Articoli/1

Mapping a Controversy of our Time: The Anthropocene

Simone Belli

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We offer a bibliometric analysis of the literature and authors of the controversial Anthropocene discipline. Thanks to digital tools, we comprehend this complexity by drawing on existing literature and digital networks. In order to appreciate the interdisciplinary character of the controversy, we show clusters of co-cited publications, co-authors, and co-occurring terms in the fields of social science, agricultural and biological science, environmental science, and Earth and planetary science. The multidisciplinary character of Anthropocene research is reflected in the co-citation analysis and the term co-occurrence analysis. We found two clusters of co-occurring terms, representing agreement and disagreement with Anthropocene, and offer a comparison of the emblematic works presented in the network.

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Introduction

What is a controversy nowadays? For Bruno Latour[1], the word 'controversy' describes science and technology that is not yet stabilised. Controversy is useful and 'expected' in science and technology because it generates debate, conflict, and the sharing of knowledge between researchers from different disciplines. In normal conditions (without controversy) this dialogue is not produced. When a researcher observes a controversy, they need to observe where participants are positioned in respect to the controversy, but to do nothing else. Often, participants are not positioned just on two sides, but are distributed in multiple positions, such as on a map[2]. Controversies are debates generated between disciplines. For this reason, Anthropocene (hereafter referred to as A) is a controversy; it is also a complex idea. In our institution, A debates grew from a discussion between colleagues from different disciplines as they sought to develop a Science, Technology, and Society (STS) syllabus for undergraduate students. The term 'Anthropocene' was discussed by members of different departments,

[1] B. Latour, *Science in Action*, London 1987.
[2] B. Latour, *Why has critique run out of steam? From matters of fact to matters of concern*, «Critical inquiry», 30, (2), 2004, pp. 225-248.

who questioned if it should or should not be considered a scientific term, and whether it was valid or invalid within the scientific community. The geologists demanded greater scientific evidence, while the social scientists proposed an analysis of the significance of A as an idea. This contest was not just over data or definition; it was also proprietorial: a struggle between different scientists about who has the right to say something about this alleged epoch. Teachers of STS discussed this term in detail with students and, later, with other researchers from their university. Thanks to this particular controversy, it was possible to initiate an interdisciplinary discourse between scientists, who usually work separately and without consideration for other's perspectives.

Over the few months that this debate transpired, we began to create a picture about the controversy.

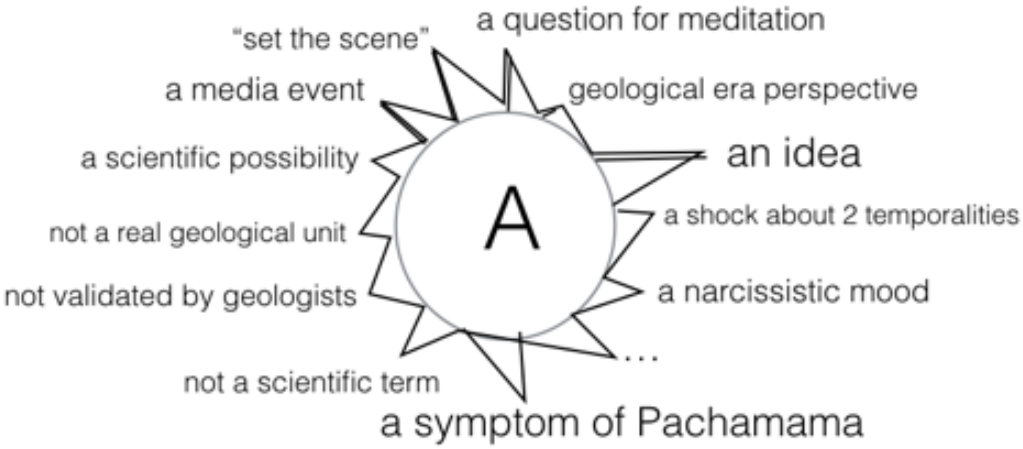

Figure 1 - *The controversy of A (Author's sketch)*

Looking at the sketch, we can start to focus on one of the multiple positions taken in the controversy; we have opened Pandora's Box! To try to move the debate from an epistemological account and into scientific territory, we offer a bibliometric analysis of the discipline and its authors. Bibliometric mapping is an interesting instrument for describing the scientific orientation of a research field across different disciplines. Thanks to digital tools, we will be able to comprehend this complex idea by drawing on existing literature and digital networks.

In order to appreciate the interdisciplinary character of the controversy, we will show clusters of co-cited publications, co-authors, and co-occurring terms from fields of social science, agricultural and biological science, environmental science, and Earth and planetary science. It is impossible to read A as an 'objective fact'[3], not because the aforementioned disciplines are producing any evidence that enables the controversy to be resisted, but because A totally subverts objective facts.

[3] B. Latour, *Agency at the Time of the Anthropocene*, «New literary history», 45.1, 2014, pp. 1-18.

1. Methods

The first step in drawing a map is observing the territory[4]. We shall not restrain our observation to any single theory or methodology, but will observe it in its whole complexity, as a composition of multiple theories and actors. For this, a researcher needs to listen to each actor's voice before drawing a map. The cartography of controversy involves a set of techniques used to investigate public disputes around techno-scientific issues[5].

But, when observation in scientific mapping becomes too complex to be managed, Venturini[6] argues that exploration and representation come together to help us observe the cartography. When faced with a theoretical controversy arising from books and papers taking multiple positions, controversy erupts because scientific writings become weapons. We need to be careful not to damage the science:

> There are no definitions to learn; no premises to honor; no hypothesis to demonstrate; no procedure to follow; no correlations to establish. Researchers are not even asked to explain what they study, but only to observe a controversy and describe what they see.[7]

Accepting this, we need to adjust our descriptions recursively during the observation of the territory, trying to simplify the complexity, attributing to each actor a visibility proportional to their weight, and providing descriptions that are adapted, redundant, and flexible[8]. We have digital tools to help us describe the complexity of a scientific controversy, and we will explain these in this paper.

The purpose of a mapping study is to uncover the cognitive structure of a research field. This paper analyses scientific publications on the topic of A that have been written by authors studying the controversy in different fields. It evaluates the leadership of the publications, the temporal evolution of the dispute, and the area and discipline covered. We will focus our search on scientific publications because they give an overview of the structure and dynamics of certain controversies. The results of these efforts will enable networks to be visualised and analysed, along with their temporal trends and principal authors. We suggest these steps for any researcher mapping a current controversy:

> -An extensive bibliographic review, including the use of bibliometric analysis. If no result is available, this means that the controversy is new; in this case, we highly recommend mapping.

[4] B. Latour, *Why has critique run out of steam?*, cit.
[5] T. Venturini, *Building on faults: how to represent controversies with digital methods*, «Public Understanding of Science», 21.7, 2012, pp. 796-812.
[6] *Ibid.*
[7] Id., *Diving in magma: How to explore controversies with actor-network theory*, «Public understanding of science», 19.3, 2010, pp. 258-273: 260.
[8] Id., *Building on faults*, cit.

-Define the type of data/publications (papers, books, patents, etc.) where the controversy is presented. We suggest focusing the analysis on scientific papers because these commonly involve area and discipline collaborations.
-Define the keywords and glossary of the map. In our case, this is relatively easy because A is a relatively new and quite specific term.
-Once the search terms have been defined, they are put in a repository like Scopus (the largest database of multidisciplinary scientific data).
-Use digital tools to bibliometrically map the results. These tools will help to manage all of the generated information. Once this is done the analysis of these landscapes begins. For this reason, the cartography of controversies is highly dependent on digital methods.

According to Michel Callon[9], digital techniques help to bring together the advantages of quantitative analysis (which allows the handling of significant amounts of data) and qualitative investigation (which remains open to the contributions and objections of the studied actors).

In the last decade, digital techniques have changed the way that researchers study a controversy. Nowadays digital tools are used to quantify bibliographic information.

For our cartography, we adopted the following techniques:

-A timeline showing the documents ordered by year (in order to know when the term came into use and when it became popular);
- A graph to identify the number of papers per author. We identified the four most prolific authors for analysis of their works;
-A graph showing the number of documents per year by source (to ascertain whether the controversy is specific to a particular discipline or if it is interdisciplinary);
-A network and a density map of bibliographic coupling (to classify the most transdisciplinary reviews);
-A density map of the most cited and co-cited works;
-A citation network of publications distributed along a timeline;
-A network and density map of co-authors to identify main collaborations;
-Cluster grouping of the co-occurrence of terms and the density of views;
-A comparison of the most representative works (as emerging from the previous network and cluster maps);
-A term co-occurrence item density map for the most prolific authors.

[9] M. Callon, *Can methods for analysing large numbers organize a productive dialogue with the actors they study?*, «European Management Review», 3.1, 2006, pp. 7-16.

2. A first approach

For Venturini[10], the evolution of a controversy is not uniform. Disputes can sometimes remain dormant for years before bursting into a sudden cascade of argument. The topic of A has followed this pattern. As observed in Figure 2, scientific papers regarding A increased exponentially from 2009.

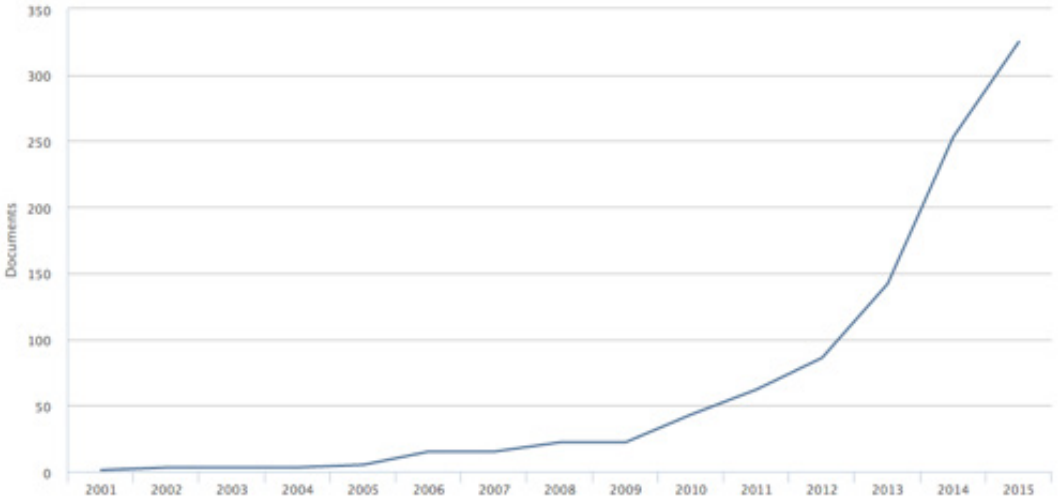

Figure 2 - *Documents by year (Source: Scopus)*

Falkowski et al.[11], Crutzen and Stoermer[12], and Codispoti et al.[13] coined a new term for the present era: the A. Some of these researchers come from environmental science and Earth and planetary science backgrounds, and were focused on oceanic denitrification and on the climatic transition from the Holocene to the A. However, it was in 2009 that A become a 'popular' term in the scientific landscape. There are three high-impact works on A within environmental science and agricultural and biological science. Two of these works are focused on pastoralism in Tibet. Miehe et al.[14] argued that, in the last two decades, synanthropes have been replacing forest and grassland in the pastures of Tibet. They linked current ecological indicator values of plants using palynological and pedological analysis. A new scenario for Tibet is possible thanks to the cooperation of palaeoecology, biogeography, and pedology. Schlutz

[10] T. Venturini, *Building on faults*, cit.
[11] P. Falkowski, R. Scholes, E. Boyle, J. Canadell, D. Canfield, J. Elser & F. Mackenzie, *The global carbon cycle: a test of our knowledge of earth as a system*, «*Science*», 290.5490, 2000, pp. 291-296.
[12] P. Crutzen, E. Stoermer, *The Anthropocene*, «Global change newsletter», 41, 2000, pp. 17-18.
[13] L. Codispoti, J. Brandes, J. Christensen, A. Devol, S. Naqvi, H. Paerl, & T. Yoshinari, *The oceanic fixed nitrogen and nitrous oxide budgets: moving targets as we enter the anthropocene?*, «Scientia Marina», 65(S2), 2001, pp. 85-105.
[14] G. Miehe, S. Miehe, K. Kaiser, C. Reudenbach, L. Behrendes, L. Duo, & F. Schlütz, *How old is pastoralism in Tibet? An ecological approach to the making of a Tibetan landscape*, Palaeogeography, Palaeoclimatology, Palaeoecology, *276*(1), 2009, pp. 130-147.

and Lehmkuhl[15] introduced the term 'nomadic A' to describe how Tibetan nomads' livestock breeding has influenced the monsoonal climate for 6000 years; the natural steppe-like vegetation has been transformed into Kobresia pygmaea pastures. Lovbrand et al.[16] examined Earth system science as a novel way to approach global environmental change research from the perspective of Michel Foucault's governmentality concept. She and her colleagues identified A as a central and ambiguous system of thought for Earth system science that harbours different strategies for sustainability. It seems that the considerable interest generating around A began with the question that Paul Crutzen and Will Steffen[17] formulated as an editorial comment in 2003: *How long have we been in the A era?* For this author, the start of the A remains more arbitrary, and generates the current controversy.

In the last six years, we have observed how the production of literature in this area has grown exponentially, until now there are 1,036 documents in Scopus that mention the term 'Anthropocene'.

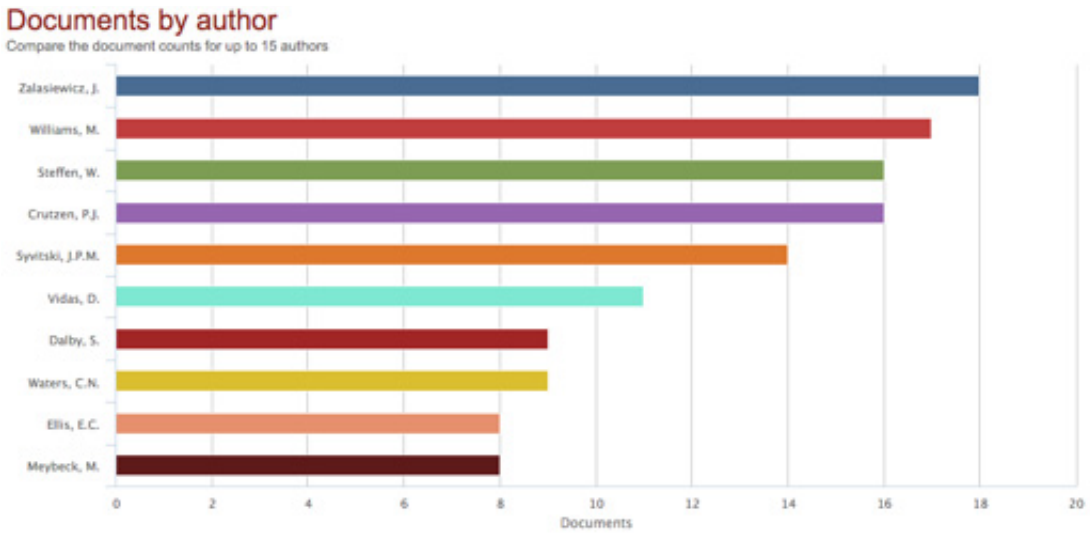

Figure 3 - *Documents by author (Source: Scopus)*

We found four authors with 16 or more publications on A. In mapping these prolific authors' works we will focus our analysis on describing their trajectories and contributions.

[15] F. Schlütz, F. Lehmkuhl, *Holocene climatic change and the nomadic Anthropocene in Eastern Tibet: palynological and geomorphological results from the Nianbaoyeze Mountains,* «Quaternary Science Reviews», 28.15, 2009, pp. 1449-1471.
[16] E. Lövbrand, J. Stripple, and B. Wiman, *Earth System governmentality: Reflections on science in the Anthropocene*, «Global Environmental Change», 19.1, 2009, pp. 7-13.
[17] P. Crutzen, and W. Steffen, *How long have we been in the Anthropocene era?* «Climatic Change», 61.3, 2003, pp. 251-257.

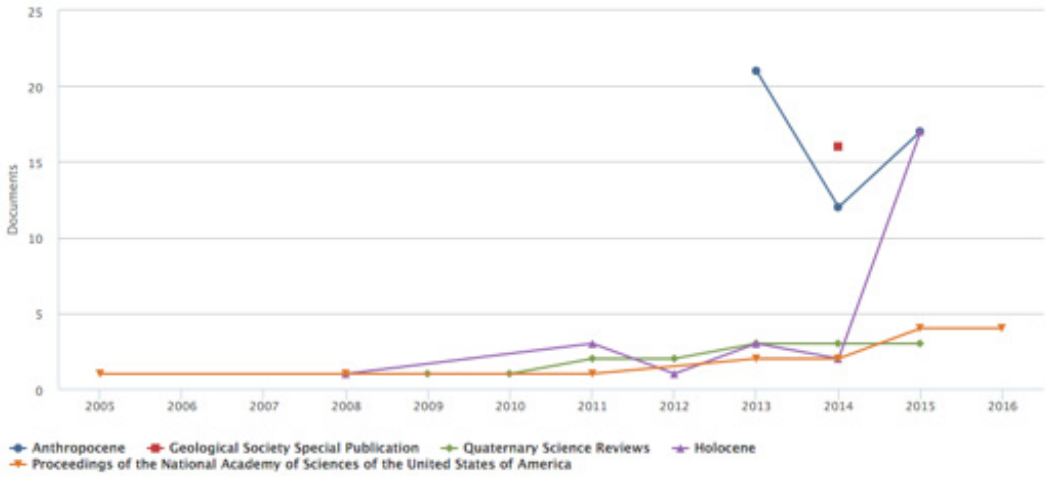

Figure 4 - *Documents per year by source (Source: Scopus)*

In the preceding years, many journals have published works on A, and in 2013 an ad hoc journal on A was instigated. During recent years, A has taken on a prime interdisciplinary position in scientific research, and is based on the interactions that people have with Earth processes. The most papers on A have been published in areas of environmental studies (41.9%), Earth and planetary studies (33.2%), social sciences and humanities (33%), and agricultural and biological science (21%). These include the significance of human activities in altering Earth's landscapes, oceans, and ecosystems over a range of time and space scales.

Just as the number of publications on A has grown exponentially, the opinions of internationally collaborating authors have diversified. This suggests that, in time and through the collective action of researchers themselves, more institutions and authors will join the international communication network that functions as a global self-organising system[18]. However, most of the publications are in English and produced in institutions in the United States, the United Kingdom, and Australia.

A great review for understanding the complexity of this controversy is the work of Smith and Zeder[19], which summarises and compares the various approaches scholars across all disciplines have taken in the past decade in defining the Holocene to Anthropocene transition.

Despite mapping the first landscape of scientific production on Anthropocene, we still do not have an entire map of this controversy. Thanks to digital tools, we can observe how authors from different disciplines collaborate to create an interesting and interconnected landscape. One of the software

[18] L. Leydesdorff, and C. Wagner, *International collaboration in science and the formation of a core group*, «Journal of Informetrics», 2.4, 2008, pp. 317-325.
[19] B. Smith, and M. Zeder, *The onset of the Anthropocene*, «Anthropocene», 4, 2013, pp. 8-13.

packages chosen for the creation of these landscapes was VOSviewer, which allows the creation of two-dimensional maps.

For Venturini[20], verifying a graph requires moving from the chart to a calculator, from the calculator to the data table, from the table to the archive that held the notes, from the notes to the sampled population, and from the sample to the actual phenomenon. Each step involved different devices and required considerable effort. Thanks to digital tools such as VOSviewer, disaggregating becomes much easier, as all of these steps can be performed without moving away from the computer[21].

Thanks to bibliographic coupling (Figure 5), we can observe the relatedness of items based on the number of references that they share. Two publications are bibliographically coupled if the same paper is cited in both publications[22]; it is the overlap in publications' reference lists[23].

The clusters are interconnected across the four most representative areas, so it is concluded that A is an interdisciplinary controversy.

It is interesting to note that the most prolific authors (Zalasiewicz, Williams, Steffen, and Crutzen) are in the middle of the network. This means that their works are the most useful and emblematic papers for authors from different disciplines, rendering them the most interdisciplinary works on A.

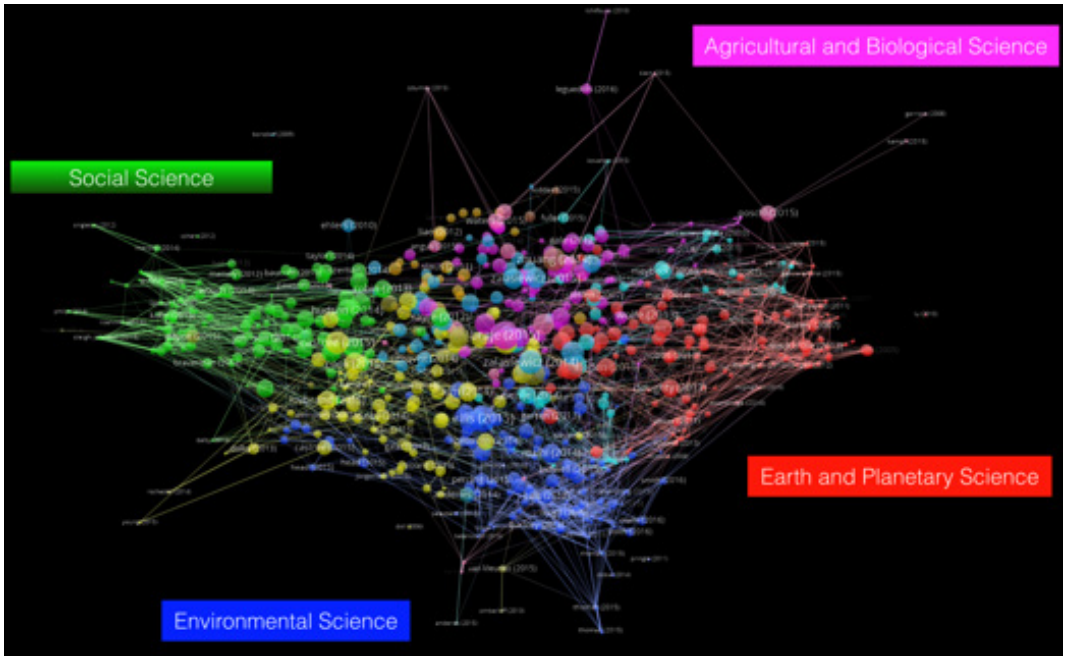

Figure 5 - *Bibliographic coupling (Elaborated with VOSviewer)*

[20] T. Venturini, *Building on faults*, cit.
[21] *Ibid.*
[22] M. Kessler, *Bibliographic coupling between scientific papers*, «American Documentation», 14.1, 1963, pp. 10–25.
[23] N. Van Eck, and L. Waltman, *Visualizing bibliometric networks*, in Y. Ding, R. Rousseau, and D. Wolfram (Eds.), *Measuring scholarly impact: Methods and practice,* London 2014, pp. 285–320.

However, in the middle of the bibliographic coupling map is a work by Todd Braje[24], published in the *Journal of Archaeological Research,* which reviewed scientific debate on the political, social, and institutional implications of A. Thanks to this review, we can map scholars from across academic disciplines in order to decode the complex interrelationships between natural and cultural systems and their effect on the future research agenda. Braje[25] added a new question to Steffer's previous one: «How long will the A last?»

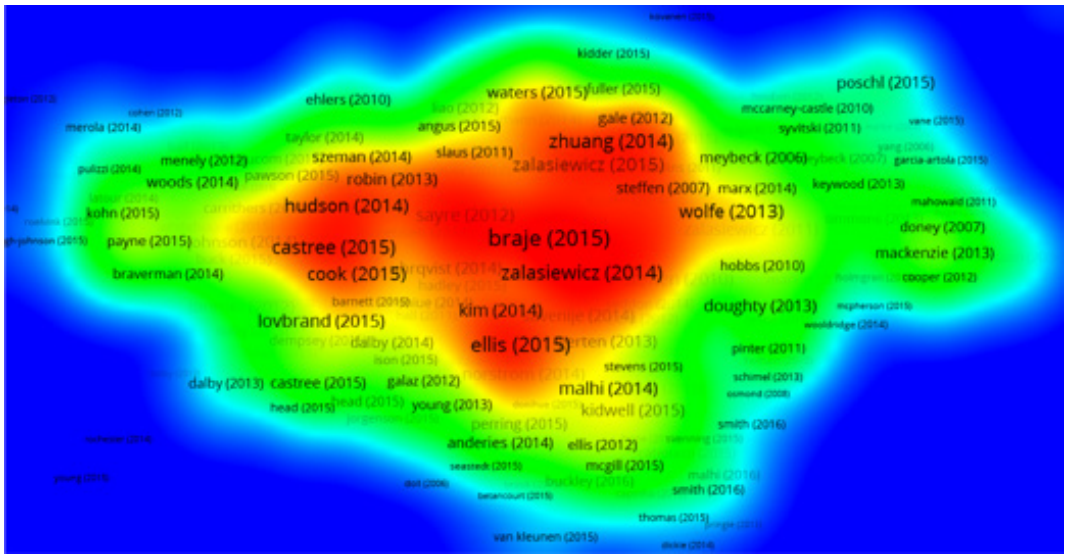

Figure 6 - *Density visualisation of bibliographic coupling (elaborated with VOSviewer)*

Figure 6 shows the same bibliographic coupling as in Figure 5, but in this case not as a network, but as a density visualisation. It is the same map, but density visualisation reveals its general structure, with the core in red and the periphery in blue. Red (darker) represents higher density, and the font size is proportional to the number of occurrences of a term. The font size is also proportional to the number of bibliographic couplings of an author. Authors occupying central positions deserve special attention because they have a better chance of shaping the controversy[26]. However, authors in the periphery are also attractive because they offer original perspectives and question what is often taken for granted, such as Poschl and Shiraiwa's work[27], which focuses on reviewing the multiphase chemistry of the atmosphere in the A. Their conclusion was «that the A is not only about mitigating negative side-effects of human activities by abstinence but also about actively using scientific knowledge and technology to protect

[24] T. Braje, *Earth Systems, Human Agency, and the Anthropocene: Planet Earth in the Human Age,* «Journal of Archaeological Research», 23, 2015, pp. 369-396.
[25] *Ibid.*
[26] T. Venturini, *Building on faults, cit.*
[27] U. Poschl, and M. Shiraiwa, *Multiphase Chemistry at the Atmosphere-Biosphere Interface Influencing Climate and Public Health in the Anthropocene,* «Chemical Review», 115, 2015, pp. 4440-4475.

and shape planet Earth for a sustainable development and healthy future of humanity»[28].

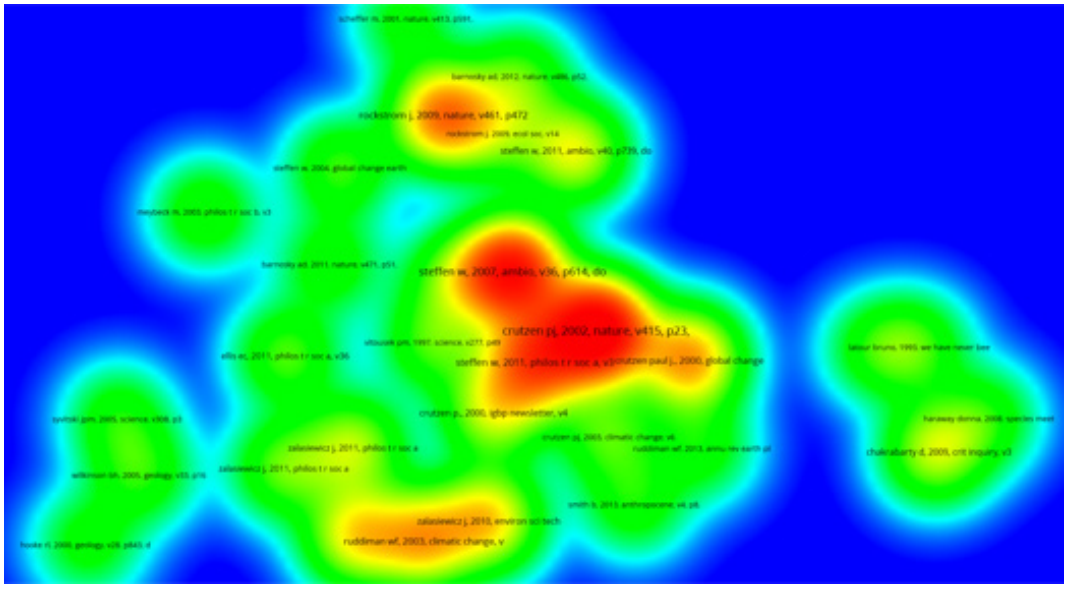

Figure 7 - *Density of the most cited and co-cited works (elaborated with VOSviewer)*

In Figure 7, we can observe the density of the most cited and co-cited works. Co-citation is defined as the frequency with which two documents are both cited in a third document. Two publications are co-cited if there is a third paper that cites both publications[29]. The greater the number of publications in which publications are co-cited, the stronger the co-citation relation between the two publications[30]. The use of co-citation analysis is useful to the study of relations between researchers[31]. Co-citation analysis builds on the idea that authors are frequently co-cited because they are similar. A high co-citation frequency between two authors does not necessarily mean that they share the same standpoint, but it indicates that they are part of the same discourse[32].

In such controversies, not all positions are equal, and authors fight to occupy important areas of the controversy. Authors that occupy influential positions deserve particular attention in the debate because they have a better chance to shape it. In the visualisation, we find Williams, Steffen, and Crutzen in the red core. They collaborate on many works, and they represent the primary

[28] Ivi, p. 4457.
[29] I. Marshakova, *Bibliographic coupling system based on references*, «Nauchno-Tekhnicheskaya Informatsiya Seriya», 2, 1973, pp. 3-8; H. Small, *Co-citation in the scientific literature: A new measure of the relationship between two documents*, «Journal of the American Society for information Science», 24.4, 1973, pp. 265-269.
[30] N. Van Eck and L. Waltman, *Visualizing bibliometric networks*, cit.
[31] K. McCain, *Mapping economics through the journal literature: An experiment in journal cocitation analysis*, «Journal of the American Society for Information Science», 42.4, 1991, pp. 290-294; H. White, and B. Griffith, *Authors as markers of intellectual space: Co-citation in studies of science, technology and society*, «Journal of Documentation», 38.4, 1982, pp. 255-272.
[32] P. Ahlgren, P. Pagin, O. Persson, and M. Svedberg, *Bibliometric analysis of two subdomains in philosophy: free will and sorites,* «Scientometrics», 103, 2015, pp. 47-73.

authors working on A, with many other authors quoting them. According to Scopus, Crutzen's 2002[33] work published in *Nature* is cited 257 times, while Steffen et al.'s 2007[34] work published in *Ambio* is quoted 248 times.

Nobel Prize winner Paul Crutzen's work, published in the 'Concept' section of *Nature*, gave a definition of A that generated a before and after in the study of the topic. Afterwards, in 2007, Steffen, Crutzen, and McNeill formulated a new question: 'Are humans now overwhelming the great forces of nature?'

The islands in green on the left side of this map are occupied by Zalasiewicz's works, most of which cite works in environmental science, and Earth and planetary science areas. Collaborating with Steffen et al.[35], Zalasiewicz discussed how various activities influence the Earth system and the need to change the human relationship with the planet. They suggested that the creation of an efficient governance system for planetary stewardship is likely to be polycentric and multilevel rather than centralised and hierarchical[36].

The island on the left side of the map is composed of Earth and planetary works. One of the most cited is Bruce Wilkinson[37]. With 121 co-citations, his work about the deep-time perspective of humans as geological agents is emblematic in its field; he works with concepts of Anthropogenic activities.

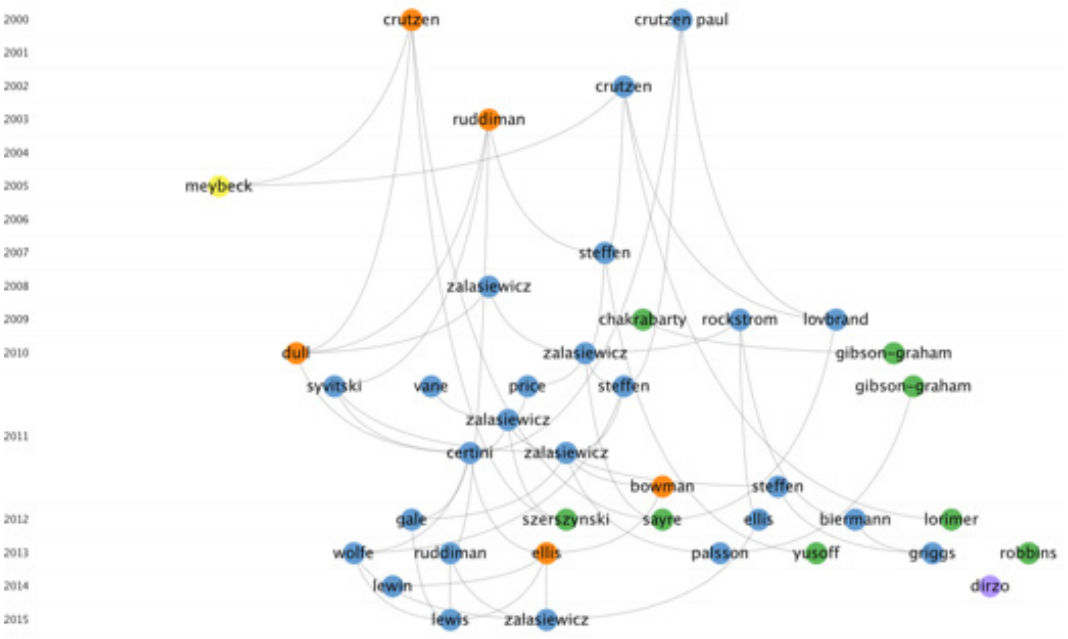

Figure 8 - *Citation network of publications (elaborated with CitNetExplorer)*

[33] P. Crutzen, *Geology of mankind*, «Nature», 415.6867, 2002, pp. 23-23.
[34] W. Steffen, P. Crutzen, and J. McNeill, *The Anthropocene: are humans now overwhelming the great forces of nature*, «AMBIO», 36.8, 2007, pp. 614-621.
[35] J. Zalasiewicz, M. Williams, A. Haywood, and M. Ellis, *The Anthropocene: a new epoch of geological time?*, «Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences», 369.1938, 2011, pp. 835-841.
[36] *Ibid.*
[37] B. Wilkinson, *Humans as geologic agents: A deep-time perspective*, «Geology», 33.3, 2005, pp. 161-164.

The island on the right is represented by social scientists and philosophers. Bruno Latour's[38] work is one of the most quoted texts on A; although he does not mention the term in the text, he ruminates on something similar. He mixed nature and society not as two opposite transcendences but as one element of mediation, which a decade later was denominated as A. His work represents a precursor to the term.

It does not matter how marginal an island on the map is, because periphery and discordant viewpoints can offer original perspectives and questions. In science, no controversy is an island; each is always composed of several sub-controversies, connected to several others situated in other islands or areas. In this way, controversies are not binary (0 or 1), but complex systems with multiple voices and authors.

In Figure 8 we observe a timeline of the citation network of publications from 1861 to 2016; from a time perspective, it can be seen how the controversy has been explored. The figure uses the same information as Figure 7 but, thanks to the timeline, we can observe how the principal works have been cited over time. As previously mentioned, A has only become a popular topic for researchers in recent years. This is evident in this timeline, as citations only start to be important in the last 10 years. Each circle of the network represents a publication. Only the 40 most-frequently cited papers are included in this visualisation. Six clusters are seen in the network, which relate to scientific area. The horizontal location of each publication is determined by its citation relations with other publications; this allows us to observe how selected authors have come to occupy the middle part of the flow (Crutzen, Steffen, Zalasiewicz).

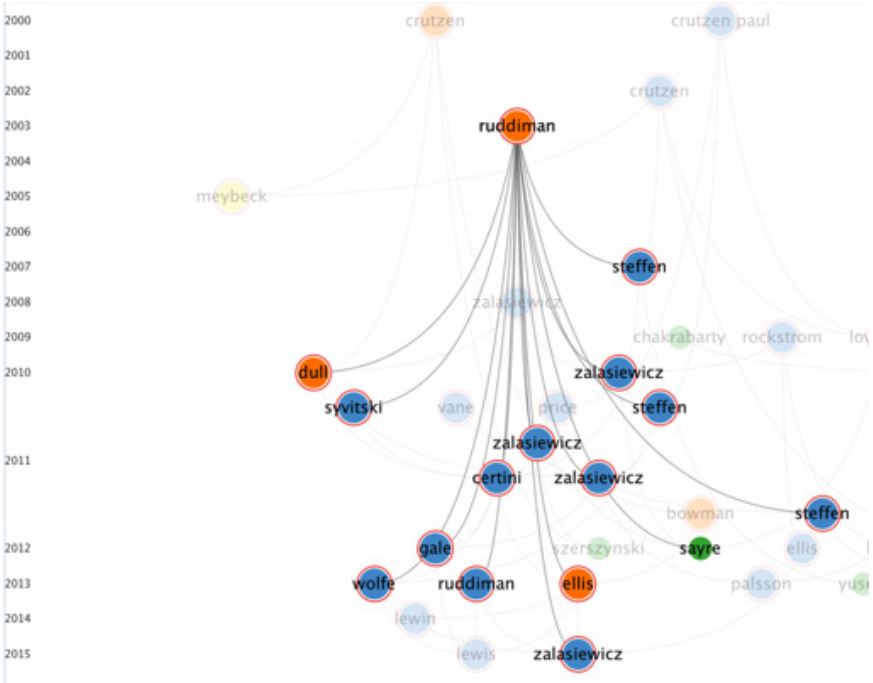

Figure 9 - *Citation subnetwork of Ruddiman's publication (elaborated with CitNetExplorer)*

[38] B. Latour, *We Have Never Been Modern*, Cambridge 1993.

The vertical location of each publication is determined by publication year. This allows us to observe the distribution of quotations and generate a flow of specific works based on the most relevant citations. Starting in 2000, with Paul Crutzen's works, the term A began to garner interest in academia. Analysing these data gives visibility to various viewpoints according to area, topic, and time. The basic tenet of a visualisation like this is that every actor can be categorised into a network and that every network can be connected tightly enough to become a single actor (as in Figure 9).We have selected the publications of just one author from Figure 8 to analyse in the Figure 9 timeline. The curved lines represent citation relations. Focusing on Ruddiman's work, we can observe how a flow has been created in the last 10 years, with publications generating different citation subnetworks in the following years. Ruddiman[39], as with Wilkinson, works with the concept of Anthropogenic activities, focusing on the greenhouse.

Ruddiman's subnetwork includes 15 publications, 12 of which are in an interdisciplinary area. Although his work is centred exclusively in environmental science, it generates an interest outside of its field.

Thanks to the interactivity of digital tools, it is not only possible to show the position of actors at a given moment in time, but also to show how this position changes through time and across area, and how this has affected the definition of the controversy itself.

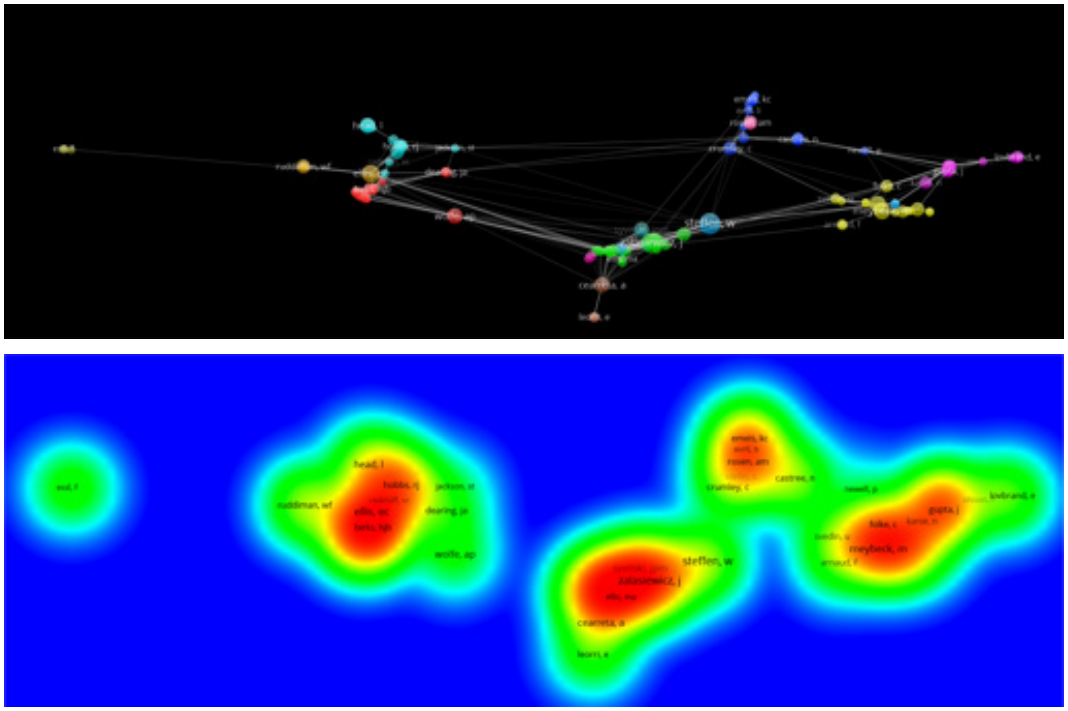

Figure 10 - *Network and density of co-authors*

[39] W. Ruddiman, *The anthropogenic greenhouse era began thousands of years ago*, «Climatic change», 61.3, 2003, pp. 261-293.

In Figure 10 we observe the network and density of the most productive co-authors on A who have more than two collaborations between them. Collaboration is more frequent in natural science than in social science, as can be observed in Figure 10. The most prolific collaborating authors are in the middle of this map. As we have seen before, many have collaborated during the last decade. Steffen is the author with the most co-authorship (78 collaborative works on A).

Up until this time, we have observed the relations between authors and disciplines during recent years, but we have not entered into why A is a controversy. For this reason, we need to analyse the networks constructed through the content of these works. By discussing this content we can observe that A is a controversy of our time.

We need to create maps based on a text corpus. These types of map use terms that appear in the title and abstract of each work. For this analysis, we decided to define a co-occurrence as comprising a minimum of ten term occurrences.

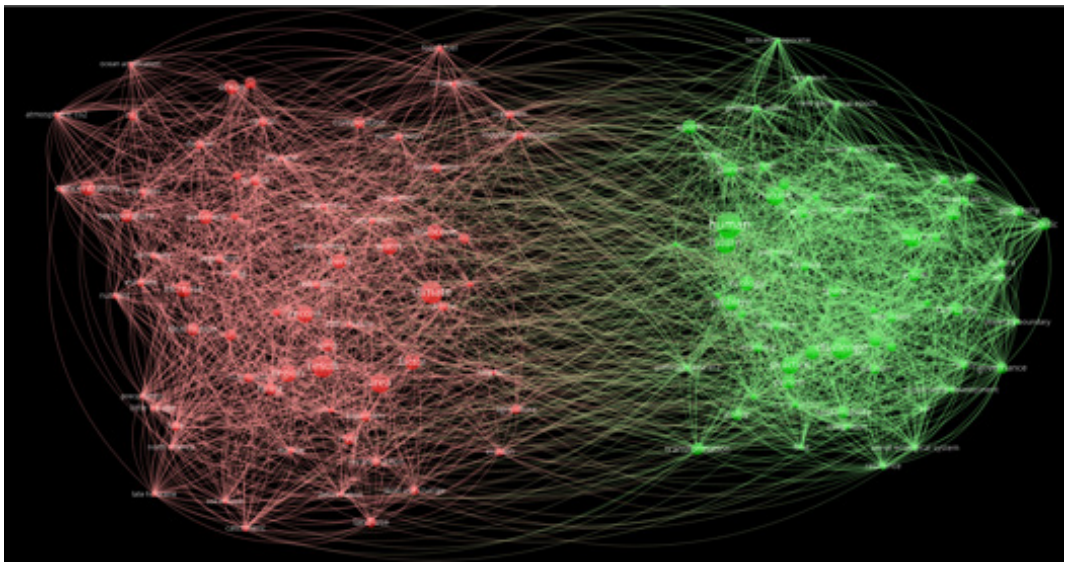

Figure 11 - *Term co-occurrence network map*

The number of co-occurrences of two keywords is the number of publications in which both keywords occur together in the title, abstract, or keyword list[40]. In this map, the more important an item is, the larger its circle. Although we know that a controversy is something complex and not binary, in Figure 11 we observe two significant clusters, one in red and the other in green.

Before beginning an analysis of these terms, we think it is important to observe how nodes in each cluster connect to create two big polarities.

Finally, looking at Figure 12, we discover the existence of a large controversy. This map shows a huge controversy divided into two cores, dependent on the co-occurrence of terms. Figure 12 explains two different territories of the same topic, that is, two ways to understand and explain A.

[40] N. Van Eck, and L. Waltman, *Visualizing bibliometric networks*, cit.

The cluster density map shows the co-occurrence of terms. In the first cluster, to the left of the map and in green, are the most frequently occurring terms: water (70), result (69), data (64), concentration (58), climate (54), ocean (52) period (48), increase (37), Holocene (35), biodiversity (34), sediment (24), industrial revolution (14), and anthropogenic activity (13). We have related these terms to the works analysed in order to ascertain which cluster holds the works of each author. Thanks to Wordcounter software, we ranked the most frequently used words in these works. Comparing the map in Figure 12 with the most frequently used 25 terms (excluding small words like "the" and "it" and using only the roots of the words), we have observed that these terms are used by authors who did not mention A in their work, but mentioned something similar to anthropogenic activities[41]. These authors prefer using terms from environmental science to show the changes, caused by human activities, that have transformed the land and ecosystem.

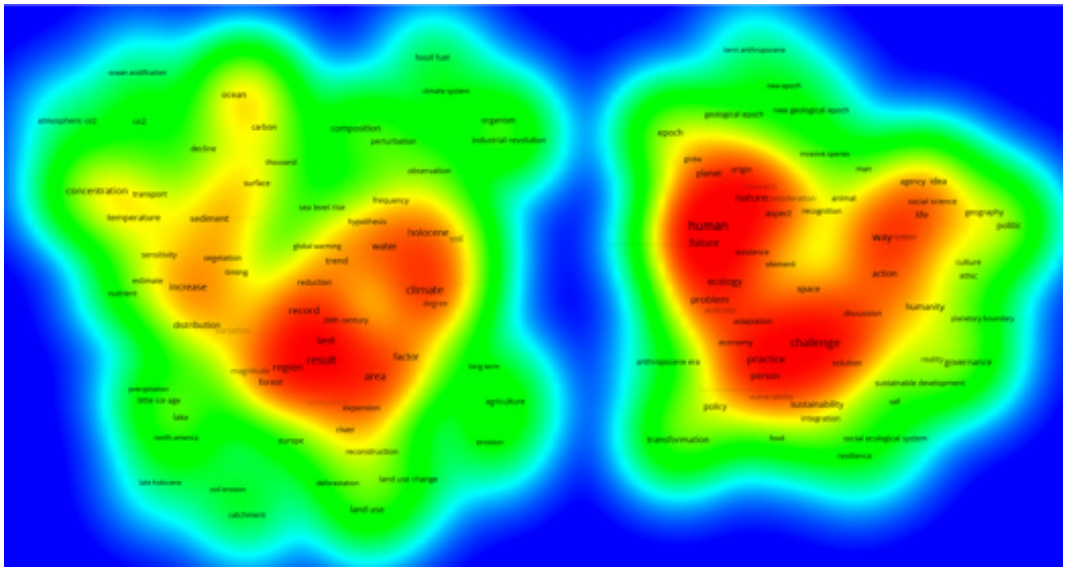

Figure 12 - *Term co-occurrence item density map (VOSviewer)*

On the right side of the map, we have the second cluster (red), where the most frequently occurring terms are human (141), science (115), future (98), challenge (83), concept (69), future (64), environment (40), geological (36), governance (35), action (34), epoch (25), resilience (21), man (21), and opportunity (18). Using the same method of comparison used with the other cluster, it appears that many authors we have previously cited[42] use terms found

[41] E. Ellis, D. Fuller, J. Kaplan, and W. Lutters, *Dating the Anthropocene: Towards an empirical global history of human transformation of the terrestrial biosphere*. «Elementa: Science of the Anthropocene», 1.1, 2013, pp. 1-8; W. Ruddiman, *The anthropogenic greenhouse era began thousands of years* ago, cit.; B. Wilkinson, *Humans as geologic agents: A deep-time perspective*, cit.
[42] T. Braje, *Earth Systems, Human Agency, and the Anthropocene: Planet Earth in the Human Age,* P. Crutzen, *Geology of mankind*, cit.; P. Crutzen, and W. Steffen, *How long have we been in the Anthropocene era?*, cit.; P. Crutzen and E. Stoermer, *The Anthropocene*, cit.; *Earth System governmentality: Reflections on science in the Anthropocene*, cit.; U. Poschl, and M. Shiraiwa, *Multiphase Chemistry at the Atmosphere-Biosphere Interface Influencing Climate and Public Health in the*

in either the first or the second cluster. No ambiguity exists in the works of the most cited or prolific authors. Every author appearing in the previous maps, and who are important to A for several reasons, are divided into either the first or the second cluster. Combining the term co-occurrence item map with the word counter for each text, gives us a clear result: controversy about A exists. These two lists of terms are very different, and we can understand why the terms "Anthropocene era" or "human" never appear in the first cluster. In the second cluster, the terms "Holocene" and "climate" never appear. In a preliminary analysis, we can assume that the first map is composed of work that does not agree with A as a new geological era, believing in the continuation of the Holocene, or at least that we are in the late Holocene era. The second cluster appears to contain works that agree with this new geological era and find humans to be the core of this new period.

Scientific papers published on A are in one cluster or the other; they hardly have any connections.

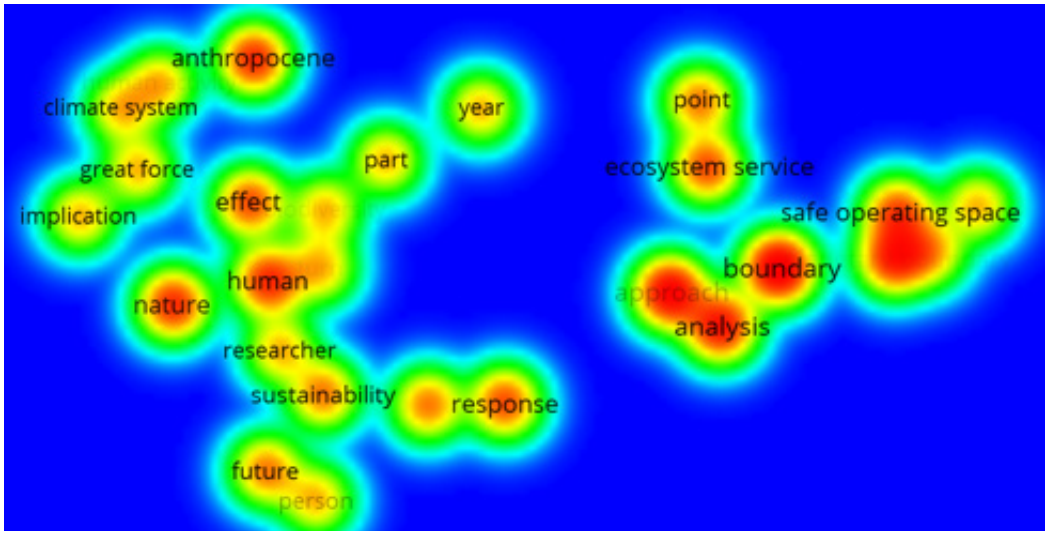

Figure 13 - *Term co-occurrence item density map for the most productive authors (VOSviewer)*

In Figure 13, we have analysed the term co-occurrence for the most prolific authors. Remembering that term co-occurrence is defined by a coincidence of more than five words, most of the terms that the authors use can be identified in the second cluster of Figure 12. The most productive and influential authors on A are positioned in the second cluster, in agreement with the concept of A. According to the cartography of controversies, Venturini[43] argued that when they are unremittingly engaged in tying and untying relations, arguing categories and identities, revealing the fabric of collective existence from multiple viewpoints and perspectives, contrasting notions and methodologies, and exploring where things get the most complicated, scholars are soon submerged by complexity.

Anthropocene, cit.; W. Steffen, P. Crutzen, and J. McNeill, *The Anthropocene: are humans now overwhelming the great forces of nature?*, cit.; J. Zalasiewicz, M. Williams, A. Haywood, and M. Ellis, *The Anthropocene: a new epoch of geological time?*, cit.

[43] T. Venturini, *Building on faults*, cit.

3. Discussion

Growth in the number of publications relating to A in the last decade has increased the controversy of whether A exists and represents a new era, as not all authors entirely agree. We applied different digital techniques in order to map this debate.

Firstly, we have observed a substantial increase in scientific publication. The multidisciplinary character of A research is reflected in the co-citation analysis and the term co-occurrence analysis. We found two clusters of co-occurring terms, representing agreement and disagreement with A, and offer a comparison of the emblematic works presented in the networks.

We have offered some scientific landscapes that make controversies exciting to investigate, particularly where cartographies and digital tools can help us to understand them. The best advantage offered by networks and maps is that they facilitate the reading of bibliometric information.

It is important to underline that exploration and representation always come together in cartography. Scholars are soon submerged by complexity as they are encouraged to take on multiple viewpoints and perspectives, to contrast notions and methodologies, and to explore things where they are most complicated.

These questions and this context has explored the relationships between scientific disciplines, between science and society, and between science and politics, as well as issues about thinking and understanding today's relationships between humanity, technology and planet Earth. We have tested the fruitfulness of digital bibliometric methods for mapping Anthropocene according to its status as a huge contemporary controversy.

Simone Belli
School of Social Science and Innovation, Yachay Tech
✉ sbelli@yachaytech.edu.ec