Climate Change and Sustainable Development:

The case of Amazonia and Policy Implications

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Abstract

The relationship between sustainable development and climate change has been extensively addressed, but with few studies focusing on the Amazonian Rainforest. This is, by far, the largest rain forest in the world and one of the most pressured by devastation resulting from economic activities. The combination of the inhabitants' welbeing and the preservation of the Amazonian region is a challenge not only to local and national governments but also to the world. Due to its dimension, its preservation is critical and the problem of climate change associated with rising temperatures, lower precipitation, and the increase of extreme weather events must be mitigated. This paper aims to study the effects of climate change on the sustainable development of Amazonia. To reach this objective a scientometric analysis was carried out based on a sample of 2,598 articles. The sample' articles reveals the evolution of the research field in terms of the increased number of works that have been published in top journals and the main drivers of climate change in Amazonia, such as deforestation, global warming, and land use. Our results indicate also that the environmental dimension of sustainable development has been the more studied. From the analysis it is recommended that policy makers implement incentives for a better forest management, design policies with realistic expectations, and rely more on technical reports and approaches to implement policies. Moreover, better integration of policies at local, regional, national and international levels is necessary to adaptation and mitigation of climate change. A set of measures to intensify the scientific approaches integrating economic and social dimensions are also proposed. This work contributes to the systematization of the literature on sustainable development and climate change in Amazonia which has not been done yet, providing also policies' recommendations to researchers and professionals for a better understanding of climate change and sustainable development in the Amazonia region of Brazil.

Keywords: Sustainable development, climate change, amazonia, scientometric analysis, deforestation, global warming.

JEL codes: Q01; Q23; Q56; O13

1. Introduction

An analysis performed by the World Meteorological Organization shows that the five-year average global temperature from 2013 to 2017 was the highest on record (UN, 2018). According to the World Economic Forum (WEF), the following five global threats exist for 2019: extreme weather, failed climate change mitigation, natural disasters, cyber-attacks, and data fraud or theft (WEF, 2019). As can be seen, three of these greatest threats are related to climate change (CC).

At the Conference of the Parties (COP) 21 in Paris, an historic agreement to combat climate change was reached through the United Nations Framework Convention on Climate Change (UNFCCC). It was agreed that the world should maintain a global temperature increase in this century below 2 degrees above pre-industrial levels and continuing efforts should be performed to limit temperature rise to 1.5 degrees Celsius above pre-industrial levels (UNFCCC, 2015). Since then, considerable efforts have been performed to analyze the different climatic impacts of 1.5 and 2.0 °C warming on extreme weather events, water availability, agricultural yields, sea-level rise and risk of coral reef loss (Schleussner et al., 2016); intense heat and rainfall extremes (King & Karoly, 2017); Su et al., 2018; land monsoon and ocean monsoon precipitation (Qu & Huang, 2019);

Since the 1990s international conventions on climate have been formalized, including the 1992 United Nations Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol (Liverman, 2009) with the main objective of reducing the four major GHGs responsible for the global warming: carbon dioxide, methane, nitrous oxide, and sulfur hexafluoride.

For the Intergovernmental Panel on Climate Change (IPCC) climate change refers to a change in climate over time, whether due to natural variability or to human activity, that has implications around the world (IPCC, 2014).

The related concept of sustainable development (SD) was proposed in the Brundtland report in 1987 (Olawumi & Chan, 2018) and was also developed at the Rio Earth Summit in 1992 (Najam, Huq, & Sokona, 2003), remaining a central concept nowadays. Sustainable development encompasses the interactions of three complex systems: the world economy, global society, and Earth's physical environment (Callens & Tyteca, 1999, Chang & Cheng, 2019 and Sachs, 2015). In 2014 UN member states proposed the Sustainable Development Goals (ODS), which consist of 17 specific goals, the most important of which are the following: ending poverty, reducing inequality, producing sustainable energy, and tackling climate change, from the current UN agenda to 2030 (Hu et al., 2018). According to Silvestre & Ţîrcă, (2019), SD is an urgent issue that requires immediate action and changes from governments, industry, and society as a whole. For Axelsson, Angelstam, Elbakidze, Stryamets, & Johansson (2011), SD is seen as a collective societal process implying the interaction among multiple stakeholders of differing levels and powers.

Latin America in general and Amazonia in particular, are important contributors for the biodiversity of the planet. Amazonia, known as the planet's lung, represents a vital ecosystem and an important source of food, water and energy to the subsistence of a lot of people. Meir et al. (2011) show that this zone of the planet is constantly threatened by unsustainable land management' policies and climate changes with the consequence of a large-scale impacts on its ecosystem. Moreover, several authors (Gloor et al., 2015; Hilker & Fatouros, 2015; Esquivel-Muelbert et al., 2019) have reinforced the concerns on Amazonia' climate change alerting specially for the length and intensity of the dry season and the increased precipitation during the wet seasons with all the consequence derived from it.

According to the Greenhouse Gas Emission and Removal Estimate System (SEEG), the Amazonian states have very high per capita emissions due to deforestation. As a result, Brazil will not meet its 2020 climate target if gross emissions are considered, and if they remain at the levels between 2010 and 2016 (SEEG, 2018). In 2018, the IPCC report, one of the most important scientific reports on climate change, argues that countries in the tropics and sub-regions of the Southern Hemisphere would suffer the greatest impacts on economic growth due to climate change if global warming were to increase from 1.5°C to 2°C, along with reduced food availability in Amazonia, Southern Africa, Central Europe, and the Mediterranean (IPCC, 2018). This phenomenon should however be analyzed more deeply attending to other factors such as the time span, the level of countries' development, and the climate regime of the countries. Being so, and according to Sequeira et al. (2018), features linked with climate change such as rising temperature and precipitation may not have a negative effect on long-run growth, despite some shorter run effects may be observable, emerging essentially in the less developed countries. Moreover the same authors presented evidence according to which precipitation has different effects in countries with different climate regimes: it may have short-run positive effects in hot and temperate countries but a negative effect in cold countries.

The development model to be sought for the Amazonia region is a great challenge, since there is not yet a comparable tropical (developed) country with an economy based on the rational use of forest resources, where social and economic progress is balanced with the conservation of nature and different native cultures (De Mello, 2015).

It is therefore necessary to understand climate change through the lens of sustainable development (Streimikiene & Girdzijauskas, 2009). However, climate change and sustainable development have been discussed in two different strands of the literature, being necessary to merge these issues (Cohen, Demeritt, Robinson, & Rothman, 1998). On the field, there is clearly a failure to study simultaneously sustainable development and climate change mitigation in Amazonia. This, together with the growing importance of both concepts (CC and SD) prompts the development of the current study.

In this work an initial pre-survey performed during January 2019 on the Scopus and Web of Science databases over the last five years using key words in "Articles" document type was conducted. This returned about 165,000 scientific articles on "climate change", of which only 0.89% were related to the Amazonia region. In the context of "sustainable development", more than 76,500 studies were published, and articles that included Amazonia represent less than 0.50%. About 5,700 articles analyze these two topics together and 60 articles refer to Amazonia, which represents about 1% of the articles (Appendix 1). This seems to confirm the dissociation between the importance of Amazonia as a priority region to contribute to the mitigation of climate change effects and the relevance that the literature related to climate change and sustainable development has dedicated to this issue. This paper seeks to contribute to fill this gap.

Moreover, initiatives on climate change strongly linked with concepts and practices of sustainable development have not been investigated in terms of processes of knowledge creation (Grist, 2008). Although there is an empirical understanding about the links between climate change and development, the majority of current research discusses these links at the theoretical level without providing suggestions for their implementation (Bizikova, Robinson, & Cohen, 2007). For example, Swart, Robinson, & Cohen (2003) have focused on scientific linkages and discuss the opportunities they provide for the development of integrated policies and the need to consider the risk of trade-offs. Olawumi & Chan (2018) carried out a scientiometric survey of the global trend and structure of sustainability research in 1991 and 2016 using techniques such as co-authorship, co-speech, co-citation, clusters, and geospatial analyses, examining 2,094 articles from the Web of Science database to generate the research networks and the geospatial study map.

Also through a systematic review of the literature, Escarcha, Lassa, & Zander (2018) have documented scientific knowledge on the impacts of climate change and adaptation in livestock systems, identifying research gaps such as a lack of research on Asia and South America and also a lack of mutual research and links between impacts and adaptation. Similarly, Husain & Mushtaq (2017) have analyzed climate change data related to environmental science and ecology over a period of five years (2009-2013), and using the Web of Science database discovered that about 17,266 articles were published in the field by different institutes around the world.

Our paper contribution is threefold. It contributes to the systematization of the literature relating sustainable development and climate change in Amazonia which has not been done yet. Furthermore, it provides based policies' recommendations in order to provide researchers and professionals with a better understanding on climate change and sustainable development in the Amazonia region of Brazil. This study represents also an important contribution to international readers since besides Amazonia region be sited (in its great majority) in Brazil it is considered the planet' lung and any change that occur in this region has important impacts on the climate change in all the planet.

This paper is structured in four sections. Following this introduction, Section 2 presents the methodology, and the research data used in this study. Section 3 presents the main results from the literature review. Section 4 presents a discussion of results, policy implications and policy proposals. Finally, in Section 5 final conclusions are drawn.

2. Methodology

A *scientometric analysis* was carried out to investigate the state-of-the-art of the research on the relation between the climate change and the sustainable development in the Amazonia region and derive policies recommendations towards climate change management and mitigation. There has been considerable interest in the research community in general to evaluate the research activities using the scientometric methods (Konur, 2012). Scientometric analysis is a technique that allows for a more comprehensive and concise capture and mapping of an area of scientific knowledge, identifying structural patterns, and drawing salient research boundaries using mathematical formulas and visualization (Olawumi & Chan, 2018). Scientometric analysis is described as one of the most used methods to evaluate and examine the research development and performance of academics, faculties, colleges, countries, and even journals in a specific research field (Konur, 2012).

Scientometrics technique analyzes the published literature to evaluate the impact of a specific research area using quantitative or statistical assessment methods to describe the publications (Hood & Wilson, 2001; Smith, 2012; Keathley-Herring et al., 2016) being . considered one of the most effective methods to assess research performance. It allows performing also a benchmarking analysis of the research topic on different disciplines and among countries, identifying changes over time (Pouris, 2012).

In order to identify the bulk of the research topics covered within the relationship between climate change and sustainability in Amazonia rainforest, Co-word analysis was used which allows to identify co-occurring keywords or terms and the co-occurring subject in the Web of Science (WoS).[1]

In this work the Web of Science (WoS) was used since it has been considered the most complete and important data source containing the top journals in the world (Boyack, Klavans, & Borner, 2005; Pouris, 2012; Song, Zhang, & Dong, 2016; Olawumi & Chan, 2018; Wang et al., 2018). Moreover, bibliometric researchers consider the WoS as an important database providing a set of metadata that is essential for this type of analysis, including abstracts, references, number of citations, lists of authors, institutions, countries, and the journal impact factor (Carvalho, Fleury, & Lopes, 2013); Gaviria-Marin, Merigó, & Baier-Fuentes, 2019). Beyond these advantages, the WoS database was used in this study because it is also considered to be the most comprehensive, avoiding conflicts generated by divergences in the input of information in the databases (Olawumi & Chan, 2018).

The WoS database was used to collect published literature on climate change and sustainable development in Amazonia, from 1990 to 2019. The selection criteria include only journal articles because they have undergone a peer review process and most authors republish their conference articles and dissertations in subsequent scholarly journals (Olawumi & Chan, 2018), making them very complete. In addition, we have selected those

[1] For these analyses the software *VOSViewi*er version 1.6.10 software was used.

written in English, as usual, because this is the major scientific language; and Portuguese, because of the geographical focus of the research, which is the Brazilian Amazonia region, where the national language is the Portuguese.

The search strategy is to select articles that contain in the title, abstract, or keywords various combinations of our search keywords (see Table 1). Fuzzy search is denoted with an asterisk ("*") (Olawumi & Chan, 2018), which is used in Amazon searches to cover the various forms of this word in articles, such as Amazonia, Amazon's, among others. With these search criteria, the data set was extracted in February 2019. The search terms are in Table 1.

Table 1. Group and Keywords search in databases.

Group	Keywords	WoS
KW1	Amazon* AND ("Climate Change" OR "Global Warming")	2337
KW2	Amazon* AND "Sustainable development"	312
KW3	Amazon* AND ("Climate Change" OR "Global Warming") AND "Sustainable development"	51
	Total	2700

Thus, a comprehensive bibliographic search retrieval and indexing was performed, as seen in Figure 1.

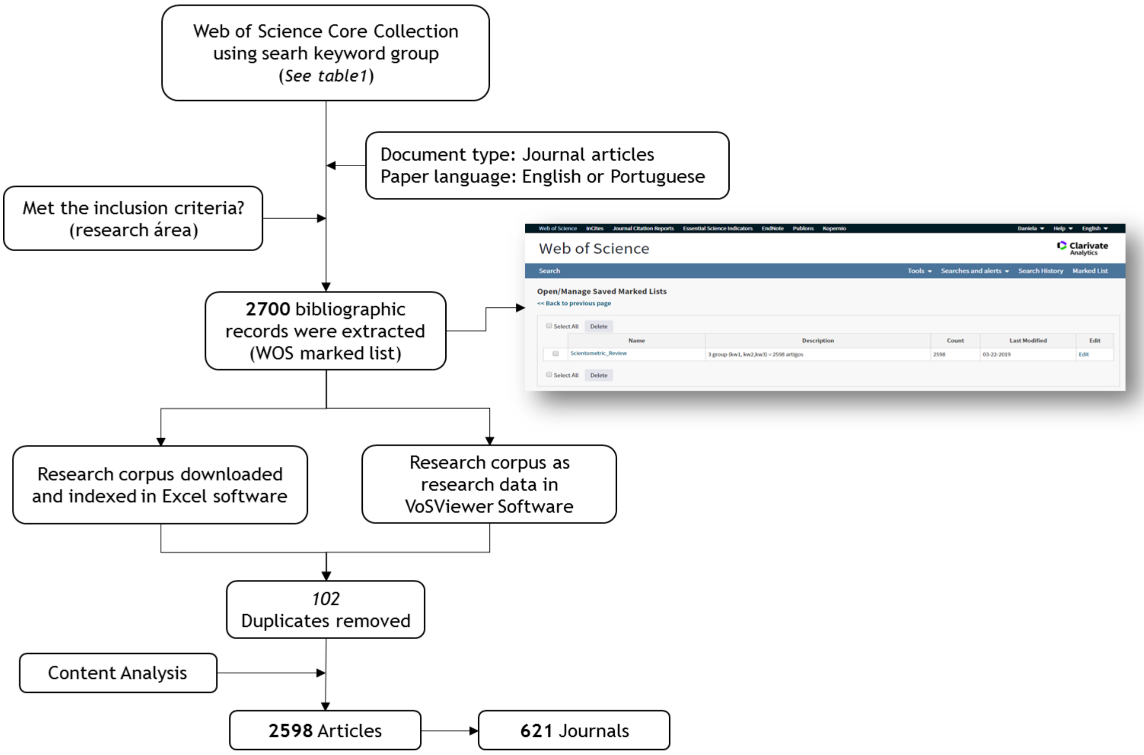

Figure 1. Literature search and indexing strategy.

Using the literature search and the indexing strategy illustrated in Figure 1, a distribution of 2,598 bibliographic records published in 621 journals by 9,330 cited authors and between the years 1990-2019 was reached.

According to the analytical report compiled by WoS, the *h-index* was 140, with the average citations per item 36,2. The sum of the number of citations was 94,056 and the number of articles that contribute for the citation was 55,739. Regarding the language, 98% of the articles were written in English and 2% in Portuguese.

3. Main Results

Regarding the set of articles extracted from the WoS database, there is a significant increase in the number of articles between 2010 crossing the threshold of 100 articles in 2010, and then in 2013 it exceeded 200 articles, reaching 300 articles in 2017 (Figure 2). This reflects the increased importance that the topic on the relation between the climate change and the sustainable development in the Amazonia region has reached along the time.

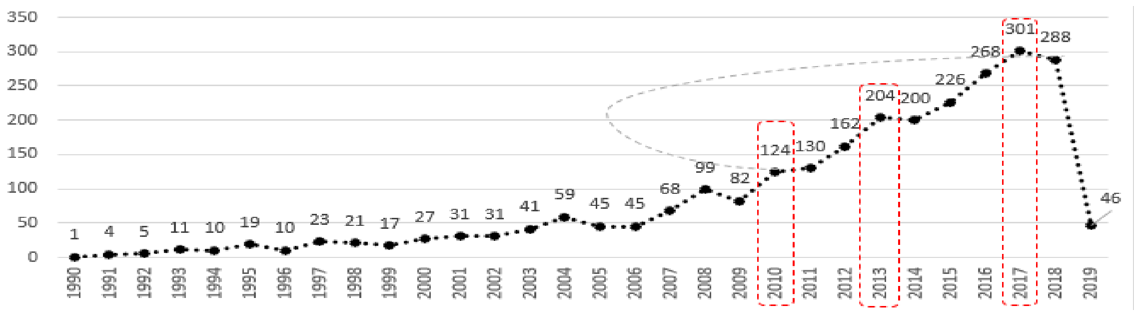

Figure 2. Distribution of the indexed research database from 1990 to 2019.

The first work on climate change and sustainable development in the Amazonia region was published in 1990, and describes the use of a coupled atmosphere-biosphere model to investigate the consequences of removing the Amazonian forests on climate (Shukla, Nobre, & Sellers, 1990). Among the sample' articles the main research areas covered were Environmental Sciences Ecology (39.76%), Meteorology Atmospheric Sciences (15.37%), Geology (13.47%), Science Technology other topics (10.08%), Biodiversity Conservation (7.92%), and Business Economics (2.34%) (Figure 3). This analysis highlights that the Environmental Sciences Ecology is the research area where the focused theme is the most explored and the social sciences approach to sustainable development comprise a minority of this literature. For instance, Business Economics, Public Administration Development Studies, and Anthropology together include only 150 articles, accounting together for 5.7% of all the literature reviewed.

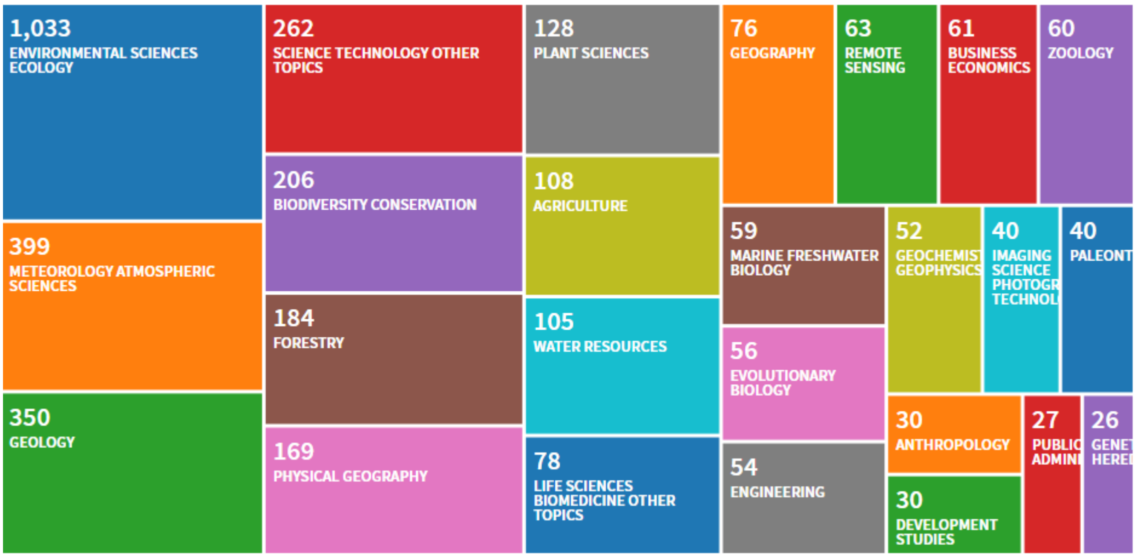

Figure 3. Top 25 main research areas.

It is interesting to see also that, the most productive authors in the literature database are affiliated with prestigious institutions that incentive research in climate change and sustainable development and also in the Amazonia region, such as the Oxford University, National Research Institute of the Amazon, James Cook University, National Institute for Space Research, Earth Innovation Institute and University of Leeds (Table 2).

Table 2. The most productive authors in the research field

Author	Affiliation	Main contribution
P. Fearnside	University of Oxford	To improve the knowledge on climate change in Amazonia (https://www.ox.ac.uk/search?query=Fearnside&wssl=1).
Y. Malhi	National Research Institute of the Amazon	To advance scientific knowledge of the Amazonia Region by supporting and promoting studies in a wide range of areas such as: tropical forest management, ecology, molecular ecology, zoology, botany, tropical agriculture, and tropical pisciculture.
W. Laurance	James Cook University - which is a public university in North Queensland, Australia and is a member of the Centre	In this university researchers have ready access to the most diverse natural laboratories in the world, such as coral reefs, tropical rainforests,

	for Tropical Environmental and Sustainability Science	coastal wetlands, woodland savannahs, and the arid outback.
J.A. Marengo	National Institute for Space Research, which is a research unit of the Brazilian Ministry of Science, Technology, and Innovation.	This Institute has a specific research program to study the Amazonia Region called the Amazon Research Program (AMZ).
D.C. Nepstad	Earth Innovation Institute	Stimulates research on reducing tropical deforestation and stabilize the climate.
Y. O. Phillips	University of Leeds	Stimulates investigations in interdisciplinary and impact-orientated topics with an emphasis on climate change and economic sustainability.

Moreover, the top-ranking journals in this research field, which contribute to the disclosure of findings to the scholarly community, thereby boosting the number of citations and co-citations of authors and documents, are identified in Figure 4. As can be seen in this figure, during the period of analysis and considering the research' sample, the Forest Ecology and Management is the journal where the research topic is more published, followed by the Global Change Biology. In the Climate Change, only 12% of the papers on the research topic are published. This may be explained by the fact that the scope of the Forest Ecology and Management journal is more closer to the research topic which is the application of biological, ecological and social knowledge to the management and conservation of plantations and natural forests, while the main topics suggested by the Climate Change journal are more in the area of atmospheric sciences and the climate change/climate impacts, in terms of the planet.

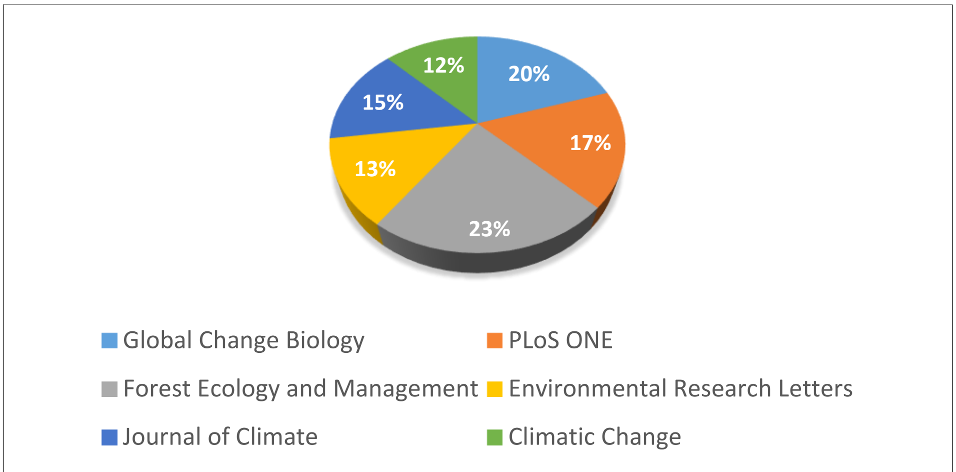

Figure 4. The high impact journals where the research topic is published.

Through a *scientometric* analysis hidden connections between several concepts present in different articles in the literature were identified (see e.g. Michel Callon, Courtial, Turner, & Bauin, 1983; Cobo, Chiclana, Collop, Ona, & Herrera-Viedma, 2014). In general, keywords of a published article can reflect its core content, representing a reliable indicator for analyzing hot topics and their distribution in a research field contributing to identify future directions of a knowledge domain (Liu et al., 2015; Zhao,2017). In the WoS database there are two types of keywords: (i) "author keywords", which are provided by authors, and (ii) "keywords plus", which are identified by the journals.

Before analyzing Figure 5(a) and Figure 5(b) it is important to note that the node colors represent the clustering relationship and the links mean the co-occurring relationships. Being so, in the network author keywords there are seven clusters with a lot of relationships between them. The links represent the co-occurring relationships which in the research' sample are identified mainly between the rose, the red and the green clusters, which reveals a strong relationship between climate change, deforestation and Amazonia. Moreover, from both figures, it is possible to state that some keywords are present in both analysis: the authors' keywords and in the keywords plus. These keywords are: "climate change," "Amazon," "deforestation," "biodiversity," and "tropical forests." The relationship between these keywords make sense since according to some authors they are in fact related. For example, according to Miles et al. (2004) climate change could result in a rise in temperatures and increased water stress, causing a decrease in forest growth contributing also to change in the forest ecosystems. Skogen et al. (2018) also consider that climate change is the major cause of biodiversity loss.

It is important to note however that, as the terms "climate change" and "Amazon" are used as search keywords, it is not surprising that they appeared most frequently in the keywords networks analysis. However, some words appear only in the keywords plus group, such as "dynamics", "variability," and "basin", while other keywords such as "global warming" and "remote sensing" are only in the group of keywords provided by the authors.

From the keyword analysis a clear concern on environmental sustainability of the Amazonia region emerges being the economic and social dimension less addressed in the literature. Other keywords with greater frequency in both the network author keywords and in the network' keywords plus are: "rain forest" (frequency = 300), "land use" (frequency = 239), "conservation" (frequency = 230); and "tropical forest" (frequency = 155).

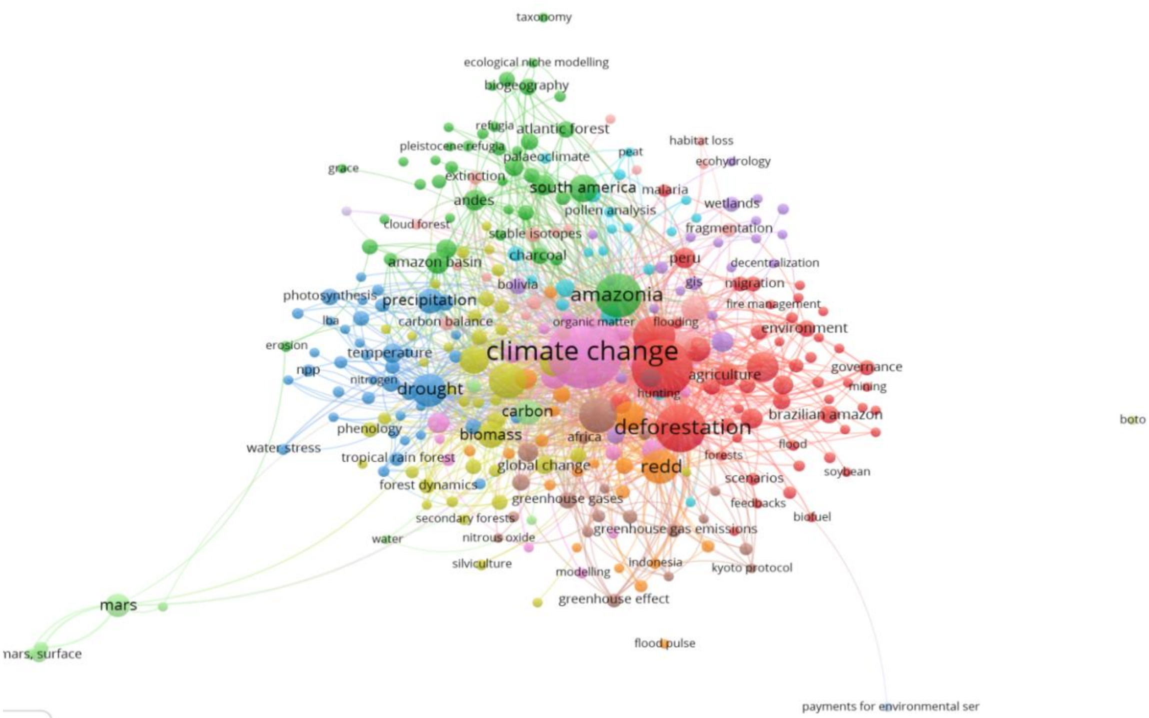

Figure 5(a). Network author keywords

Summing up, considering both the network author analysis and the keyword plus, the main factors related to climate change that have been considered strategic to influence the sustainable development of the Amazonia region are: global warming, deforestation, land use, and drought. In line with this result and according to Fearnside (2018) the challenges to sustainable development in Amazonia can be divided into two categories: i) counteracting the forces that lead to unsustainable development and, ii) offering alternatives to the current economy that is almost entirely based on destruction of natural ecosystems.

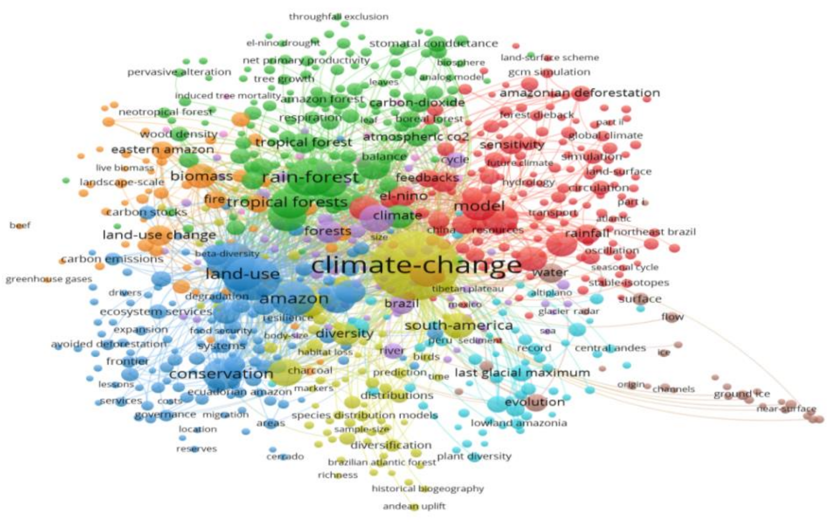

Figure 5(b). Network keywords plus.

To make more robust these results another analysis was performed excluding keywords that were identical or already used in the search in WoS database[2]. After the exclusions, the most cited keywords are those presented in Table 3.

Table 3. Most cited keywords not considered in the keywords provided by authors or in keywords plus

Most cited keywords not considering the search' words	Frequency
Deforestation	526
Tropical forest	455
Rain forest	300
Land use	239
Conservation	230
Drought	193
Model	183
Biodiversity	192
Brazil	181
Dynamic	172

In this analysis, few words were identified as being related to sustainable development. The only two words that are related indirectly with it are "model" (authors' keywords and keywords plus =156) and "dynamic" (authors' keywords and keywords plus =150). To complement this analysis the article of Olawumi & Chan (2018) focusing the sustainable development in Amazonia was analyzed. According to this work the keywords most cited in the context of sustainable development are: sustainability, management, system, indicator, model, energy, performance, impact, environment, and design. Consequently, the main factors considered strategic to those authors are: impacts, sustainable development, management, and environment.

For a deeper analysis, a study of the articles published during the last 10 years was performed using the keywords "climate change," "global warming," "sustainable development," and "Amazon*." The main results from this analysis are the following: i) in 2010 there is a notable increase in the keyword "climate change" representing 34%; ii) in the period from 2012 to 2014 a fluctuation is observed, iii) from 2015 to 2017 an increase is reached; and iv) in 2018 it increased again to 25.64%. This indicates that research topics

[2] The keywords excluded were: Amazon* AND ("Climate Change" OR "Global Warming"); Amazon* AND "Sustainable development"; Amazon* AND ("Climate Change" OR "Global Warming") AND "Sustainable development."

regarding climate change have become increasingly a hot topic in some periods, but not in a constant way.

The keyword "Amazon*" has increased almost 277% from 2009 to 2018. This indicates that the research on Amazonia is now in a higher maturity level compared to the year 2009, when only 13 papers were published. The term "global warming," in turn, maintains a low frequency of articles focusing on it in a deep way during the 10 years of analysis, observing however an increase from 2009 to 2018 but insignificantly. In the sample articles the keyword "sustainable development" presents a low frequency during the period of analysis being quite unstable during the last years (Figure 6).

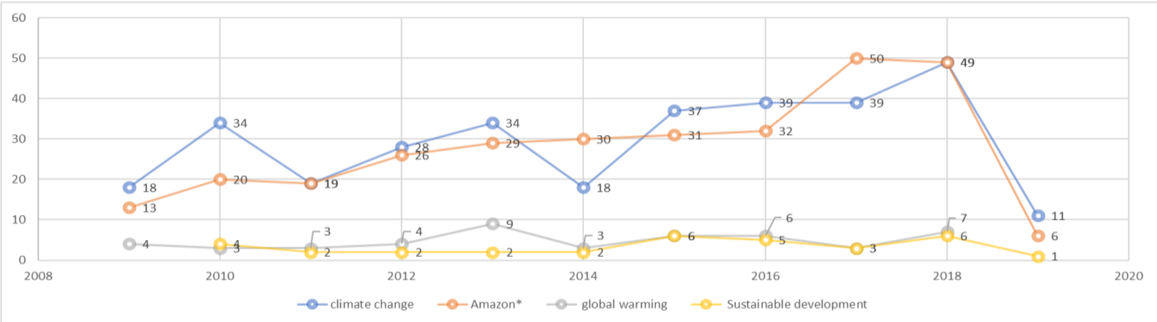

Figure 6. Timeline of keywords during the last 10 years: "Amazon," "climate change," "global warming," and "sustainable development".

The 20 keywords in sample' articles focusing on climate change and sustainable development in Amazonia with the highest frequency during the last two years were: climate change, amazon, deforestation, Amazonia, Brazil, reducing emissions from deforestation and forest degradation (REDD), global warming, tropical forest, sustainable development, drought, remote sensing, land use, South America, conservation, biomass, precipitation, fire, biodiversity, Amazonia basin, and Peru. Among these keywords some represent factors responsible for the negative impacts on the sustainable development of Amazonia region (deforestation, land use, fire) and other are related to the consequences of them (climate change, global warming, drought, precipitation).

Analyzing both keywords' types (author and keywords plus) the climate change and deforestation are overwhelmingly represented and are central in this literature (see Figure 7). Beyond these two keywords, others like tropical forest, conservation, biomass, model, and carbon are identified in the research' sample.

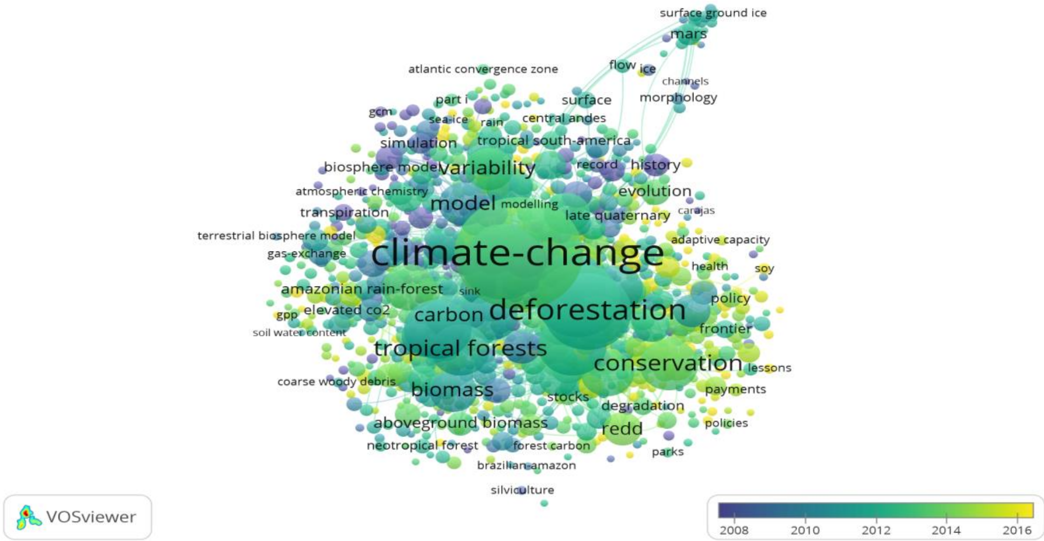

Figure 7. Network keywords: author and keywords plus.

4. Discussion and Policy Implications

The research topic of climate change and sustainable development in the Amazonia region has received global attention from government agencies, academics, practitioners, and international organizations. This study provides a scientific visualization of this phenomenon using a *scientiometric* technique drawing important conclusions to derive and devise policy implications and recommendations, respectively.

There is a significant increase in the number of articles about this topic between 2010 and 2018, being the main scientific areas covering it the following: Environmental Sciences, Ecology, and Meteorology and Atmospheric Sciences. It should be noted that in our sample the Business and Economics area ranks only in the 14th place, which may be a concern since this area could make important contributions, not only for better mitigation of the main factors responsible for climate change, but also by suggesting ways to improve the sustainable development of countries or regions suffering from this phenomenon. Associated with this concern many authors (Dale et al., 2001; Parker et al., 2000; Stewart et al., 1998; Spittlehouse and Stewart, 2003; Reyer et al., 2017; Garcia-Gonzalo et al., 2017) argue that several options regarding climate change adaptations are related to a better forest management taking advantage of the potential for increasing economic growth and limiting risks of fires and deforestation. Better forest management can help to minimize or mitigate the main factors responsible for climate change. It is known that the forest is a strategic resource in an industry in which actions today determine the development some 70–90 years later (a tree planted today may stand that long before final logging). *Long-term business and economic decisions regarding climate change are therefore important.*

The creation of *unrealistic expectations in societies on the capacity for planning and mainstreaming climate adaptation has resulted in limited implementation* (Mimura et al., 2014) and in the failure of existing models and analyses to handle the concepts and variables of climate change policy in the forest sector (Wellstead et al., 2013). It is therefore crucial to identify the logics that affect policy processes and cause inaction (Noble et al., 2014). The business and economics field has thus an important contribution regarding climate change. Moreover, Levin, Cashore, Bernstein, & Auld (2012) consider that the impact of climate change has a multilevel nature requiring by this way the adoption of a multilevel approach supported by various theories for a better understanding of business strategies' influence on climate change mitigation. This point of view is supported by many other authors (Hoffman and Jennings, 2012; Okereke et al., 2009; Sæverud and Skjærseth, 2007).

In 2007 The United Nations Intergovernmental Panel on Climate Change Report concluded that the globally averaged net effect of human activities since 1750 has been one of the main sources of global warming (Mukherjee and Mukerjee, 2016). Studying the impact of business activities on climate change and consequently on sustainable development of regions or countries is therefore considered a hot topic that deserves more attention from the scholarly community.

In our study some interesting results were reached. The main factors identified through the keywords analysis that have been considered strategic in influencing the sustainable development of the Amazonia region and related to climate change, are the following: global warming, deforestation, land use, and drought. In the Lima Declaration on Biodiversity and Climate Change: Contributions from Science to Policy for Sustainable Development, in 2017, Painter, Montoya, & Varese (2017) argued that the Amazonia's deforestation, land use, and unsustainable resource extraction are the greatest direct threats to the sustainable development of that region representing a risk to species, ecosystem functions, and human well-being. From their point of view, these threats result from a *lack of knowledge to guide sustainable management, the existence of few economic alternatives and a global demand for products, and poor territorial governance that results in illegal resource extraction and poorly planned development*. *Territorial management is therefore* *crucial to reach a planned, sustainable, and efficient land use*, making it possible to achieve sustainable development in that region. Territorial management is considered essential for an efficient distribution of people and use of resources in a specific geographical area or territory and to improve the population's living conditions and strengthen mechanisms for sustainability. However, Schultz et al. (2015) defend that it requires an adaptive governance approach in which decision making processes should involve multiple government and non-government stakeholders at multiple levels to negotiate, coordinate, and agree on management actions to deal with local and large-scale perturbations.

Other strategies that can be implemented to mitigate the negative influence of climate change on the sustainable development of Amazonia can be found in Malhi et al. (2008), which is the most cited article in the sample. They suggest the following set of strategies to mitigate the climate change in Amazonia, contributing positively for the sustainable development of the region: control of deforestation and fire use, new financial incentives, appropriate forest management approaches and adaptation measures, conservation strategies in protected areas, and greater political will at local, national, and international levels. They also mention the importance of using mix-models along with information generated by specific technical reports to support the implementation of these strategies.

Attending to the literature review and considering the results reached in this work Table 4 was performed to summarize the main problems to be solved, some proposed solutions and the expected results from these solutions.

Table 4. Identified Problems and Policy Design

Problems to be solved	Solution	Expected Results
Social and economic dimension are sparsely studied	Create a Social Sciences Higher Education School focusing on Amazonia responses to climate change	Incentive research integrating economic and social dimensions in featuring climate change response of Amazonia agents.
Policies base on high expectations	Evaluate social and economic agents' response to policies to form more correct expectations	Provides better planning and longer-term planning
Inconsistencies between local, federal, national and world level	Approve specific SDG with measurable targets for Amazonia	Provides a strategic document that can be

policies or discourses			concatenated between the United Nations, Brazil, the Federal States and Municipalities

The creation of a higher education and research school to study the effects of climate change in Amazonia and the implementation of specific solutions would be a *keystone* of the knowledge formation in Amazonia contributing to create the right environment for multidisciplinary research within the social sciences (the specific research that seems to be lacking according to our review). This school would have an important role in studying the effects of past policies and the reasons of potential failure or success promoting also the field of socio-economic experiments to evaluate the reaction of agents to given incentives. For example, it is important to incentive agents to relocate from areas subject to flooding. However, those relocations should obey to correct incentives to relocate only the people that need to be relocated but also to maintain social and cultural cohesion. The independence of school from political interests or cycles is also an important issue to design long-term roles.

Long-term planning is also related to the establishment of specific targets coherent with the sustainable development goals. It is worth noting the role of the Sustainable Development Solutions Network (http://unsdsn.org/), which has done specific work about Amazonia (and example is de document *Mapping the Renewable Energy Sector to the Sustainable Development Goals: An Atlas*, from June 2019). However, in order to monitor the effects of policies implementation, it is necessary to quantify the goals. Table 5 gives a sketch of these goals divided by climate change consequences (by line) and sustainable development dimension.

Table 5. Goals by Climate Change consequences and Sustainable Development (Sustainability) Dimensions

Sustainability / Climate change	Social	Economic	Environmental
Higher temperatures	✓ Better health provision	✓ Better construction technologies ✓ Better settlements technologies	✓ Reduce Greenhouse gas emissions
Extreme Events (Fires, Floodings)-	✓ Better health provision ✓ Relocation	✓ Better prevention technologies and organization	✓ Better forest management

	policies from dangerous areas with social and cultural concerns		
Ecosystems Damage/Biodiversity Loss	✓ Environmental education	✓ Funding for mitigation measures through fiscal measures	✓ Mitigation measures

Knowledge about climate-change adaptation and sustainable development can be translated into public policy through processes that generate usable knowledge. The idea of usable knowledge in climate assessments stems from the experiences of national and international bodies that offer credible and legitimate information to policymakers through transparent multidisciplinary processes (academics, committees, panels, etc). It requires the inclusion of local knowledge, together with indigenous knowledge, to complement more formal technical understanding generated through scientific research and considering also the role that institutions and governance play in transferring scientific information into effective action. Moreover, Fiscal measures may be implemented to mitigate ecological damage, subsidizing good practices and taxing activities with negative impact on ecosystems as is the case of natural resources extraction (e.g. rubber extraction from the forest or mineral extraction). On the environmental dimension, we highlight the reduction in emissions, better forest management and mitigation measures.

5. Conclusions

We have conducted a *scientometric* analysis of publications on the topics of climate change and sustainable development in the Amazonia region during the period of 2008 to 2016 on 2,598 journal articles during the time span from 1999-2019.

The analysis on the main articles in the sample reveals the evolution of the research field in terms of the increased number of works that have been published in top journals during these two decades and the main drivers of climate change in Amazonia, such as deforestation, global warming, and land use. Also, the articles focused mainly on environmental aspects since the journals in which these works are published belong to the scientific areas of environmental sciences, ecology, biology, meteorology, and biochemistry.

One of the striking items of evidence highlighted by this study is the overwhelming presence of articles that characterize the effects of climate change on the “current” stage of

Amazonia's bioecological equilibrium coming from the environmental sciences, ecology, biology, meteorology, biochemistry fields. Regarding the sustainable development of the Amazonian rain forest, studies that focus on the interactions between humans and nature from a social science point of view account from only a minority of the literature. Thus, given the demographic and economic pressure that the Amazonia region is experiencing and its importance to the global habitat, it is necessary to increase the approaches that focus on sustainable development that also consider social and economic concerns.

In order to create a significant body of knowledge concerning the relationship between climate change and sustainable development in Amazonia within the social sciences we purpose three policy measures: *(i)* create a Social Sciences Higher Education School focusing on Amazonia responses to climate change which can also contribute to *(ii)* better evaluate social and economic agents' response to policies enabling policy making with more accurate expectations. Finally, we purpose to *(iii)* approve specific sustainable development goals for Amazonia considering the effects of climate change. Those sustainable development goals should include quantitative goals linked with social aspects (reduction in hunger, poverty and inequality, improvement in health and education provision), with particular attention to social and cultural cohesion within and between indigenous people. They should also include concerns about possible migrations in response to climate change. Moreover adaptation and mitigation policies should be included considering the development of cleaner technologies that integrate economic growth with environmental protection.

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