence in a broad spectrum (mainly environmental oriented). Glauco's Estácio Gonçalves analysis did not culminate in a strong associated topic, we found traces of sensing, climate and temperature.

As already covered by the analysis in de Aguiar *et al.* [2023], we reiterate the perceived importance of Artificial Intelligence, and its correlates, in WCAMA. In several of these groups, the majority of research is guided by these technologies. Through the development of topics year by year, the tendency for this involvement is to grow.

3.3 Authorships and authors analysis

In this section, we analyze the dimensions of authorship and authors. Due to an atypical situation, we started with a treatment disclaimer to improve the analysis and, consequently, the results. When we indicate first authorship, we refer to the first author and related information; when we indicate authorship, we refer to all authors, not just the first author or first authorship; when we indicate co-authorship or co-author, we refer to all authors excluding the first author.

Figure 3 shows the number of authors per publication. The Figure associates the number of authors and the respective number of publications; e.g., 26 publications in WCAMA have three authors. Positions order the numbers; fortuitously, the number of authors follows the positions, except for the eleventh position, which, instead of having eleven authors,

has 21.

While the greatest number of authors per publication in other CSBC events is three [Carvalho *et al*., 2023d], in WCAMA it is four; i.e., more publications with four authors. There is only one publication depicting one authorship [Campelo, 2014]. On the other hand, it presents the publication with the greatest number of authors in a single publication in the last eleven years of CSBC (2013 – 2023) [Mazzega *et al*., 2013], 21 authors.

The number of publications with one, two, or three authors totals ≈35%. Considering the remaining ≈65%, we noticed more authors collaborating, participating, and working in research, promoting, and moving research in the environmental management and natural resources research, WCAMA's area, through publications and the number of authors.

Even though the author's numbers are higher (4 instead of 3), the variation in the number of authors, excluding the outlier of 21 authorships [Mazzega *et al*., 2013], is slight. Other events in the same category, workshops, feature more publications with eleven or more authors [Carvalho *et al*., 2023d]. So even if we perceive more authors associated with a publication, the publications with the largest authorships reach a lower number. Publications by 4 to 7 authors account for ≈58%.

Figure 4 shows the number of publications per author. ≈84% of WCAMA authors were present in one authorship, i.e., without recurrence in other publications. Compared to other CSBC [Carvalho *et al*., 2023d] workshops, this is a significantly high amount, ≈5% discrepancy above. In this sense, we need to delve deeper into the interpretation of what constitutes first authorship.

Authors forward original and authorial research and scientific contributions through academic-scientific communications, which present this information and knowledge to the respective epistemic community, in the case of WCAMA, the agency of research involving computational aspects on the management of natural resources and the environment. In this sense, we present two perspectives: a low and a high recurrence of authorship. Here, we focus on the first case, which occurs in this work.

Low recurrence may indicate a high amount of completed research communicated, the entire scientific method is exposed, the procedure or protocol is detailed, the analyses and discussions presented, and the contributions consolidated. All this in just one publication, one authorship. On the other hand, it may indicate an abandonment of space, an instrumental relationship with WCAMA, in which authors dispose of what is interesting, sound, or necessary for a publication, even partially or minimally, and then do not return to complement, continue or extend the same research (as first authors or co-authors). For example, there is an obligation or demand to publish in the ongoing instruction path, and instrumentally, publishing in WCAMA facilitates or unblocks academic obstacles.

This data on authorship may indicate a fragmented or dispersed community. The motivations for the materialization of this data are unknown. They are input for future work that studies why WCAMA authors do not return to this scientific space to complement, continue, or extend their research. In this sense, even if the organization or coordination of the event recurs year after year, ensuring its survival and completion, the community has a high turnover, and only fragments of total research are incorporated. In this sense, there is little cohesion and consistency in the continuous participation of researchers (thus also research) in this space. This fragmentation or dispersion impairs the formation of epistemic solid communities, lines of research, consistent and linked research, and the maturation of topics.

We perceive that communicating completed and consolidated research in its significant majority in just one publication and isolated in authorship is an unlikely option, considering the limited space for WCAMA's scientific communication and the complexity and completeness of entirely carried out research.

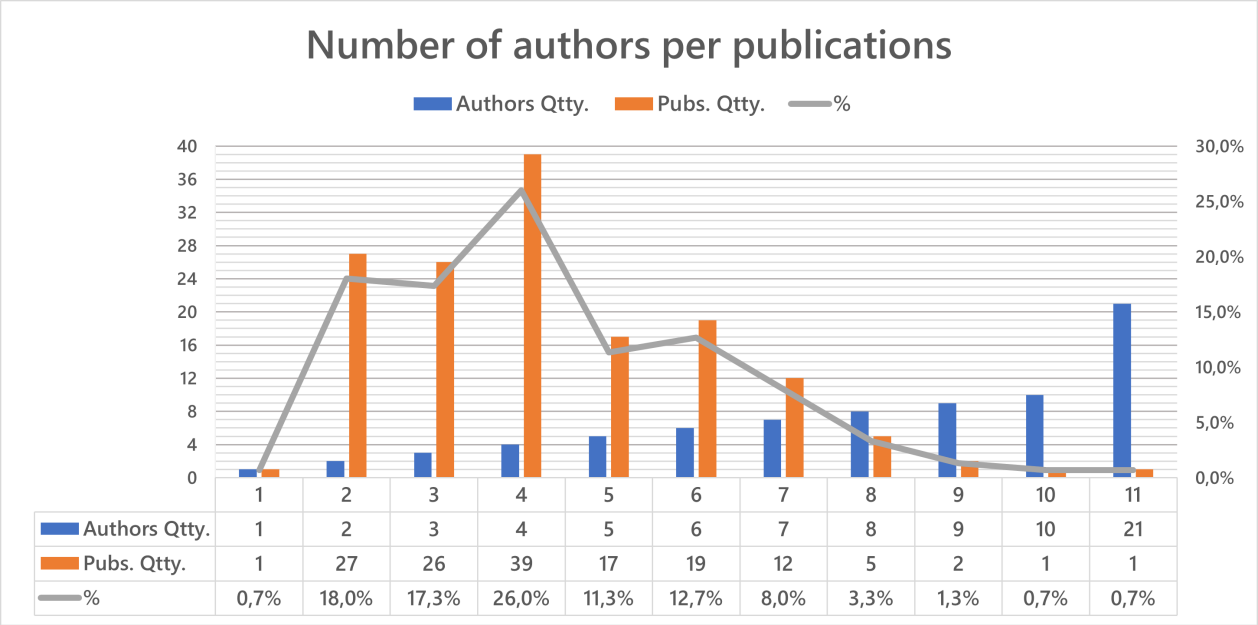
Compared to other CSBC workshops, the highest number of authors indicates other deviant behavior. The number of authors with 1 to 4 authorships accumulates ≈98%, in eleven of the total fourteen editions of WCAMA. Compared to other CSBC workshops [Carvalho *et al*., 2023d], this is a significantly high value. However, its complement that arouses strangeness, less than ≈2% authors repeat their authorship five or more times. Again, this way, we combine the data observed in Figure 4 with the data in Table 2.

Danielo G. Gomes is WCAMA's most prolific author, totaling 12 authorships. However, scientific communications with his participation began in 2018. Between 2018 and 2023, he promoted and managed research on bees and related topics at WCAMA. The second position is that of Antonio Rafael Braga, who follows Danielo G. Gomes in this line of research and all authorships. Antonio Rafael Braga is the first author in one publication only [Braga *et al*., 2019], in which Danielo G. Gomes appears as co-author; the latter being only co-author in his 12 occurrences of authorship. It constitutes the most prolific group on the topic already covered in Section 3.2, bees.

Furthermore, both have the highest number of authors per edition of the event, six. They were published in all WCAMA years between 2018 and 2023. In the eleven years analyzed (2013 — 2023), no author published continuously as an author or co-author in WCAMA. There is no topic, theme, or line of research, generally supported by an author or a limited collective, that is present in all or most editions.

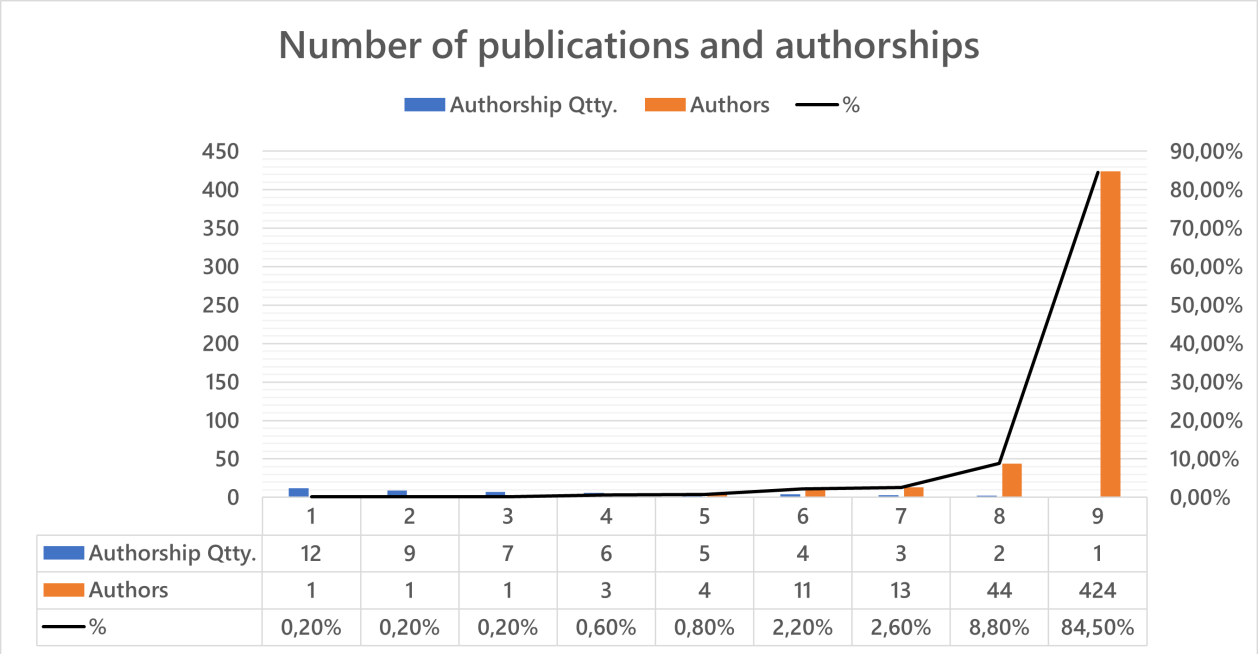
Through continuous and consistently active researchers, topics of significant significance and observed importance since 2013 have appeared and disappeared quickly and without stability. Analyzing other occurrences, Diana F. Adamatti and Marilton Sanchonete de Aguiar deal mainly with water resources and Glauco Gonçalves with thermography and temperature aspects. These authors head these topics in their authorship trajectories at WCAMA.

Considering the abstracts, keywords, authors, and authors, a possible interpretation is the fragmentation of the workshop's central theme, management of natural resources and the environment, into several sub-topics and associated items at a lower conceptual level, emphasizing the technique and technological aspects. That is, works that deal with the topic of the workshop at a higher, generic, and comprehensive level are absent, significantly limited, or restricted to a tiny collective, and that could either connect more researchers from different components or groups or explicit last for a



	1	2	3	4	5	6	7	8	9	10	11
Authors Qtty.	1	2	3	4	5	6	7	8	9	10	21
Pubs. Qtty.	1	27	26	39	17	19	12	5	2	1	1
%	0,7%	18,0%	17,3%	26,0%	11,3%	12,7%	8,0%	3,3%	1,3%	0,7%	0,7%

Figure 3. Number of authors per publication (2013 – 2023)



	1	2	3	4	5	6	7	8	9
Authorship Qtty.	12	9	7	6	5	4	3	2	1
Authors	1	1	1	3	4	11	13	44	424
%	0,20%	0,20%	0,20%	0,60%	0,80%	2,20%	2,60%	8,80%	84,50%

Figure 4. Number of authorship and publication (2013 – 2023)

more significant number of editions, not just five or six.

As WCAMA deals with such a comprehensive, complex, and general theme(s) and topic(s), putting together a high-level research or research front is complex and arduous and escapes the isolated computing *episteme*. Mainly because, at a high level of abstraction and generalization, the phenomena and elements of reality that WCAMA embraces are outside the scope of computation. Furthermore, the event demonstrates that computing can bring potential and significant benefits to the management of natural resources and the environment and that the latter is a priority in the epistemology(ies) of the former. For example, no computational research or practice should disregard, waste, belittle, ignore, or devalue natural resources and the environment.

Table 2 shows the most prolific authors in WCAMA, 2013 – 2023. Compared to other CSBC workshops [Carvalho *et al*., 2023d], the first position has a low number of occurrences (12), e.g., Gustavo Guedes authors 15 publications in the Brazilian Social Network Analysis and Mining (BraSNAM) (2013 – 2022); Adenauer Yamin authors 24 publications in the Brazilian Symposium on Ubiquitous and Pervasive Computing (SBCUP) (2013 – 2022).

The maximum number of publishing editions is six, by Danielo G. Gomes and Antonio Rafael Braga, in the same publications and interval (2018 – 2023); and by Marilton Sanchonete de Aguiar (2014, 2015, 2019 – 2022). The other amounts of authorship follow the number of editions involved without relevant discrepancies. The two biggest authorships per year (4) are Danilo G. Gomes (2023) and Rafael dos Santos (2020); the latter are his only authorships at the

event, concentrated in the same year.

Table 3 shows the first authorships in WCAMA, 2013 – 2023. Again, the number of authors in this category is small. There is a phenomenon of academic maturity progression combining the data in Table 3 and Table 2. A phenomenon noticeable through data from other events, e.g., in the Brazilian Symposium on Multimedia and Web Systems (*Simpósio Brasileiro de Sistemas Multimídia e Web* – WebMedia) [Carvalho *et al*., 2022], does not occur at WCAMA. Authors establish themselves in communities with first authorship and then return to authorship as co-authors supporting and developing research or mentoring first authors. First authorships cease or diminish, giving way to co-authorships, and authors remain in that space and community, this time agency others' primary research. In WCAMA, this phenomenon is absent, perhaps due to its youth as an event (fourteen editions) or due to the aspect already mentioned above of an instrumental space for research disposal, resulting in a dispersed and non-continuous community.

The largest number of repeat first authorships (3) is by Daniel de Amaral da Silva, who, together with Danielo G. Gomes and Antonio Rafael Braga, advances the research topic on bees at WCAMA.

In addition to the authors in Figure 3, all others (137, ≈96%) are first authors who did not return as such. Of these 137, 114 (≈85%) had only this participation as primary, isolated authorship.

Few researchers remain in the community and establish their primary research. Others also participate as co-authors, such as Antonio Rafael Braga, with one first authorship and eight co-authorships. However, in-depth future work is needed to analyze this phenomenon, i.e., do people continue their primary research as co-authors, or do they not persist with it in WCAMA and engage in co-authorship in other research? Why is recidivism for first-time researchers so low? Does the research have any continuity, even though it has other authors?

We developed an authorship grouping matrix (Figure 5) among authors with four or more occurrences, to verify the most significant partnerships and co-authorships. For example, Danielo G. Gomes presents several co-authorships with Breno M. Freitas, Daniel de Amaral da Silva, Isac Gabriel Abrahão Bonfim and Ícaro de Lima Rodrigues, but mainly with Antonio Rafael Braga, in which he is present in all his publications . Hugo Figueiredo presents a strong collaboration with Cláudio Baptista, Marilton Sanchonete de Aguiar with Diana F. Adamatti, Victor de Medeiros with Glauco Estácio Gonçalves, José Maurício Cunha Fernandes with Willinghton Pavan.

We can also depict these collaborations and partnerships through SNA with social network graphs. Figure 6 and Figure 7 expose the complete graph of WCAMA (2013 – 2022). The color of the edges represents years of publication and collaboration in an unordered way to simply show different associations by year. More recent associations overlap older associations, exposing collaborations that persist over the years. Initially, we present two complete graphs in two different distributions, Fruchterman Reingold and Force Atlas [11].

Figure 6, using the Fruchterman Reingold distribution, presents all node labels [12]. We highlighted the publication by [Mazzega *et al*., 2013] in the central right corner, isolated from the others, the collaboration of 21 authors, the nodes. In this arrangement, we can already see the isolated components and groups.

Unlike the quantitative analysis of authorship involvement, in Figure 6, Table 2, and Figure 5, collaborations and partnerships are the most relevant factor, i.e., the more collaborations and partnerships, the greater the degree and its graphic expressiveness. Secondarily, the number of authorships drives the degree due to the expected and probable dynamic that a greater number of authorships indicates greater collaborations. However, in WCAMA, there is a significant deviation between some positions in the number of authorships (Table 2) and collaborations (Figure 5), culminating in the graphic result in Figure 7.

To synthesize and present a graphical result with better readability, we built the same data scheme in another visualization, with the Force Atlas distribution, shown in Figure 7. We filter nodes between degree 10 and the largest calculated 24. Mazzega *et al*. [2013] is not depicted in Figure 7 for better visibility.

Using the Force Atlas heuristic, nodes with the lowest degree are "pulled" to the center. Nodes that are part of the components and present a lower degree show this behavior. For example, one of the nodes connected with Fabrício Farias represents isolated authorship in a single work while the others are nearby. We perform simple manual graphic shifts to allow the legibility of names without affecting the main space semantics between distances.

Danielo G. Gomes remains in first place with the highest degree of collaboration (24). Unlike authorship, Antonio Rafael Braga is in eighth position, with a degree of 14, as his collaborations are mostly with Danilo G. Gomes and the associated component. Breno M. Freitas, who was in the eleventh position in authorships, is in the twelfth position in collaborations (13).

After Danielo G. Gomes (24), with respective degrees, follow Cláudio Baptista (20); Hugo Figueirêdo and Willington Pavan (19); Marilton Sanchonete de Aguiar and Carlos Amaral Hölbig (17); Glauco Estácio Gonçalves (16); and Antonio Rafael Braga, Victor de Medeiros, and Diana F. Adamatti (14). The number of authors is not necessarily associated with the degree of collaboration. The second, third, and fourth names on this list performed better in collaborations than in authorship.

In this analysis, we can perceive the seclusion behavior of components or groups, which collaborate and publish mainly among themselves. Another similar case is that of Marilton Sanchotene de Aguiar and Diana F. Adamatti; while the first remains close in the position of authorship (3rd) and collaboration (5th), the second falls in the position of collaborations (10th) compared to authorships (4th), due to its recurrence

[11] `https://en.wikipedia.org/wiki/Force-directed_graph_drawing` [accessed 04-04-2023]

[12] A version in .SVG format is available in the supplementary material (Section **??**, which allows navigation by search tools (ctrl + f). Enables the search for specific authors, without the graphic limitation of readability in Figure 6, due to the size of the font due to the degree of the nodes (the lower the degree, the smaller the font).

Table 2. General authorships by year, depicting authors gender, and most current region of authors' affiliation

#	Author	Reg.	Gender	Qtty.	Eds.	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1	Danielo G. Gomes	CE	M	12	*6*	0	0	0	0	0	1	1	1	3	2	4
2	Antonio Rafael Braga	CE	M	9	*6*	0	0	0	0	0	1	1	1	2	1	3
3	Marilton Sanchotene de Aguiar	RS	M	7	*6*	0	1	1	0	0	0	1	1	2	1	0
4	Diana F. Adamatti	RS	F	6	*5*	0	0	1	0	0	0	1	2	1	1	0
5	Glauco Estácio Gonçalves	PA	M	6	*5*	0	0	0	0	0	0	1	1	1	2	1
6	Cláudio Baptista	PB	M	6	*4*	0	0	3	1	0	1	1	0	0	0	0
7	Hugo Figueirêdo	PB	M	5	*4*	0	0	2	1	0	1	1	0	0	0	0
8	Victor de Medeiros	PE	M	5	*4*	0	0	0	0	0	0	1	1	1	2	0
9	Willingthon Pavan	RS	M	5	*3*	0	0	0	2	1	2	0	0	0	0	0
10	Carlos Amaral Hölbig	RS	M	5	*3*	0	0	0	2	1	2	0	0	0	0	0
11	Breno M. Freitas	CE	M	4	*4*	0	0	0	0	0	1	1	1	1	0	0
12	Alen Vieira	AM	M	4	*3*	0	0	0	1	0	1	2	0	0	0	0
13	Daniel de Amaral da Silva	CE	M	4	*4*	0	0	0	0	0	0	0	1	1	1	1
14	Danielli A. Lima	MG	F	4	*4*	1	1	0	1	0	0	0	0	0	0	1
15	Fabrício Farias	PA	M	4	*3*	0	0	0	0	0	0	1	0	2	1	0
16	Gustavo Pessin	PA	M	4	*4*	0	0	0	1	1	1	0	0	1	0	0
17	Isac Gabriel Abrahão Bomfim	CE	M	4	*3*	0	0	0	0	0	0	0	0	1	1	2
18	José Maurício Cunha Fernandes	RS	M	4	*2*	0	0	0	2	0	2	0	0	0	0	0
19	Pedro L. P. Corrêa	SP	M	4	*3*	0	1	0	0	0	0	0	0	2	0	1
20	Alan Calheiros	-	M	4	*2*	0	0	0	0	0	0	0	2	0	0	2
21	Rafael dos Santos	SP	M	4	*1*	0	0	0	0	0	0	0	4	0	0	0

Table 3. First authorships by year, depicting authors gender, and most current region of authors' affiliation

Author	Reg.	Gender	Qtty.	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Daniel de Amaral da Silva	CE	M	3	0	0	0	0	0	0	0	1	1	0	1
Renato O. Miyaji	SP	M	2	0	0	0	0	0	0	0	0	1	0	1
Ícaro de Lima Rodrigues	CE	M	2	0	0	0	0	0	0	0	0	1	1	0
Sílvia Albuquerque	MG	F	2	0	0	0	0	0	0	0	1	1	0	0
Carolina G. Abreu	DF	F	2	1	0	1	0	0	0	0	0	0	0	0
Danielli A. Lima	MG	F	2	1	1	0	0	0	0	0	0	0	0	0

in the same component as Marilton Sanchotene de Aguiar, as he leads it quantitatively regarding collaborations and authorship.

Concluding, we analyze authors and authorship and expose the giant components of 2013- 2022 and 2013- 2023. We can notice a change in components between these two analyses at two different moments of the event. Given the semantics of the data and concatenated information, we can consider the giant component as the set of collaborations and researchers that conduct the most involved research in an event or context analyzed. They have the most significant social and scientific agency in that specific analysis, which does not mean they are the "best" or "largest" research.

At WCAMA, in 2022, the component was led by Alen Vieira, Paulo de Souza, and Gustavo Pessin, who was connected by Gustavo Pession's involvement in a 2016 publication on water resources [Vieira and Pessin, 2016]. This 2013 – 2022 giant component deals with water resources (Alen Vieira) and bees (Paulo de Souza), connected by Gustavo Pessin's associations.

After the 2023 edition, the giant component changed, led by the quantitatively significant participation of Danielo G. Gomes and associated co-authors. Bee was a relevant topic in the previous giant component and is the primary and main topic of this one in 2023. That is, it is the research component that drives the largest group of WCAMA at this specific moment.

We built the giant components of authorship collaborations in each year of WCAMA, represented in Figures 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20. It exposes the giant components of partnerships in publications of the respective years. For example, in 2019, it comprised a single publication with nine authors.

These objects graphically reinforce the isolation factor and emphasis on closed collaborations at WCAMA, in 2013 [Mazzega *et al*., 2013], 2014 [Pires *et al*., 2014], 2017 [Mazzonetto *et al*., 2017], 2018 [Pereira *et al*., 2018] and 2019 [Leitzke *et al*., 2019] giant components are isolated, unitary publications. In 2021 and 2023, the giant components involve two nearby institutions (UFC and IFCE) from the same region (CE), containing more than one collaborative work. The giant component of 2020 follows the significant quantity in Table 5 indicating the broad participation of INPE authors, with little external involvement.

3.4 Gender analysis

Quantitative gender analysis [13] is shown in Table 4. The inference engine does not identify data marked as "-" in this category, resulting in the unknown. More than 95% of general and first authorships were labeled efficiently and effec-

[13] We know the difference between sex and gender. Approaches involving mechanically and statistically labeled data due to the volume of *CSBCSet* and supplementary data present this conceptual limitation, i.e., without the authors involved announcing their gender. Furthermore, this is significant data for investigating women's involvement in Brazilian computing [Ribeiro *et al*., 2020; Santana and Braga, 2020]. Despite semantic differences, we use the term gender, even if limited to feminine and masculine.

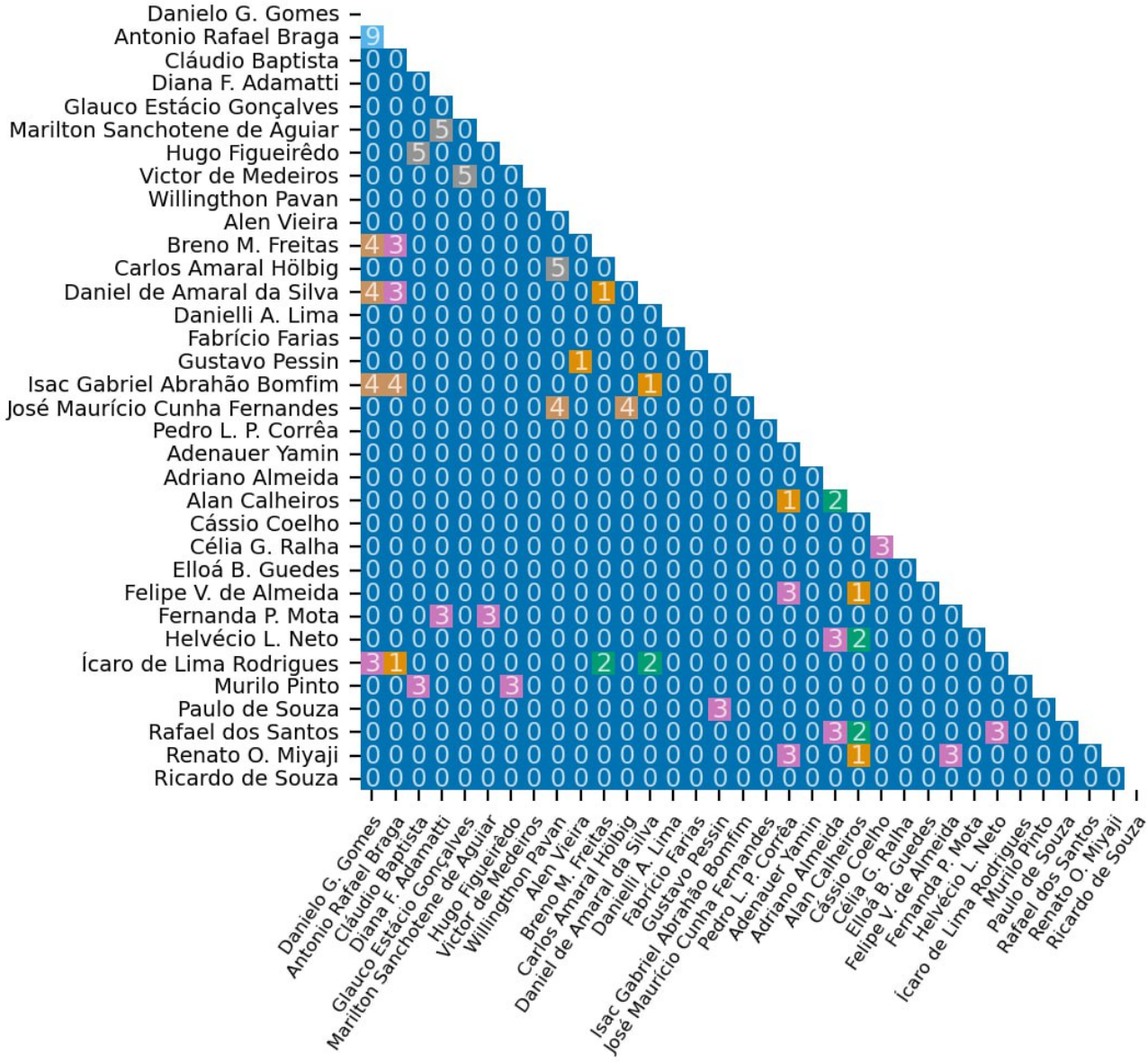


Figure 5. Authorships and collaboration heatmap

tively [14].

A punctual treatment was necessary in this dimension. As the gender inference engine resulted in Willington Pavan's gender as unknown ("-"), we manually adjusted it, given its relevance in the results.

The gender disparity in WCAMA authorship is stark, as evidenced by Table /reftab:GeneralAuthorshipAnalysis. Among the twenty-one most prolific authors, with four or more occurrences, only two are women. This represents less than 10

We conducted a series of cross and combined analyses to delve deeper into this dimension. However, none of them presented significant results, whether by region, institution, or other different aspects.

For example, institutionally, if we compare the twenty highest occurrences of authorship between men and women, the institutions with the highest occurrence of one and the other are different. Male authors are more present in UFC, UFPA, and UFRPE; the female ones in UFPel, UFRPE, and FURG. Women are more likely to be responsible for recidivism (≈40%) than men (≈17%). Women tend to publish more often and return (more than one authorship). We present two possible interpretations for this phenomenon. Firstly, women's participation is so low that the data presents compromised or biased quality for statistical analysis; second, despite women's participation being quantitatively lower, in fact, women present more consistent and persistent recidivism and participation. Most men publish once and leave the event, and many women publish more than once and return.

Above all, in all analyses, all quantities and occurrences were higher for men. For example, we did not find an institution or region where the numbers were equal or higher for women and were consistently higher for men. There are only male authors in GO, BA, SE, and PR, even if there are

[14] Excluding Mazzega *et al*. [2013], containing 21 authors presenting compromised nomenclature for valid automated identification.

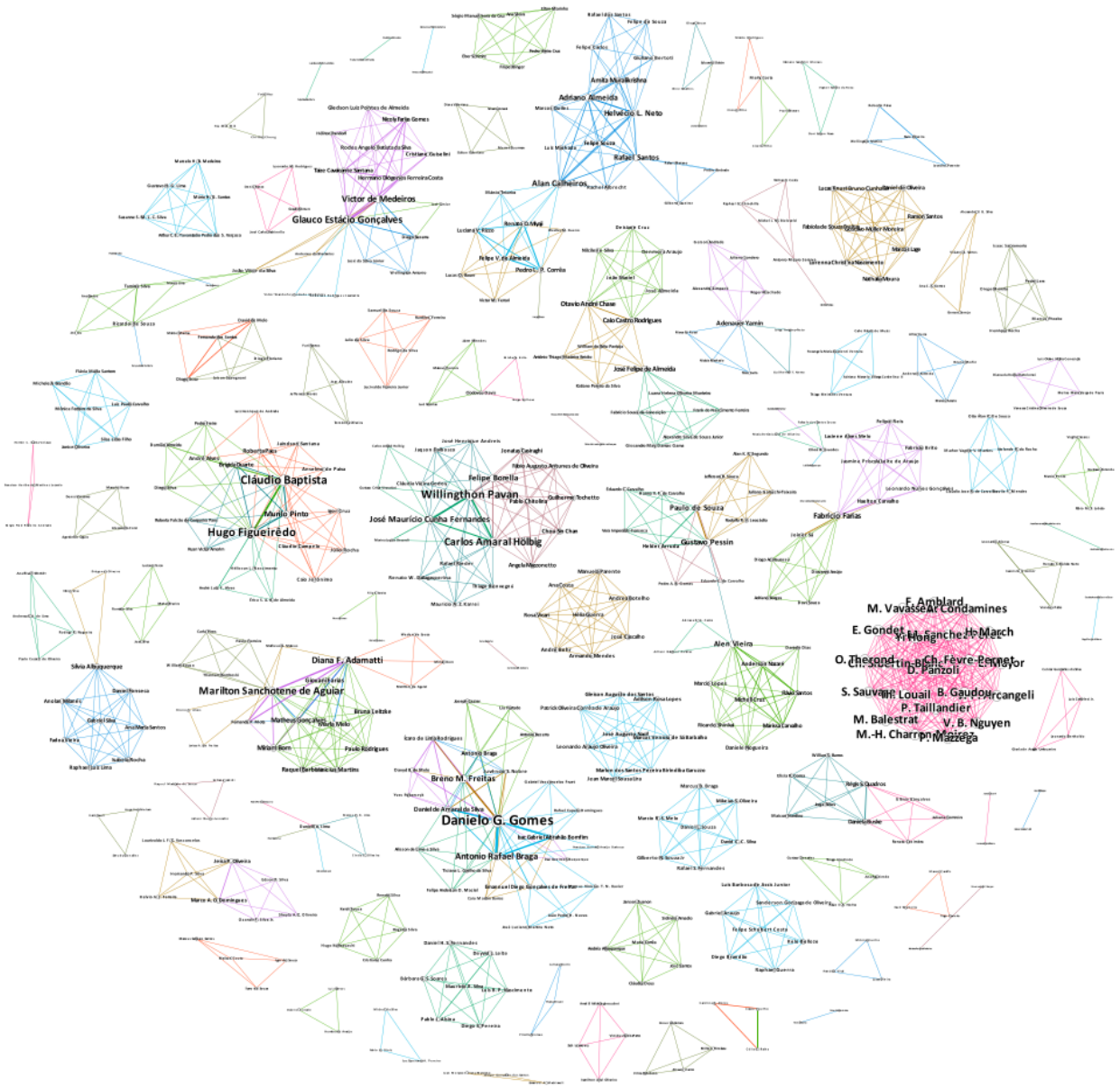


Figure 6. Complete graph of WCAMA's authors collaborations (2013 – 2023), using Fruchterman Reingold distribution

Table 4. Gender analysis

All authorships								First authorships							
Year	**Total**	**-**	**%**	**M**	**%**	**F**	**%**	**Year**	**Total**	**-**	**%**	**M**	**%**	**F**	**%**
2013	51	24	**47,06%**	17	**33,33%**	10	**19,61%**	2013	10	1	**10,00%**	7	**70,00%**	2	**20,00%**
2014	48	9	**18,75%**	31	**64,58%**	8	**16,67%**	2014	14	1	**7,14%**	9	**64,29%**	4	**28,57%**
2015	44	2	**4,55%**	34	**77,27%**	8	**18,18%**	2015	10	1	**10,00%**	7	**70,00%**	2	**20,00%**
2016	37	0	**0,00%**	29	**78,38%**	8	**21,62%**	2016	8	0	**0,00%**	8	**100,00%**	0	**0,00%**
2017	29	2	**6,90%**	24	**82,76%**	3	**10,34%**	2017	8	0	**0,00%**	6	**75,00%**	2	**25,00%**
2018	57	1	**1,75%**	41	**71,93%**	15	**26,32%**	2018	14	0	**0,00%**	9	**64,29%**	5	**35,71%**
2019	106	3	**2,83%**	74	**69,81%**	29	**27,36%**	2019	22	0	**0,00%**	13	**59,09%**	9	**40,91%**
2020	76	5	**6,58%**	57	**75,00%**	14	**18,42%**	2020	18	1	**5,56%**	12	**66,67%**	5	**27,78%**
2021	83	2	**2,41%**	63	**75,90%**	18	**21,69%**	2021	18	1	**5,56%**	15	**83,33%**	2	**11,11%**
2022	50	2	**4,00%**	30	**60,00%**	18	**36,00%**	2022	10	1	**10,00%**	5	**50,00%**	4	**40,00%**
2023	80	0	**0,00%**	66	**82,50%**	14	**17,50%**	2023	18	0	**0,00%**	14	**77,78%**	4	**22,22%**
	661	50	**7,56%**	466	**70,50%**	145	**21,94%**		150	6	**4,00%**	105	**70,00%**	39	**26,00%**

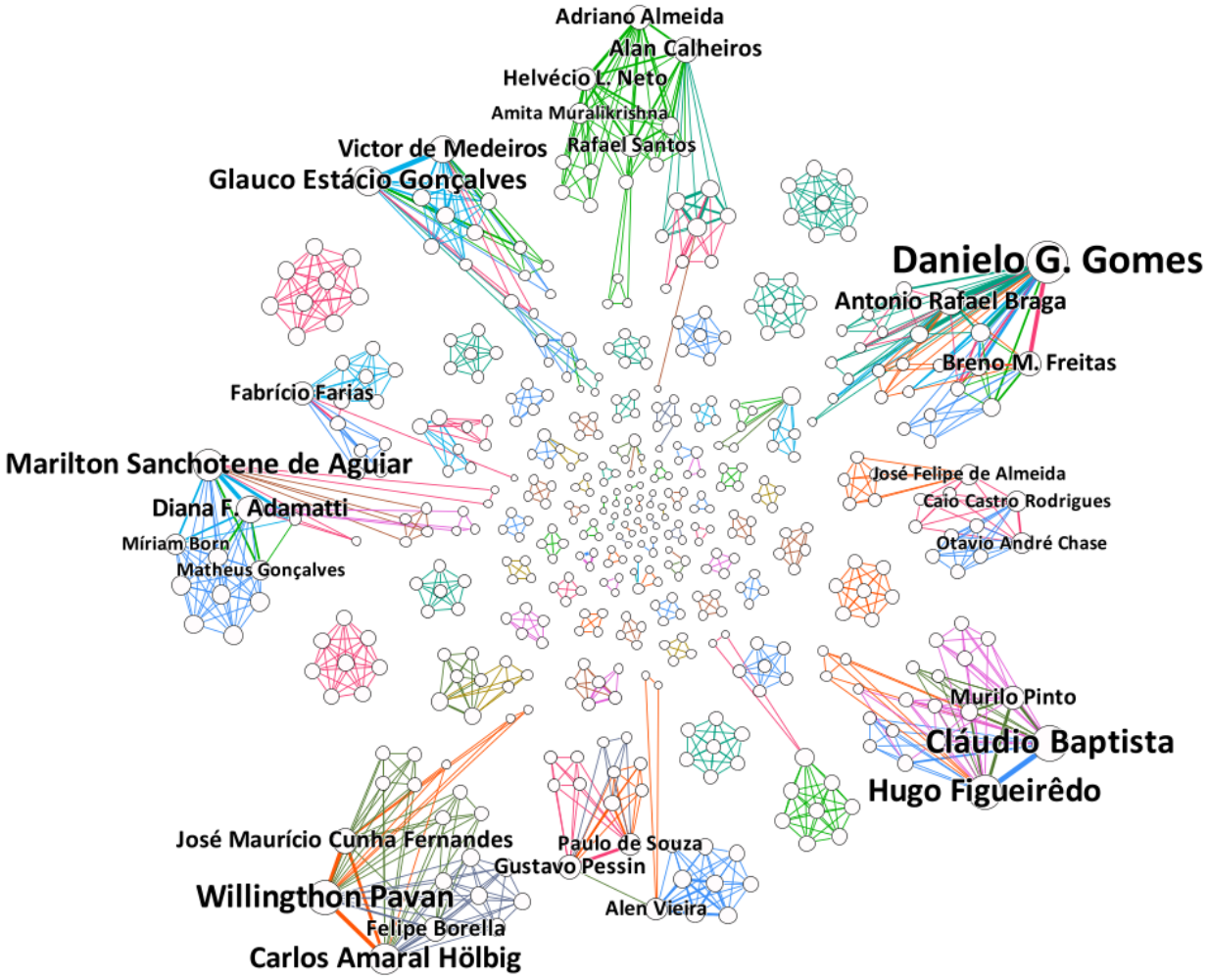


Figure 7. Complete graph of WCAMA's authors collaborations (2013 – 2023), using Force Atlas distribution (filtered by highest degrees)

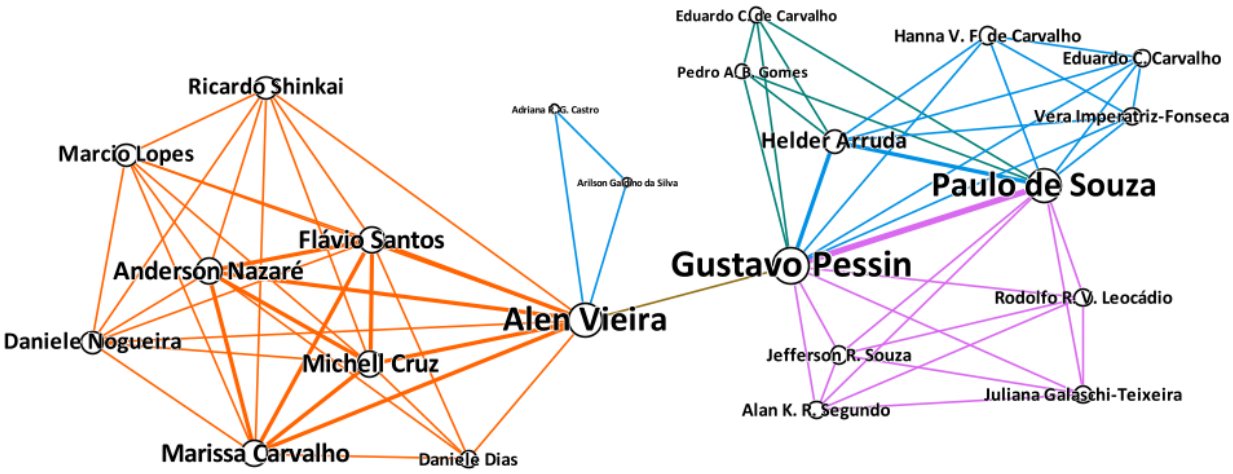


Figure 8. WCAMA's giant component (2013 – 2022)

few. Of the regions with more than 50 authorships for men, the equivalent for women is significantly lower; CE is 56 to 3; PA is 63 to 11; RS is 71 to 29. In the latter, Diana F. Adamatti's presence is relevant.

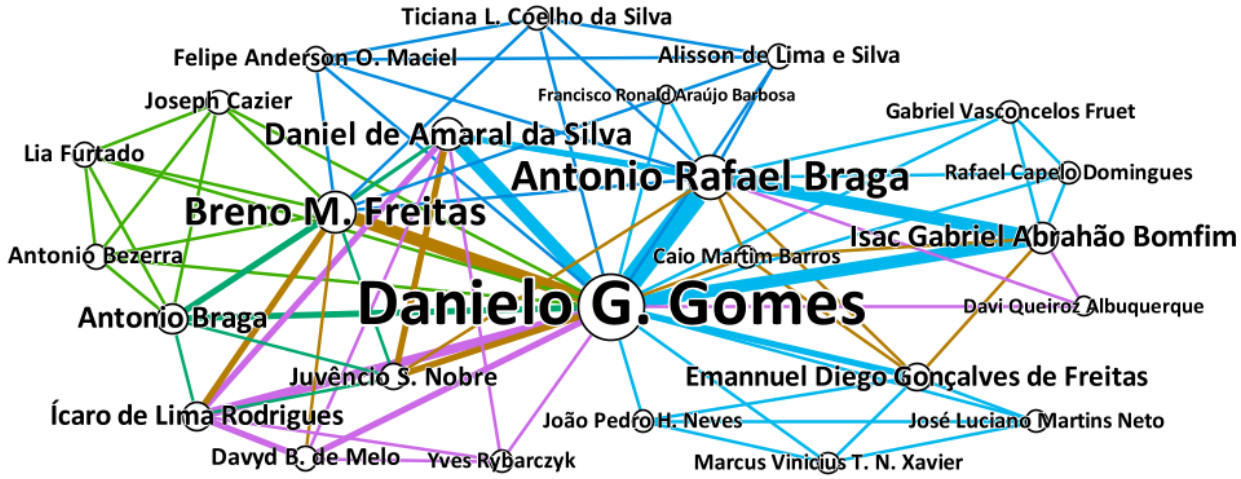


Figure 9. WCAMA's giant component (2013 – 2023)

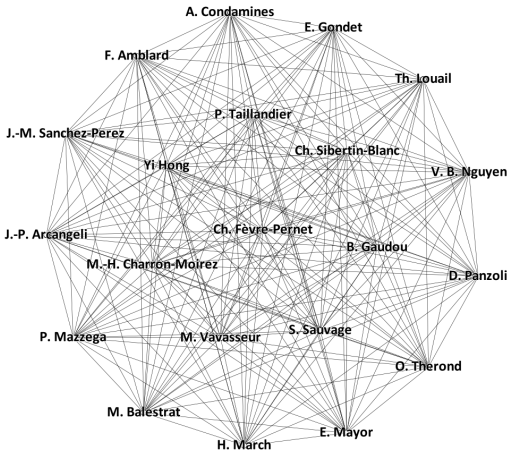


Figure 10. Giant Component of WCAMA 2013

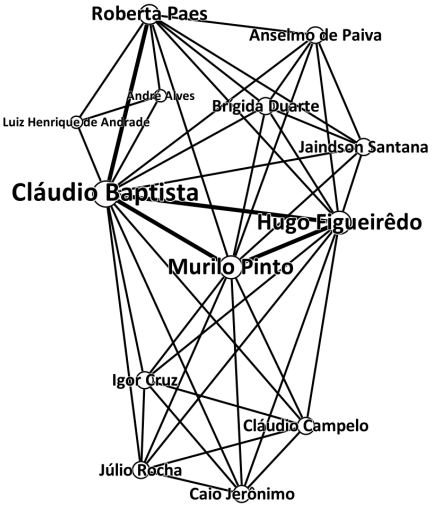


Figure 12. Giant Component of WCAMA 2015

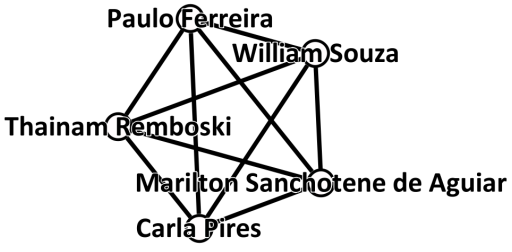


Figure 11. Giant Component of WCAMA 2014

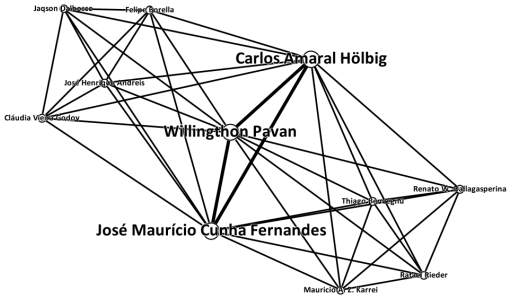


Figure 13. Giant Component of WCAMA 2016

The gender analysis explicitly exposes the scarcity of women's participation in authorship and in other related dimensions in WCAMA and its epistemic area. In this sense, practical and engaged future work involves discussing this phenomenon with the community and making decisions accordingly, participatory and collectively. It brings to the surface the nagging concern: Is the issue of gender an important and worrying dimension for the WCAMA community? And if so, what should we do about it?

3.5 Language analysis

Language results are depicted in Figure 21. Brazilian Portuguese (pt-br) is the dominant language of WCAMA, considering its strong influence on the Brazilian scenario, environment, and natural resources. In no year does the number

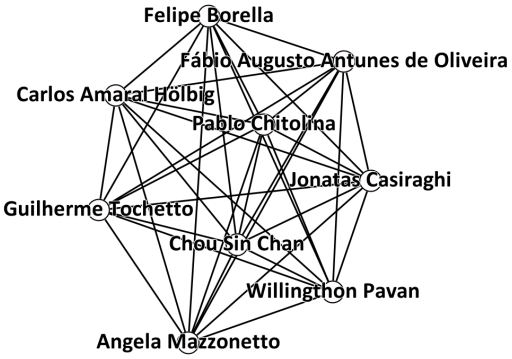


Figure 14. Giant Component of WCAMA 2017

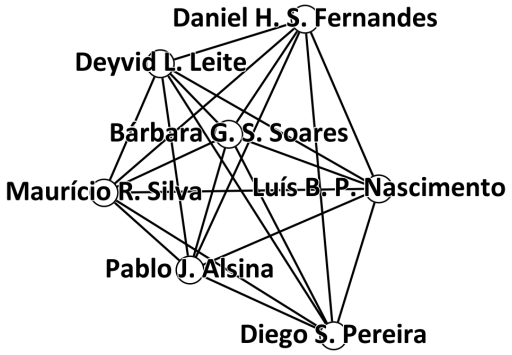


Figure 15. Giant Component of WCAMA 2018

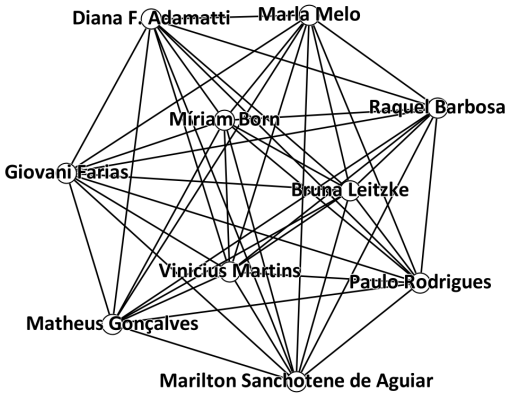


Figure 16. Giant Component of WCAMA 2019

of publications in English (en) exceed those in Brazilian Portuguese, only in 2013, there is a tie (5 and 5, 50% and 50%). In total (2013 – 2023), 88% of publications in Brazilian Portuguese and 12% in English.

Regarding this dimension, the data leads to a simple and well-established analysis. Although linguistic aspects present dilemmas for specific spaces [Carvalho *et al*., 2024], the data indicates that Brazilian Portuguese is the most accepted and used language in WCAMA. Considering the phenomena and elements of reality that WCAMA deals with, summed with the complexity, richness, and specificity of the Brazilian scenario, it is reasonable that the authors aim at an internal Brazilian audience literate in Brazilian Portuguese.

The opposite, communicating Brazilian phenomena and

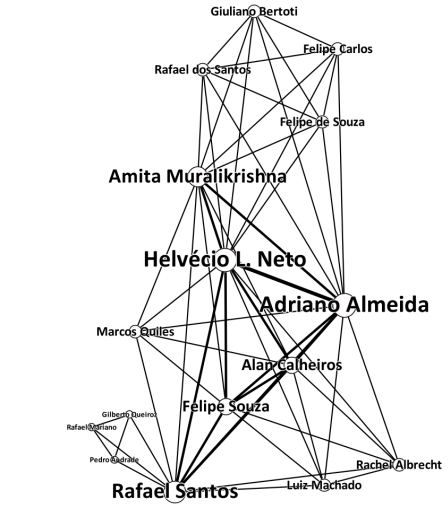


Figure 17. Giant Component of WCAMA 2020

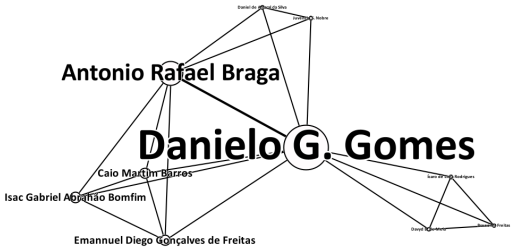


Figure 18. Giant Component of WCAMA 2021

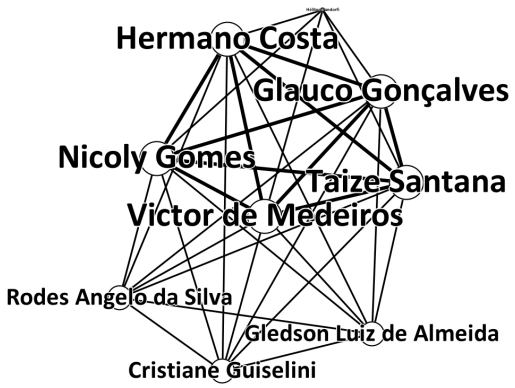


Figure 19. Giant Component of WCAMA 2022

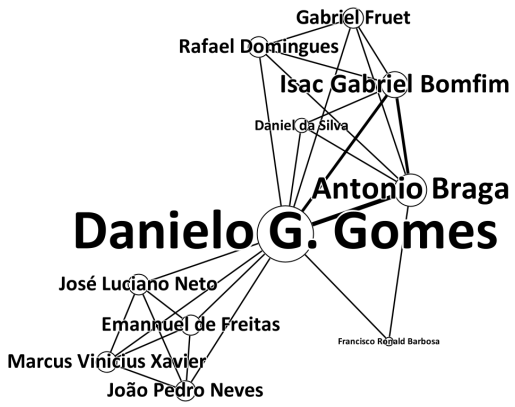


Figure 20. Giant Component of WCAMA 2023

experiences in English that are primarily interesting and enriching for Brazilians initially seems illogical, given the expected potential audience. For example, in English, there is a logical opening to communicate research that deals with bees in general, regardless of climate, geographic aspect, contextual specification, or region. Suppose the research deals with Brazilian animals or natural resources in the Brazilian context and with Brazilian specificity. In that case, Brazilian Portuguese should be primary — a publication with two versions in two languages [Carvalho *et al*., 2024].

3.6 Institutional Analysis

As a graph, the analysis of institutions/affiliations relationships is shown in Figure 22. The nodes represent the institutions, and the size represents the respective degree, i.e., quantitative relevance; the edges represent the relationships between institutions, and the width represents the quantitative relevance of this interaction. Table 5 and Table 6 complement the graph with the number of authors per institution.

UFCG (8), IFPB (7), and UFPA (7) present the greatest collaboration metrics. Although FURG and UFPel have fewer collaborations, collaboration between them is recurrent. Two facts are notable: (i) the number of collaborations with institutions other than national universities, such as institutions related to the environment or European universities. This information exposes the WCAMA community's open nature to collaborations outside the academic and national bubble, which its primary epistemic interest can explain; (ii) the relevance of institutions outside the Southeast-South axis and less influence in Brazilian academic dynamics. On the other hand, compared to other events as long-lived as WCAMA, the number of institutions is lower [Carvalho *et al*., 2023d].

Table 5 shows the institutional habit of authors in WCAMA. UFPA, UFPel, and FURG regularly publishing for the most significant number of years; UFRPE shows a recent and significant interest, as even with the first publication dating back to 2019, it has already risen to the third highest number of authors. Some other institutions present authorships from time to time, such as UFOPA, CEFET-MG, or USP. Even though the IFPB is relevant in terms of collaboration (Figure 22, in authorship terms (Table 2), it is below many others.

A rising highlight is UFC. Leveraged by publications led by Danielo G. Gomes and Antonio Rafael Braga, they published several works in 2023, elevating the university to first position in number of authors. On the other hand, the degree of collaboration is mediocre (4), because many of the collaborations are internal, at UFC.

Another significant and unusual highlight in academic-scientific spaces is the presence of the National Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais* – INPE) as one of the top five in terms of number of institutional authors. As an atypical phenomenon, they accumulated 23 authorships in 2020, the highest value in all years for all institutions.

The combination of Table 2, Table 5, and Table 6 exposes the authors and their respective institutions leveraging the authorship amounts.

Table 6 shows the institutional habit of first authorship in WCAMA. The placement offset between tables is a few positions. For example, although UFPel has many authorships as a whole (36), first authorships are few (6). The São Paulo University (*Universidade de São Paulo* – USP) gains first authorship placements (7), even with fewer overall authorships (23). Two institutions that stand out in primary, rather than general, authorship are the Federal Institute of Triângulo Mineiro (*Instituto Federal do Triângulo Mineiro* – IFTM) and University of Brasília (*Universidade de Brasília* – UnB).

3.7 Institutional Geolocation Analysis

Table 7 exposes the institutional geolocation data. We can analyze the geographic spaces and regions in which WCAMA authorship occurs. As well as where they do not occur, which may mean some specific case of exclusion or desired inclusion.

According to **institutional geolocation analysis**, RS has the largest number of authors (≈20%), spread across regional institutions. In second place is PA with ≈15% and CE with ≈11%. A threat to this result is the number of null base values ("-"), accumulating ≈12%, potentially unbalancing these quantities.

We strive to complete geolocation data; however, some institutions have sectors, branches, divisions, or similar in different locations. Accessing each publication and extracting this data is a highly arduous task with no guarantee of good results. For example, not all affiliations, such as INPE, present complete geolocation information despite the significant number of authors.

As outlined in Section 3.6, the North and Northeast regions have significant participation, mainly given the proportionality of the small amount of WCAMA work. Future studies can delve into this data in more detail, analyzing this geolocated solid positioning.

The quantities and numbers raise concerns. Only in these regions, by these institutions, and by these authors, is the management of natural resources and the environment and the resolution of associated problems involved with computing investigated, studied, or researched? For example, are there no problems or questions in this episteme in ES that are of interest to WCAMA? If there is research, in which spaces are they communicated? Is WCAMA open and embracing new research and diverse thinking, or is it rigorous and conservative in its reviews and acceptances?

To complement the analysis, we built a collaboration graph between regions, shown in Figure 23. Initially, expectations were zero about what information to extract from such an analysis, until its design exposed us to valuable insights. NaN represents the unknown institutional locations ("-").

Several UFs present self-contained publications, in collaborations that are not the same as those of their regions, they are represented by isolated nodes, eith edges that leave themselves and return to themselves. Two UFs present external collaborations only, SE and MA.

In this specific analysis, SP stands out significantly, while authors or institutions from other locations stand out in the other analyses. Here, we note that even though PA, CE, PB, and RS stand out in other dimensions, the largest number

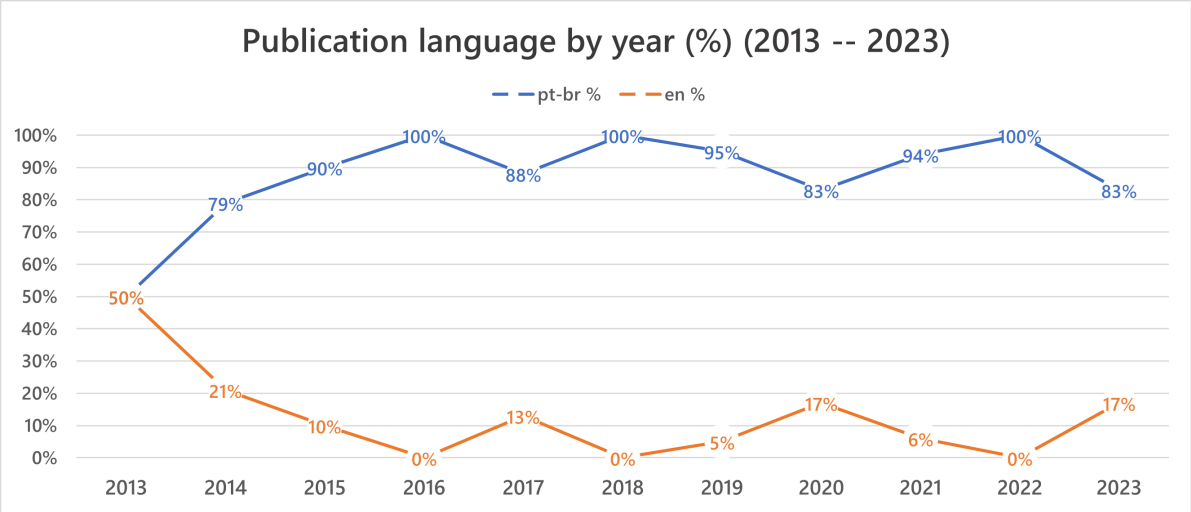


Figure 21. WCAMA's publications language, proportional by year (2013 – 2023)

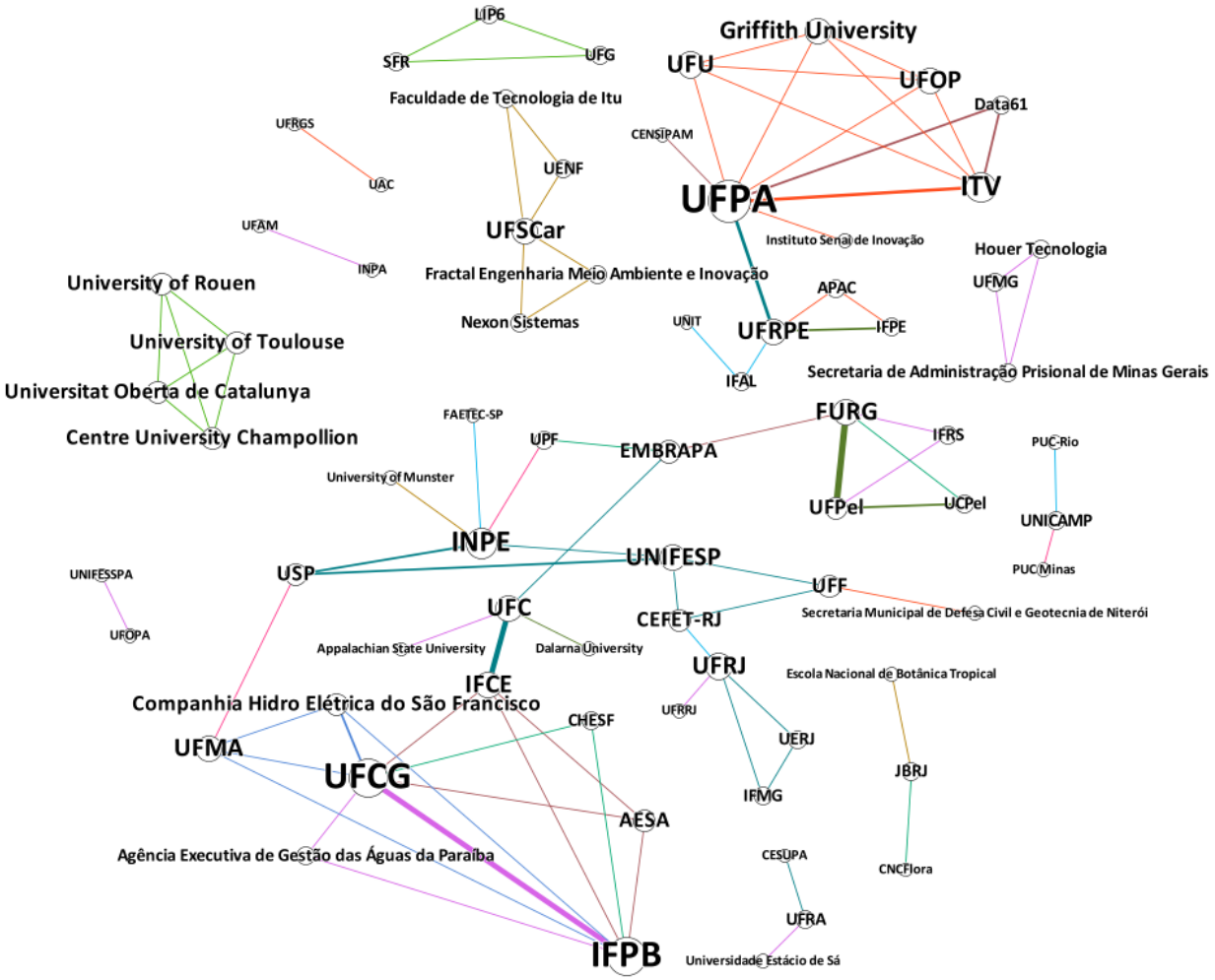


Figure 22. Complete graph of WCAMA's institutional collaborations (2013 – 2023)

of regional collaborations originate from SP, a much greater number (7) than the other regions below, such as PB (4).

These "isolated" regions can also be good opportunities for collaboration if topics, themes, or research interests inter-

Table 5. Institutions analysis, all authorships

Institution	Reg.	Qtty.	Eds.	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
UFC	CE	50	*6*	0	0	0	0	0	6	5	6	11	7	15
UFPA	PA	48	*9*	0	4	0	2	2	4	14	4	8	9	1
UFRPE	PE	40	*5*	0	0	0	0	0	0	12	8	5	13	2
UFPel	RS	36	*8*	6	5	2	7	0	0	2	4	5	5	0
INPE	-	30	*4*	0	3	0	0	1	0	0	23	0	0	3
UPF	RS	29	*3*	0	0	0	13	8	8	0	0	0	0	0
FURG	RS	25	*8*	5	0	2	2	0	2	7	4	2	1	0
USP	SP	23	*5*	0	2	0	0	8	0	0	1	8	0	4
UFRA	PA	22	*4*	0	0	0	0	0	6	4	0	6	0	6
UFCG	PB	20	*5*	0	1	11	4	0	2	2	0	0	0	0
Univ. of Toulouse	-	18	*1*	18	0	0	0	0	0	0	0	0	0	0
CENSIPAM	-	17	*3*	0	0	0	1	0	2	14	0	0	0	0
CEFET-MG	MG	11	*2*	0	0	0	0	0	0	0	8	3	0	0
IFCE	CE	10	*4*	0	0	0	0	0	1	0	0	2	1	6
IFPB	PB	10	*5*	0	0	3	1	0	1	2	0	0	0	3
UFF	RJ	10	*3*	0	0	0	0	2	0	0	0	7	0	1
UFOPA	PA	10	*2*	0	0	5	0	0	0	5	0	0	0	0
UFG	GO	10	*3*	2	4	0	0	0	0	0	4	0	0	0

Table 6. Institutions analysis, first authorships

Institution	Reg.	Qtty.	Eds.	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
UFPA	PA	13	*8*	0	1	0	1	1	1	4	1	3	1	0
UFC	CE	12	*6*	0	0	0	0	0	1	1	1	3	2	4
UFRPE	PE	9	*5*	0	0	0	0	0	0	3	2	1	2	1
FURG	RS	8	*7*	2	0	1	1	0	1	1	1	1	0	0
USP	SP	7	*4*	0	1	0	0	3	0	0	0	2	0	1
INPE	-	6	*3*	0	1	0	0	0	0	0	4	0	0	1
UFPel	RS	6	*6*	1	1	0	1	0	0	0	1	1	1	0
UPF	RS	5	*3*	0	0	0	2	1	2	0	0	0	0	0
UFRA	PA	4	*4*	0	0	0	0	0	1	1	0	1	0	1
IFTM	MG	4	*4*	1	1	0	1	0	0	0	0	0	0	1
UFCG	PB	4	*3*	0	1	2	0	0	0	1	0	0	0	0
UnB	DF	4	*3*	2	0	1	0	0	0	1	0	0	0	0
CENSIPAM	-	4	*3*	0	0	0	1	0	1	2	0	0	0	0

sect. Another notable factor is the relationship due to geographic proximity, which SP surpasses compared to the others that remain in its vicinity. The RS situation is a curious fact. Even though its institutions and authors are well positioned in other dimensions, it is a significantly self-contained region. Institutions and authors collaborate mainly within UF. Even though RS is closer to SC and PR, which are from the same Brazilian region, there is no collaboration between them.

3.8 Social Networks Analysis

Table 8 presents 15 ARS metrics for co-authorships between 2013 and 2022. It is possible to see that WCAMA has a low diameter, varying between 1 and 2, over the years. This result proves that WCAMA has a community with many publications by authors who collaborate. The exception is the co-authorship network in 2020, whose diameter increased to 3. In 2013, WCAMA presented a co-authorship network with the most significant number of edges (a total of 249 edges), but this number reduced from 2014 to 2017 and started to increase from 2018. The year 2019 presents the most significant number of nodes (authors) and the second largest number of edges (co-authorship relationship) among authors.

When analyzing the quantities and sizes of clicks on the giant graphs and components over the years, we perceive that 2019 stands out for the co-authorship network, having a higher number of clicks (29) than other years. These clicks are also greater than the size of other years (value equal to 10). The exception is 2013, with a clique size equal to 21. Another important aspect is that both the giant component and the network as a whole have a high clustering coefficient equal to or greater than 0.82, indicating that authors at WCAMA tend to publish together at this event.

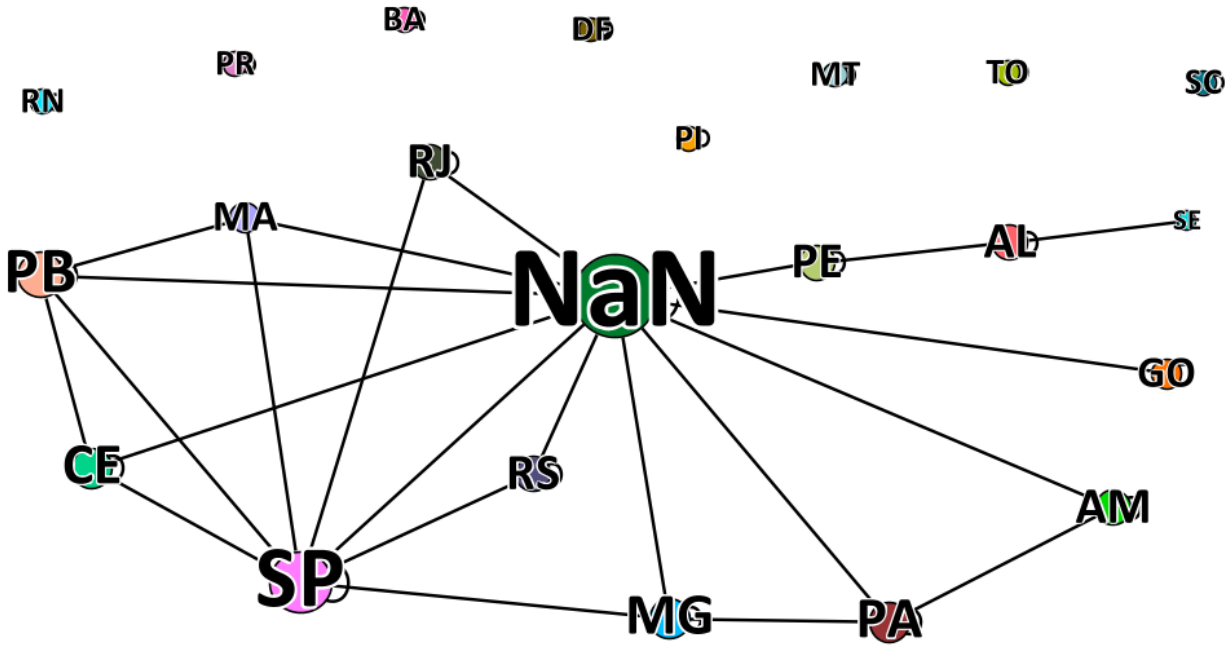


Figure 23. Complete graph of WCAMA's Brazilian Federative Units collaborations (2013 – 2023) (NaN is unknown, as in the database)

Table 7. Institutions geolocation analysis, all authorships

Region	FU	Qtty.	%	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Midwest	DF	9	1,68%	4	0	3	0	0	0	2	0	0	0	0
Midwest	GO	10	1,87%	2	4	0	0	0	0	0	4	0	0	0
Midwest	MT	6	1,12%	0	0	0	0	2	0	0	0	0	0	4
Midwest	MS		0,00%	0	0	0	0	0	0	0	0	0	0	0
North	AC		0,00%	0	0	0	0	0	0	0	0	0	0	0
North	AP		0,00%	0	0	0	0	0	0	0	0	0	0	0
North	AM	14	2,62%	0	0	3	0	0	3	4	0	0	2	2
North	PA	81	15,14%	0	4	5	2	2	10	23	4	14	9	8
North	RO		0,00%	0	0	0	0	0	0	0	0	0	0	0
North	RR		0,00%	0	0	0	0	0	0	0	0	0	0	0
North	TO	3	0,56%	0	0	0	0	0	0	3	0	0	0	0
Northeast	AL	9	1,68%	0	0	0	0	0	0	0	3	0	0	6
Northeast	BA	7	1,31%	3	0	4	0	0	0	0	0	0	0	0
Northeast	CE	61	11,40%	0	0	0	0	0	7	5	6	13	8	22
Northeast	MA	2	0,37%	0	0	1	0	1	0	0	0	0	0	0
Northeast	PB	30	5,61%	0	1	14	5	0	3	4	0	0	0	3
Northeast	PE	47	8,79%	0	0	0	0	0	0	12	8	8	17	2
Northeast	PI	3	0,56%	0	0	0	0	0	0	0	0	3	0	0
Northeast	RN	7	1,31%	0	0	0	0	0	7	0	0	0	0	0
Northeast	SE	2	0,37%	0	0	0	0	0	0	0	2	0	0	0
South	PR	2	0,37%	0	0	0	0	0	2	0	0	0	0	0
South	RS	105	19,63%	11	5	7	23	8	12	10	11	8	10	0
South	SC	15	2,80%	0	5	4	0	0	4	0	2	0	0	0
Southeast	ES		0,00%	0	0	0	0	0	0	0	0	0	0	0
Southeast	MG	43	8,04%	5	2	0	3	1	0	2	8	6	4	12
Southeast	RJ	28	5,23%	0	1	0	0	2	0	6	3	7	0	9
Southeast	SP	51	9,53%	4	12	0	0	9	1	4	3	10	0	8

4 Final remarks

This work presents general quantitative and SNA analyses spanning eleven years of WCAMA through its publications, data, and metadata. Meta-scientifically examining WCAMA contributes to computational research in environmental and natural resource studies. By dissecting its dynamics, we assemble a portion of the puzzle using data, generating information and knowledge, and making a meta-scientific contribution to the maturation, memory, and culture of the landscape [Ioannidis *et al*., 2015; Ioannidis, 2018]. There needs to be more similar or closely related work to this.

With the analyses carried out in this work, compared with other CSBC workshops [Carvalho *et al*., 2023d] and other

Table 8. Metrics of co-authorship network over a decade at WCAMA.

Metrics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Diameter	1	1	2	2	1	1	1	3	2	2
Graph Density	0.195	0.063	0.109	0.14	0.156	0.07	0.049	0.067	0.062	0.108
Giant Component Density	1	1	0.564	0.709	1	1	1	0.466	0.466	0.916
Absolute Size of Giant Component	21	5	13	11	9	7	10	16	10	9
Relative Size of Giant Component	0.42	0.108	0.342	0.333	0.333	0.129	0.103	0.246	0.135	0.209
Max Number of Cliques in Giant Component	1	1	3	2	1	1	1	4	3	2
Max Size of Cliques in Giant Component	21	5	7	7	9	7	10	7	5	8
Max Number of Cliques in Graph	10	13	10	8	8	14	22	18	18	10
Max Size of Cliques in Graph	21	5	7	7	9	7	10	8	9	8
Clustering Coefficient of Giant Component	1	1	0.878	0.903	1	1	1	0.875	0.893	0.940
Graph Clustering Coefficient	0.921	0.872	0.959	0.909	0.732	0.876	0.935	0.825	0.947	0.929
Number of Nodes in Giant Component	21	5	13	11	9	7	10	16	10	9
Number of Nodes in Graph	51	47	39	34	28	55	98	66	75	44
Number of Edges in Giant Component	210	10	44	39	36	21	45	56	21	33
Number of Edges in Graph	249	69	81	79	59	105	234	144	174	103

Brazilian computing events [Carvalho *et al*., 2023b,c], we noticed some behaviors and characteristics.

WCAMA presents a dispersed and fragmented community in terms of collaborations in formal communications and publications. Observing Figure 7, we notice an excess of isolated groups and small giant components (Figure 8 and 9), also isolated. There is an apparent absence of a common thread that reaches such a high level of generalization or abstraction that it connects the community, i.e., each of these groups is not dealing with natural resource and environmental management at a high level, but at a specific level, specialized and fragmented. Even though this is a plausible feature in a workshop-level event, it is still excessively accentuated at WCAMA.

Even if there are specific intersections between groups and components, as indicated in Section 3.2 and Section 3.3, we notice isolation and bubble phenomena with specific research. The number of authors of just one occurrence indicates impaired support for continuous research. The low numbers of recurrences indicate ephemeral lines or topics of research not supported by most of the fourteen years of WCAMA, i.e., we could not find an expressive element that had relevant expression in all, or most, of the years.

In a complementary way, WCAMA is an event with a complex theme, categorically necessary and significantly valuable for society in the 2020s. However, under the umbrella of "management of natural resources and the environment" there is so much room that culminated in a community with little joint research and highly fragmented when it comes to collaborations and partnerships in formal research.

Behind this, there is a solid and engaged community to sustain fourteen years of event organization. So even if, in the scientific aspect, there is explicit isolation, fragmentation, and division, in the organizational aspects of WCAMA, there is collective dedication and engagement for its maintenance. Even though scientifically, we see from the numbers and graphs that it is a divided community, organizationally and politically, they engage with the event's future, which ties the community together.

Other aspects are of relevant practical value. Increase women's participation, engagement, and inclusion, maintaining it. Search for researchers and research from isolated regions that still need to be covered. Better integrate groups or components, taking advantage of the strengths and potential of each one with their topics or lines of research, especially those that present an objective and apparent intersection. Try to sustain authors and authorships for more editions, motivating them to continue their research at WCAMA and integrate the community, strengthening and diversifying it.

In addition to the descriptive analytical contributions presented here, there are certain limitations and threats to validity [Wazlawick, 2014; Marconi and Lakatos, 2017]. This work is limited to WCAMA as a space for computational research in Brazil's environmental and natural resource studies, and the time frame covered from 2013 to 2023. However, this should be sufficient for its complementing, which is welcome. Due to space constraints, some graphical analysis results have been omitted and can be accessed and appreciated with better quality in the supplementary online repository (indicated in Section 2). This work is limited to the analyses and metrics performed, with others serving as potential future quantitative or qualitative projects exploring various dimensions or perspectives, such as alternative SNA approaches or metrics.

5 Open data and access

Respecting the values of open and accessible data and aligned with the principles of this space, the Journal on Interactive Systems, we make the databases and artifacts generated available in an online repository [15].

Part of the data used was already structured and available in a previously published database.

Acknowledgements

This study was funded by the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financial Code 001.

This is an extended version of the paper "Meio ambiente, recursos naturais e... abelhas? Investigando uma década de WCAMA" Carvalho *et al*. [2023a], published on the *XIV Workshop*

[15] `https://zenodo.org/records/10718831` [accessed 28-08-2024]

de Computação Aplicada à Gestão do Meio Ambiente e Recursos Naturais. Awarded second place for best paper.

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