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How Academia and Society Pay Attention to Climate Changes: A Bibliometric and Altmetric Analysis

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Abstract

With the help of social web, social users can create, manage, share or react without undergoing the formal mechanisms of quality control. The way social users respond to scholarly outputs on the social web is called social citation, which can show the broadening of impact from academia to society. Climate change is one of the most life-threatening issues that everybody should be sensible and react to. Studying the scientific and social citations of articles dealing with climate changes, the present study attempts to provide new insights into the amount of social users' attention and reactions. It also investigates the correlation between scientific and social citations to shed light on the potential of altmetrics as an alternative or supplementary to its traditional predecessor. Besides, the study aims to carry out co-word analysis of scientific texts in the field and identify hot topics. Our findings showed that 3141 out of 6100 climate changes related articles retrieved from WoS were present in Altmetric explorer. They received 84380 and 17361 social and traditional citations, respectively. The articles were revealed to be mostly represented in Mendeley (133002 reads) and Tweeter (72108 tweets) followed by News outlet, Facebook, and blogs. The results of Spearman correlation test revealed a significant, though weak, correlation between WoS citations and social citations including Tweets, Mendeley readers, Facebook posts, blog posts, Google+ posts, news outlet and Article Attention Score. Multidisciplinary sciences were the most productive subject areas with the highest number of scientific and social citations. Co-word analysis of the articles showed that greenhouse gases emission; warming; species; adaptation; precipitation; energy; country, soil and crops are among the most frequent words. The value of the present study lies in the clarification of the extent to which social network users pay attention to climatic issues and how much is the power of altmetrics in showing the impact of science on society. Visualization of climate changes articles helps redirect cultural-political debates and associates discourses. It can help raise awareness in people and engage them in environmental conservation.

Keywords

Climate change; Altmetrics; Citation; Co-word analysis; Social media.

Introduction

The emergence of social web, alternatively known as Web 2.0, has provided new opportunities for assessing scientific impact. Social web has created a shared web space for exchanging information, beliefs, ideas, and comments, where the user acts not only as a content consumer, but as a content producer and agent in a collective, decentralized process (Donato, 2014). Social web has offered social users a potential for authorship, either for those who share and manage their formal knowledge using the social platforms (Huang et.al., 2018) or for those who create and disseminate their content without undergoing the formal mechanisms of quality control such as peer review. In this way, it has altered the way people interact with information resources (Tredinnick, 2006) by providing them the opportunities to view, read, download, save, comment on, tweet, recommend, and bookmark their sources of interest (Torres-Salinas et al., 2013). The new varied environment is, therefore, promising to offer a set of metrics required to measure the impact of scientific articles (Sud & Thelwall, 2014) to help avoid the problems intrinsic to peer review such as budgetary and temporal limitations, personal biases, and subjectivity of peer review (Herrmann et al., 2011; Sud & Thelwall, 2014; Jamali Mahmoie, 2011), as well as inefficiency of traditional citation metrics like citation time lag, self-citations, negative citations, homographs, language biases, and superficial treatment in measuring article impact. The most important deficiency of formal citations as reflected in the references of papers indexed in citation databases is that they cannot reflect the full impact of research outputs on the whole society, but only on a limited part, i.e. scholars as authors. However, scientific impact is a multi-faceted construct which may not be captured through a single metric or on a single section of society (Bollen et al., 2009). Alternative metrics, also known as altmetrics or social citations, are derived from the social web and has provided opportunities for measuring the impacts of science beyond the scientific community, by recoding users' reactions towards any information resources in a faster, broader and more cost-efficient way. They could compute a wide range of scientific impacts beyond the borders of formal publications (Li et al., 2011; Wouters & Costas, 2012), on different social sections (academic and non-academic) such as economy, culture, environment, and politics (Bornmann & Haunschild, 2017). Although altmetrics have their own challenges, they are potentially considered as substituting or complementing citation metrics (Priem et al, 2010; BarIlan, 2012; Bornmann, 2014; Livas & Delli, 2017) that are not fully representative of the scientific impact, but just reflect science-on-science impacts. Having tracked over 95 million mentions for 23 million research outputs (about-our-data…, 2018), Altmetric.com is the most comprehensive resource for collecting data on research output from social networks (Robinson-García et al., 2014). To identify how much and what type of attention a research output has received, Altmetric.com, designed, the Altmetric Attention Score and donut (Liu & Adie 2013). The AAS is an automatically calculated, weighted count of all of the attention a research output has received. It is also important to note that Mendeley readers and CiteULike bookmarks do not count towards the score (Altmetric.com, 2019). Each of the colors in the Altmetric donut in Figure 1 represents a different source of attention.

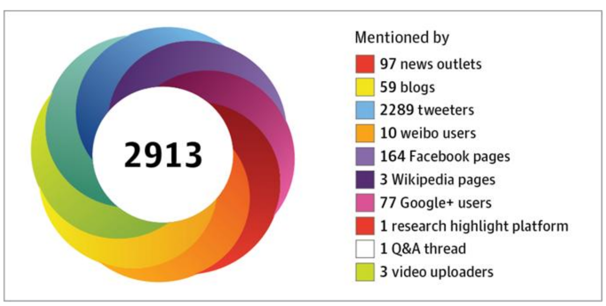

Figure 1. Colors assigned to each metric in Altmetric donut

Given the significance of social impacts of science, the altmetric measures has been used to study a wide range of fields, namely information sciences (BarIlan, 2012; Maflahi & Thelwall, 2016); organ transplantation (Knight, 2014); emergency medicine (Barbic et al., 2016); orthodontics (Livas & Delli, 2017). However, just limited researches were found to deal with the social impact of climate changes (CC) using altmetrics.

CC is a complex long-term atmospheric-oceanic phenomenon at the global level affected by such factors as solar, oceanic, and volcanic activities as well as increased greenhouse gases concentration in atmosphere. The United Nations Framework Convention on Climate Changes (UNFCCC) defines it as weather changes due to human activities that are directly or indirectly beyond natural changes (Whitmarsh, 2009). Greenhouse gas concertation, increased temperature, altered and decreased precipitation in the northern and tropical latitudes are some of the CC evidences (Guilderson et al., 1994). Considering the inevitable outcomes of CC, national and international organizations as well as scientists in the fields of physics, chemistry, meteorology, earth sciences, social, and political sciences have sought to identify climate states in the past and predict future trends (Haunschild et al., 2016). Prevention and treatment of climate-change-induced harms are serious issues addressed by not only policy-makers and scholars but also the general public and social users and is, thus, a hot topic in social networks. Dramatic changes in climate patterns and adverse effects of human intervention in climate oscillation (Anderegg et al., 2010) have added to the challenges in the field and attracted the attention of scholars with various research backgrounds (Haunschild et al., 2016) as well as social users, turning the field into an interesting topic to study. With regard to the fact that almost all global systems are affected by CC and that human beings' activities are the main cause, with 95 percent certainty, for global warming according to the report by the Intergovernmental Panel on Climate Change (IPCC, 2014), the field of CC not only rivets the attention of scientists of various disciplines (Haunschild et al., 2016) but also becomes an issue of public concern in daily conversations. CC was one of the main topics of interest to users from among 18.5 million mentions or social citations captured by Altmetric.com in 2017[1] and that is why the year 2017 was selected for this study. To the best of the authors' knowledge, research on CC studies has so far concentrated on bibliometric, visualization and co-word analysis of research articles (Haunschild et al., 2016; Li & Zhao, 2015; Wang et al., 2014; Li et al., 2011). There is, therefore, a lack of citation analysis of CC-related papers using altmetric approach. Thus, given the public sensitivity and concerns about the issues related to CC, it is important to understand to what extent and in what subject areas the scientific endeavors in the field attract social and academic attentions. To do so, the present study investigate the impact of CC-related articles by examining the quantity of attentions they received from academia and society. In the present study, attentions from academia and society are respectively measured using citation counts extracted from WoS and different altmetrics derived from altmetric (news outlet, blogs, Tweeter, Facebook, Mendeley, Wikipedia, policy documents, peer review, Google+, etc.) as reported by Altmetric.com. The correlation between their scientific and social citations are also examined in order to test whether the social metrics in the field could reflect the same picture as their academic impact, and thereby to shed light on the applicability of altmetrics in CC research evaluation (Sud &

[1] Available online 17 May 2018 https://www.altmetric.com/top100/2017/#list&about

Thelwall, 2014; Hammarfelt, 2014; Haustein et al., 2015; Ortega, 2016). Finally, carrying out a co-word analysis, it endeavors to identify the main trends in the field.

Research Questions

1. To what extent are CC-related articles represented across various altmetric measures?
2. Is there any significant relationship between citation counts and social citation metrics in CC?
3. What are the most (traditionally or socially) cited areas of research in CC?
4. What are the main research trends in the field of CC in both journal and article level?

Research method

Applying a citation analysis method with both traditional and altmetric approaches, the present study measures citation and altmetric performances of CC-related papers as represented in WoS and Altmetric Explorer, respectively. In the present study, "scientific citations" or "traditional citations" refers to formal citations used in papers indexed in WoS and represented in TC and Z92 fields. Also, "social mentions" or "social citations" refers to any kind of users' reactions in social media and networks to the papers, including bookmarks in CiteULike, reading in Mendeley, tweeting in twitter, posts in Facebook, blogs, Google+, citation in Wikipedia or policy documents etc. as recorded by Altmetric.com.

Research trends are measured at two journal and article levels, using WC field of WoS representing the journals subject categories and co-words extracted form titles and abstracts of the papers by VOSViewer, respectively. Some of the journals were found to be assigned to more than one category. Therefore, the shares of these categories were calculated using fractional counting in order to avoid inflation of the article numbers.

The research sample consisted of all articles published in 2017 in the field of CC indexed in WoS. To delineate the field, we used the vocabularies identified by Haunschild, Bornmann and Marx (2016) and combined them in a disjunctive query limited to titles, year 2017 for all document types in the Advanced Search of WoS. These words include (climate change), (climate warming), (global temperature), (global warming), (greenhouse gas), (greenhouse effect), (greenhouse warming) truncated to search all their derivations. The query was like below:

TI= (climat* chang*) OR TI= (climat* warming*) OR TI= (global temperature*) OR TI= (global warming) OR TI= (greenhouse gas*) OR TI= (greenhouse effect*) OR TI= (greenhouse warming)

The query helped retrieve 6100 documents in February 2019. Since article DOI is necessary for using Altmetric data, after excluding those documents without DOIs, the research sample

[2] Z_9: total times cited count including Web of Science Core Collection, BIOSIS Citation Index, Chinese Science Citation Database, Data Citation Index, Russian Science Citation Index, SciELO Citation Index.

decreased to 5434 documents. The social citation scores including AAS, Tweets, Mendeley readers, Blogs, News, Google+, and Facebook, Reddit, policy documents, Wikipedia, video, F1000, peer review, Q & A mentions, were then, collected using the free access courtesy of Altmetric explorer.

To merge the data, the DOIs of the retrieved articles from both WoS and Altmetric.com were compared in Excel using Vlookup function. To analyze the data, descriptive and inferential techniques including frequencies and Spearman correlation were conducted in SPSS 20 and co-word analysis in VOS viewer (1.6.13). As recommended by Van Eck & Waltman (2018), while creating a co-occurrence map in VOS viewer, a thesaurus file was built and used to merge and standardize variations of terms, for example, different synonyms (e.g., flux and emission), different spellings (carbon dioxide and dioxide carbon), abbreviations or full terms (ghg and greenhouse gas), plural or singular forms (model and models). It was also used to ignore general terms such as introduction, conclusion, method, and results frequently repeated in title and abstract of articles.

Results

The status of social and scientific recognition of CC papers

3574 out of the total 5434 articles were retrieved in Altmetric explorer with 18876 scientific citations and 84380 social citations from various media except for Mendeley readers. Social citations per paper is 27 in social networks while the average scientific citations per paper is 6 for 3141 papers with AAS>0.

Table 1. Frequency distribution of the articles retrieved from WoS and Altmetric

<table>
<tr><th>CC Articles</th><th>Frequency</th><th>Percent</th><th>Scientific Citations</th><th>Social Citations without Mendeley</th><th>Social Citations with Mendeley</th></tr>
<tr><td>with AAS> 0</td><td>3141</td><td>52</td><td>17361</td><td rowspan="2">84380</td><td rowspan="2">217382</td></tr>
<tr><td>retrieved in Altmetric</td><td>3574</td><td>59</td><td>18876</td></tr>
<tr><td>with DOI</td><td>5434</td><td>89</td><td>23359</td><td colspan="2">-</td></tr>
<tr><td>indexed in WoS</td><td>6100</td><td>100</td><td>23573</td><td colspan="2">-</td></tr>
</table>

The retrieved articles had the highest usage counts in Mendeley (133002 reads) and Tweeter (72108 tweets), respectively. Four hundred thirty three articles of those read in Mendeley received no attentions from other social networks and thus their AAS values were set to zero. News outlet, Facebook and blogs with 7156, 2449 and 1778 mentions ranked three to five, respectively (Figure 2). Table 2 summarizes the status of the articles in social media.

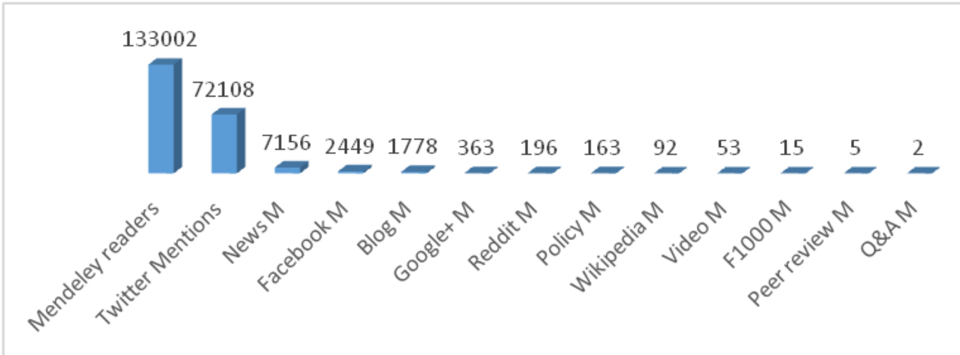

Figure 2. Citations to CC articles in social media

Table 2. Articles with highest mention counts in Altmetric

Social media	Article title	Mention counts
AAS	Global warming and recurrent mass bleaching of corals	**3334**
Tweeter		**2180**
News		**423**
Blogs		**44**
Mendeley	Biodiversity redistribution under CC: Impacts on ecosystems and human well-being	**1454**
Facebook		**61**
Google+	Quantifying the influence of global warming on unprecedented extreme climate events	**28**
policy Doc	Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm	**8**
Reddit	1) Nutritional and greenhouse gas impacts of removing animals from US agriculture 2) Greater future global warming inferred from Earth's recent energy budget	**6**
Wikipedia	Assessing ExxonMobil's climate change communications (1977–2014)	**6**

The article entitled "global warming and recurrent mass bleaching of corals" also obtained the highest traditional citation count (n=387 citations) which shows that this article is in the spotlight of both scientists and social users.

The correlation of social citations and WoS citations

The results of Spearman correlation revealed a significant, though weak, correlation between AAS on the one hand and WoS citations ($r = 0.115$, $p<0.01$) and Z9 ($r = 0.12$ $p<0.01$) on the other hand. The results also showed a significant weak correlation between citations and the number of tweets on Tweeter ($r = 0.105$, $p<0.01$), readership counts in Mendeley ($r = 0.065$, $p<0.01$), number of user posts on Facebook ($r = 0.073$, $p<0.01$), number of blog posts ($r = 0.081$, $p<0.01$), number of posts on Google+ ($r = 0.051$, $p<0.01$), and number of releases on news outlet ($r = 0.059$, $p<0.01$) (Table 3).

Table 3. Correlation of citation counts with social mentions

	News	Blog	Policy	Twitter	Facebook	Google+	Reedit	Mendeley	Aas
Correlation Coefficient	.059**	.081**	.022	.105**	.073**	.051**	.023	.065**	.115**
Sig. (2-tailed)	.000	.000	.184	.000	.000	.002	.171	.000	.000
N	3574	3574	3574	3574	3574	3574	3574	3574	3574

** Correlation is significant at the 0.01 level (2-tailed)

However, no significant correlation was found between the WoS citations and other altmetric measures including peer review websites, Q&A websites, F1000, Wikipedia, policy documents, Reddit, and video releases. This may relate to the high number of socially uncited papers (Table 4).

Table 4. Socially uncited publications

altmetrics	Socially uncited paper		Socially cited paper		Sum of social citations
	No	%	No	%	
Reddit	3024	96.3	117	3.7	196
Policy docs	3035	96.6	106	3.4	163
Wikipedia	3071	97.8	70	2.2	92
video	3104	98.8	37	1.2	53
F1000	3126	99.5	15	0.5	15
peer review	3136	99.85	5	0.15	5
Q&A	3139	99.94	2	0.06	2

Verification of the Web of science categories (WC) assigned to journals publishing the 6100 CC-related articles showed that they were scattered among 207 categories. Further analyses revealed that about 80 percent of the articles (n=4900) were assigned to 16 percent of the subject categories, which follows the Pareto principle (i.e. 80/20 rule). The top ten subject areas of the articles included 1) *E*nvironmental Sciences; 2) *M*eteorology & Atmospheric Sciences; 3) *E*nvironmental Studies; 4) *M*ultidisciplinary Sciences; 5) *W*ater Resources; 6) *E*cology; 7) *G*eosciences, Multidisciplinary; 8) *G*reen & Sustainable Science & Technology; 9) *F*orestry; and 10) *E*nergy & Fuels.

An analysis of the 3141 articles, showed that *E*nvironmental Sciences, *M*eteorology & atmospheric sciences, and *M*ultidisciplinary Sciences were the most productive subject areas (Fig. 3). Among them, only Multi-disciplinary was found to be also highly-cited, signifying the inclination of academia towards CC-related contributions from different specialization.

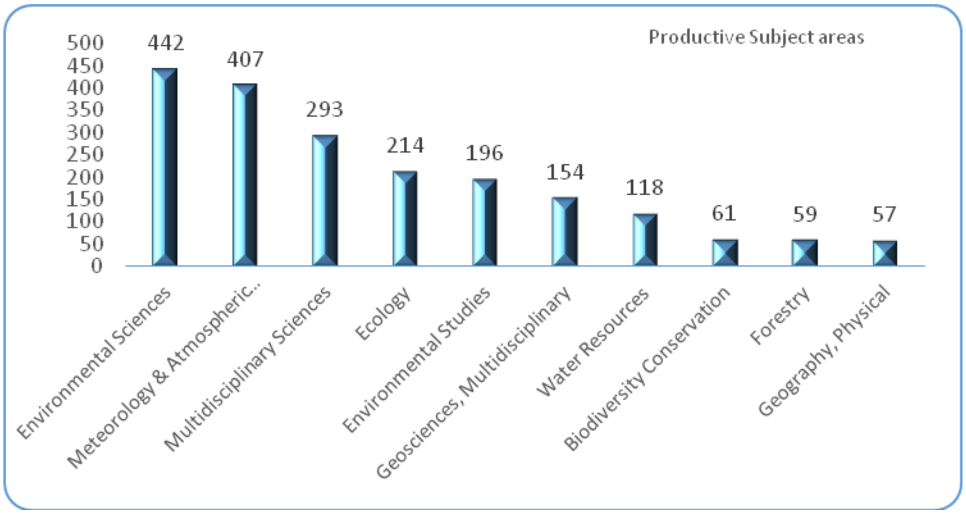

Figure 3. Subject areas with the highest number of CC articles

Figure 4 illustrates the highly cited subject areas. As seen, *P*hysics, Mathematical; *M*ycology; and *M*ultidisciplinary Sciences are the top three subject areas that gained the highest number of citations. On average, they received 31 accounting for 9 percent of the total citations received by the CC collection.

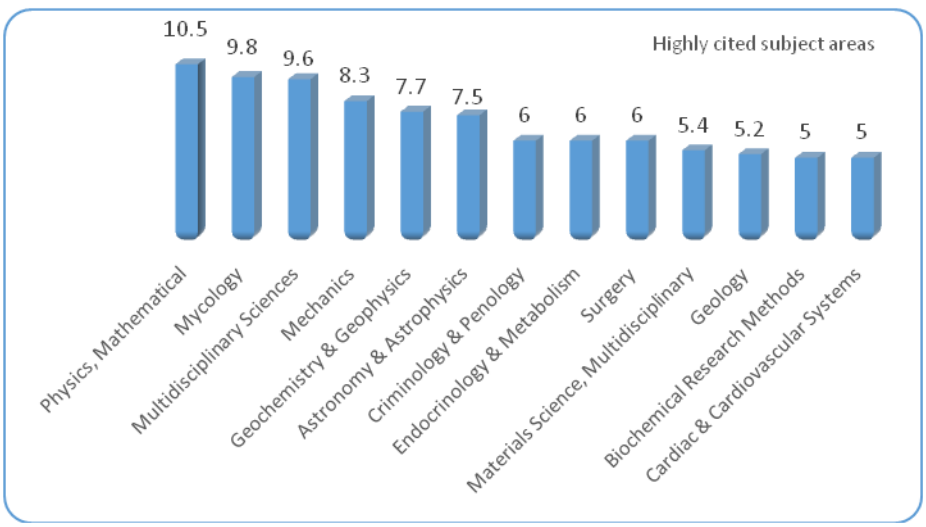

Figure 4. Highly-cited subject areas

Figure 5 illustrates the subject categories with the highest attention scores. *C*ardiac & Cardiovascular Systems; *M*edicine, General & Internal; and *M*ultidisciplinary Sciences are the three subject categories that received the highest attention scores in different media from social users.

*M*ultidisciplinary Sciences, Endocrinology & Metabolism and Cardiac & Cardiovascular Systems are the three highly cited subject areas either in terms of social or scientific recognition.

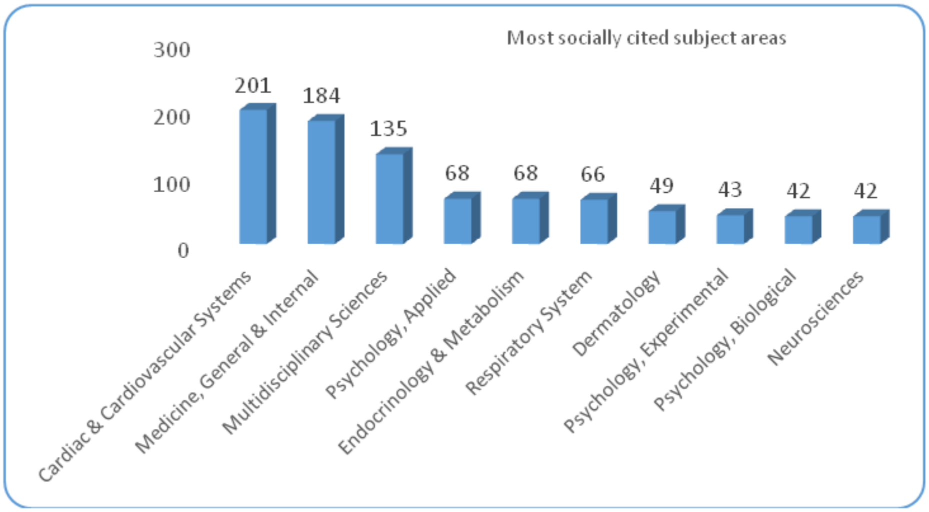

Figure 5. Subject categories with the highest AAS

In order to identify the main research trends in the CC fields, the contents of the titles and abstracts of the 6100 articles retrieved from WoS were analyzed using co-word technique in VOSviewer (1.6.13). The analysis resulted in the identification of a number of 107993 keywords. Of these, 1864 keywords had the minimum threshold of 10 co-occurrences. A number of 1115 keywords were identified as "the most relevant", which constituted 60 percent of the identified items. As the most frequent keywords or co-occurrences may demonstrate the concentration of research in a given field (Liu et al., 2012), they were considered as the representatives of the main research trend of the CC field. Recent research has pointed towards the benefits of visualizing climate science for lay audiences (Ballantyne et al., 2016). Table 3 illustrates ten keywords with the highest occurrences.

Table 5. Top ten terms pertaining to CC with the highest occurrence frequency, links strength, and total link strength

Row	Term	Occurrence	Term	Weight <link>	Term	Weight <total link strength>
1	Greenhouse gas	966	Warming	1042	Greenhouse gas	11637
2	Emission	879	Adaptation	959	Emission	11004
3	Warming	846	Emission	948	Warming	8562
4	Species	746	Greenhouse gas	947	Species	7874
5	Adaptation	739	Species	923	Adaptation	7444
6	Precipitation	696	Policy	914	Precipitation	7203
7	Policy	666	Precipitation	904	Policy	7010
8	Country	494	Country	880	Soil	6124
9	Soil	474	Application	844	Country	5631
10	Energy	416	Product	842	Co_2	5480

As shown, the most frequently used terms and phrases in the field of CC included greenhouse gases; their emission that leads to more warming; impact on plant and animal species (Change in biodiversity and genetic storage); adaptation (To maintain plant and animal species and proliferation of resistant species); caused changes in precipitation; and requires sound policies by countries on energy consumption and conservation of soil and crops. VOSviewer has a considerable potential in the graphical representation of conceptual structures of scientific fields. The illustration in Map 1 displays the most important items with labels and larger circles.

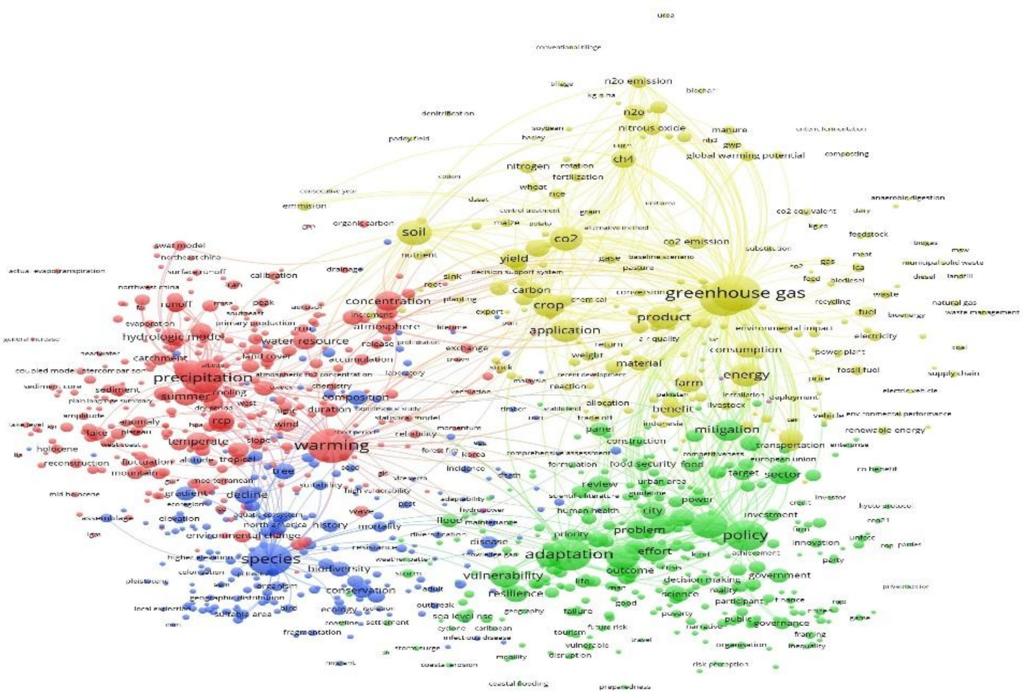

Figure 6. Co-occurrence map of CC terms

Every color represents a cluster, and the size of circles indicates how strongly a set of terms are related. All circles with the same color belong to the same cluster. The software output reveals four clusters of the key terms illustrated in Table 4. Two climate experts checked the subject clusters produced by the co-word analysis and analyzed them as follows:

- Cluster 1 displayed in red on the top left hand corner of the map includes articles on global warming, precipitation, its consequences and finally effect on different climate component such as wind, water resources, lakes and sea, anomaly and season fluctuation. The earth has warmed by about 0.74 °C in the last century, and global mean temperatures are projected to increase more by 4.3 ± 0.7 °C by 2100 (IPCC summary, 2007). The Intergovernmental Panel on Climate Change (IPCC) has concluded that global warming is inevitable and that human activity is likely to be the main cause (IPCC, 2007). According to the IPCC, as human activities continue to add greenhouse gases to the Earth's atmosphere, global temperatures are expected to rise, causing the Earth's climates to change. These climate changes may affect precipitation patterns, severe and extreme weather events and environmental systems over time (Shepardson et al, 2009). In the future, the anthropogenic global warming, with its associated changes in precipitation, is projected to move the boundaries of the climatic zones still farther (de Castro et a, 2007; Lemke and Stein, 2008). Close relationship between precipitation and warming is shown as well in the first cluster.

- Cluster 2 displayed in green on the bottom right hand corner of the map includes articles on CC policies, acceptance, and adaptation. The issue of adaptation and policy making in the field of climate changes is very important. Climate change adaptation strategies require creating a link between an obvious expectation of warming and the way global warming could affect habitats, species, and even people, to clear actions and objectives that would best address those climate impacts (Poiani et al, 2011), which show how concepts of clusters intertwined. World Bank projects can be mentioned in policy making to mitigate climate changes. The World Bank is investing in the "blue economy", using innovative ways to manage aquaculture and fisheries, and address threats to ocean health caused by marine pollution, containing litter and plastics. Further, in 2019, 53 percent of the Bank's agricultural investments are directly financing climate mitigation and adaptation measures, up from 28 percent just four years ago. The World Bank's work on urban development has been instrumental in building resilient cities. For example, the World Bank helped the Beira city in Mozambique strengthen its resilience to weather-related hazards; rehabilitating its storm water drainage system and installing flood control stations and a water retention basin. When Cyclone Idai hit in March 2019, Beira faced less damaging flooding than other parts of the country[3].
- Cluster 3 displayed in blue on the bottom left hand corner of the map includes articles on diversity of plant and animal species. According to different studies, two environmental challenges of the earth: global changes in climate and land use (habitat degradation), can lead to reduced biodiversity and eventually lead to the sixth mass extinction of plant and animal species (Jetz et al., 2007). Multiple lines of research suggest that climate changes could become an eminent cause of extinction over the coming century, both via direct impacts on species and through synergies with other drivers of extinction (IPCC summary, 2007). If climate changes and habitat conversion do threaten similar species, then global biodiversity may homogenise even more rapidly than previously predicted, truly ushering in the 'Homogocene' (Baiser et al, 2012).
- Cluster 4 displayed in yellow on the top right hand corner of the map includes articles on greenhouse gases, include co_2, ch_4 and n_2o and their emissions, energy, soil, crops, and mutual impacts of them on climate change. Health and agriculture may be sensitive to climate change. Therefore, public awareness of global warming and its change is crucial. Now, policies, such as carbon pricing by the World Bank can deliver additional benefits,

[3] https://www.worldbank.org/en/topic/climatechange/overview#1

reducing air pollution and congestion while avoiding the increased costs of remedial measures associated with high-carbon growth paths. Further it enables businesses to manage risks, plan their low-carbon investments, and drive innovation, which lead to reduction of greenhouse gases.

Table 6. The main keywords constituting the Clusters of CC articles

Cluster		Term	Terms of each cluster
Number, color	Name		
1st cluster, Red	Observed changes	warming, precipitation, basin, concentration, river, RCP[4], vegetation, summer, temperate, water resource, winter, hydrologic model, atmosphere, air temperature, GCM[5], sea, ratio, correlation, measurement, models	334
2nd cluster, Green	Adaptation and mitigation	adaptation, policy, country, framework, vulnerability, mitigation, sector, effort, problem, opportunity, city, decision, planning, resilience, industry, review, economic, plan, outcome	319
3rd cluster, Blue	Species Vulnerability	species, decline, tree, biodiversity, composition, conservation, gradient, disease, migration, history, fish, trait, timing, survival, environmental condition, disturbance, phenology, ecology, mortality, North America	239
4th cluster, Yellow	Gas emission	greenhouse gas, emission, soil, energy, co_2, product, crop, application, farm, yield, ch_4, technology, treatment, benefit, carbon, consumption, n_2o, material, biomass, co_2 emission	223
N. of all terms			1115

Discussion and conclusion

The findings reveal that the average social citations per paper is 27 in social networks while the average scientific citations per paper is six in journals. The aggregate number of citations including 84380 social citations (regardless of Mendeley readers) along with 17361 scientific citations signifies the extent to which both scholars and social users are interested in CC issues. The retrieved documents from WoS contained highly cited paper with the highest citation of 387, compared with the AAS which is 3334 for the same article. Citations are generally limited in their number due to different reasons such as limited coverage of journals in databases (Moed, 2006), unbalanced coverage of disciplines (Mingers & Leydesdorff, 2015), and technical and typographical errors (Verbeek et al., 2002). However, social networks are less-limited in comparison in providing opportunities for their users to comment on research articles, broad coverage of altmetric resources (BarIlan et al., 2012; Priem et al., 2012), reduced language

[4] RCP (a representative concentration pathway) is a greenhouse gas concentration.
[5] GCM (a general circulation model) is a type of climate model.

limitations, improved information seeking process (Priem et al., 2010), global reach and immediate impact (Mazov & Gureev, 2015), variety of social networks, and availability of gadgets for social media users (Sotudeh et al., 2018). It seems, thus, to be expected that social citations to articles outnumber their scientific citations by several times. Moreover, some articles with altmetric citations might have received no scientific citations. The findings showed that an article titled "global warming and recurrent mass bleaching of corals", which reflects global warming concerns and its impact on animal and plant species, obtained the highest attention score of 3334 in Altmetric.com and received 387 journal citations.

Due to its nature and affinity with human life, the field of climate studies attracts attentions which are backed by the high AAS values of its articles. Mendeley readers and Tweeter users showed the highest attention to CC articles; these two services typically receive top attention scores. The results of Spearman correlation showed a significant, though weak, correlation between the quantities of scientific citations and social mentions from many social media covered by Altmetric (including Tweeter, Mendeley, Blogs, News, Google+, Facebook). The statistical results showed a significant weak correlation between social media and WoS citations. Various studies reported a statistically significant relationship between the number of citations and the number of tweets (De wintere, 2015; Bornmann, 2015; Bornmann, 2014; Haustein et al, 2014a; Thelwall et al., 2013 & Eysenbach, 2011), and Mendeley readership (Mohammadi & Thelwall, 2014; Haustein et al., 2014b, Riahinia et al, 2018). The results of Spearman test also showed a significant weak correlation between citations and AAS, which was previously confirmed by Barbic et al. (2016), Huang et al. (2018) and Barakat et al. (2019). It should be mentioned that this is not a cause-effect but a bilateral relationship whereby an increase in citations of the traditional or social platforms helps a better performance in another. On the one hand, several studies have suggested that the representation of research articles on social media not only improved the AAS but also contributes to their traditional citation increase (Zahedi et al., 2014; Mohammadi & Thelwall, 2014; Haustein et al., 2014; Erfanmanesh, 2017; Bong & Ale Ebrahim, 2017, Riahinia et al., 2018). On the other hand, scientific citation adds to the attractability of research articles to be discussed on social media.

The results of subject analysis helped identify top ten subject areas that were either most productive, most traditionally or most socially recognized. *M*ultidisciplinary sciences are the one and only subject area found to be top in all of the tree indicators. It is noteworthy that social users are more interested in medicine-related issues; for example, the side effects of climate changes on the skin and respiratory and cardiovascular systems, while scientists are more inclined to other CC issues related to basic sciences.

Visualization of CC articles helps redirect cultural-political debates and associated discourses. It can help raise awareness of people and engage them in environmental conservation (O'Neill & Smith, 2014). Organizations, scientists, journalists, and artists tend to visualize climate status in different ways (Yusoff & Gabrys, 2011; Cameron et al., 2013). Scientometric scholars create visualizations in order to identify the strengths, weaknesses, and gaps of various disciplines and facilitate research decisions. Visualization of CC articles using VOSviewer created four clusters containing articles on warming, precipitation and its outcomes; policies on CC and acceptance; diversity of plant and animal species; and greenhouse gases and emissions. As stated above, an article in the field of plant and animal species attracted the most social and scientific citations. Some of the current clusters are consistent with the clusters produced by Haunschild, Bornmann and Marx (2016) whose findings identified the key terms in the titles of articles over 35 years of publication to be CC, impact and effect while politics, adaptation, emission, precipitation, plant and animal species life, and CC constituted the main key terms of the clusters. They claimed that the recognition of human-induced CC would direct the future research in the field toward adaptation and mitigation; the two concepts identified as major key terms in the second cluster. It is noteworthy that according to the co-word map, authors focused rather on the CC effects on plants and animals, as well as policy making in the field, while social users are more interested in CC consequences for human beings.

The history of CC research dates back to over 40 years ago. Several studies have carried out bibliometric and visualization analyses on the research output in the field. However, there was a lack of research on the comparison of the social citations and journal citations in CC articles. The results of this study can help researchers, editors and policy makers better understand the importance and benefits of using social media and tools to publish climate research articles in order to make them more visible and inform laypeople faster and broader. Further, the implication of the present study lies in the clarification of the extent to which social network users pay attention to climatic issues and how much is the power of social networks in showing the impact of science on society. Considering the value and correlation of altmetrics with traditional citations, they may be used in research evaluation. However, due to the weakness of the correlation coefficients, the replacement of the social and traditional metrics is not recommended, but it is possible to use them as complementary indicators in evaluating research.

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