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SPECIAL FEATURE: REVIEW ARTICLE

The Sustainability–Peace Nexus in the Context of Global Change

Three decades of research on climate change and peace: a bibliometrics analysis

Ayyoob Sharifi[1,2] · Dahlia Simangan[1,2] · Shinji Kaneko[1,2]

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Abstract

Over the past 3 decades, a vast body of research has been published on the interactions between climate change and events that undermine negative peace. Consequently, several review papers have been published in the last few years on this nexus. However, there is still a lack of a comprehensive bibliometrics analysis of the field. Accordingly, the main aim of this study is to fill this gap to advance our understanding of the existing literature. For this purpose, we analyzed 1337 articles indexed in the Web of Science using VOSviewer and SciMAT that are two commonly used software tools for science mapping and bibliometrics analysis. The SciMAT tool was also used to examine thematic evolution of the nexus over three consecutive sub-periods (i.e., 1990–2007, 2008–2014, and 2015–2020). Results show that research on this nexus has grown steadily since 1990, but the trends have rapidly increased after the publication of the IPCC assessment report in 2007. Four major thematic focus areas were identified, namely, (1) war and violent conflict, (2) political tensions and institutional mechanisms to deal with conflicts, (3) disasters and other climatic impacts that may lead to massive human displacements, and (4) conflicts/cooperation related to water resources. Results of the SciMAT analysis confirm and add weight to these findings. They also show that, over time, issues related to environmental security have gained more attention. An important finding is that the focus has mainly been on war and violent conflicts and other events are not well addressed. The article concludes with some recommendations for future research.

Keywords Climate change · Negative peace · Conflict · War · Bibliometrics · Thematic evolution

Introduction

Climate change is increasingly recognized as a threat multiplier with the potential to undermine global peace and security (Mach, Kraan et al. 2019). Contrary to the traditional framing of security, which is primarily concerned with military conflict and state survival, the post-Cold War discourse on security has broadened to include non-traditional security issues, including climate change (Anthony, Emmers et al. 2006). In fact, since the end of the Cold War in 1991 that was almost co-incident with the surge of interest in sustainable development and global climate change issues following the Rio Summit, a paradigm shift in the traditional notion of security has occurred (Koubi 2019). It is now recognized that security threats are not just triggered by conventional geopolitical and territorial disputes, but environmental factors may also undermine peace and security (Koubi 2019; Virji, Sharifi et al. 2019). These concerns are substantiated by empirical evidence showing that climate-induced stressors, such as drought, may be contributing factors that affect the likelihood and duration of conflicts (Solomon, Birhane et al. 2018). Climate change may also indirectly contribute to conflict through, for instance, intensifying poverty and/or causing massive displacements of people (HRC 2019; Koubi 2019).

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Handled by Hassan Virji, Hiroshima University, Japan.

✉ Ayyoob Sharifi
sharifi@hiroshima-u.ac.jp

[1] Graduate School of Humanities and Social Sciences, Hiroshima University, Higashi Hiroshima, Japan

[2] Network for Education and Research on Peace and Sustainability, Hiroshima University, Higashi Hiroshima, Japan

Over the past few years, several initiatives and institutions have been developed to explore linkages between climate change and peace (e.g., The Center for Climate and Security, Environmental Peacebuilding, etc.). Also, many studies have been published on the linkages between climate change and peace-related issues such as conflict and security (see "Results and discussions"). With the impacts of climate change becoming increasingly more apparent, this trend is expected to continue in the future. Following this increase in the number of publications, several review articles have been published to synthesize the existing evidence and further clarify the nature of pathways and causalities between climate and conflict. For instance, Koubi (2019) reviewed evidence on the direct and indirect links between climate change and conflict and found that, although mixed evidence has been reported in the literature, climate change contributes to conflict under certain socio-economic and institutional conditions. Similar results have been reported in a study by Sakaguchi, Varughese et al. (2017) that show mixed evidence on the climate change-violence nexus. In contrast, review articles that have focused on regions suffering from institutional instability and pre-existing socio-political tensions show more robust links between climate change and conflict. For instance, Solomon, Birhane et al. (2018) demonstrate how climate variabilities have worsened the impacts of conflict in the Horn of Africa. In a similar way, evidence shows that water stress is a contributing factor to conflict in the Middle East (Gleick 2019).

These studies have significantly improved our understanding of the nature of causal linkages between climate change and peace. Here, it should be noted that there is still no universal definition of 'peace' in the literature. A widely used approach is to use a dichotomous definition that differentiates between 'negative peace' and 'positive peace' (Galtung 1969). The former indicates the absence of conflict and violence, while the latter refers to factors and conditions that contribute to building and sustaining peaceful communities (e.g., through equitable distribution of resources, corruption reduction, human rights acceptance, etc.) (Amadei 2019; IEP 2019). The existing reviews discussed earlier are mainly focused on factors and events that undermine 'negative peace'. They often focus on one event, namely armed conflict (Sakaguchi, Varughese et al. 2017; Gleick 2019), failing to simultaneously cover other events such as arms race, crime, assault, etc. While being comprehensive is desirable, a systematic review of a vast body of research would be a challenging task. Recent developments in data analytics and text mining, however, can provide some solutions that allow expanding the scope to include various events that undermine negative peace. In fact, over the past decade, several bibliometrics analysis software tools have been developed for science mapping and performance analysis, among other purposes (Cobo, López-Herrera et al. 2011a, b). Science mapping is used to visualize the overall structure of a research area and identify major themes and sub-themes that have structured its evolution. It can also be used to present the complex thematic inter-relationships in a simple manner. In contrast, performance analysis is mainly focused on metrics related to various items such as documents, journals, authors, institutions, and countries. In view of this, the main objective of this article is to provide a broad overview of existing research on the nexus between climate change and various events that undermine negative peace by utilizing bibliometrics analysis methods. Therefore, it complements existing review articles that mainly use systematic review and meta-analysis techniques to examine linkages between climate change and violent conflict. Results of this review can help better understand the landscape of research on climate change and peace in order to expand the current knowledge about the nexus, identify well-developed research areas, and understand emerging and under-studied research themes that need further attention. Furthermore, results can also be used by interested researchers and policy makers as a point of reference when navigating the field.

The article is structured as follows. Materials and methods used for the review are presented in "Materials and methods". "Results and discussion" reports the results of performance analysis and science mapping. Finally, the article concludes with some discussions and recommendations in "Conclusions".

Materials and methods

This review involved three major steps, namely, creation of review database, performance analysis and science mapping using VOSviewer, and thematic evolution analysis using SciMAT (see Fig. 1). Details related to each step are provided in the remainder of this section.

Creation of the review database

As mentioned earlier, the main objective of this review is to provide a bibliometrics analysis of existing literature on climate change and events that undermine negative peace. Accordingly, a broad-based search string was developed that includes different variants of terms related to events that undermine negative peace, such as violence, conflict, crime, murder, etc. (see the Electronic Supplementary Material (ESM)) for details). Since we are focusing on the absence of peaceful conditions, the term 'peace' was not included in the search string. This search string also aligns with previous research showing that negative peace is often represented by conflict-related terms in the literature (Gleditsch, Nordkvelle et al. 2014). Accordingly, we assume that the selected terms are appropriate for retrieving relevant papers and excluding

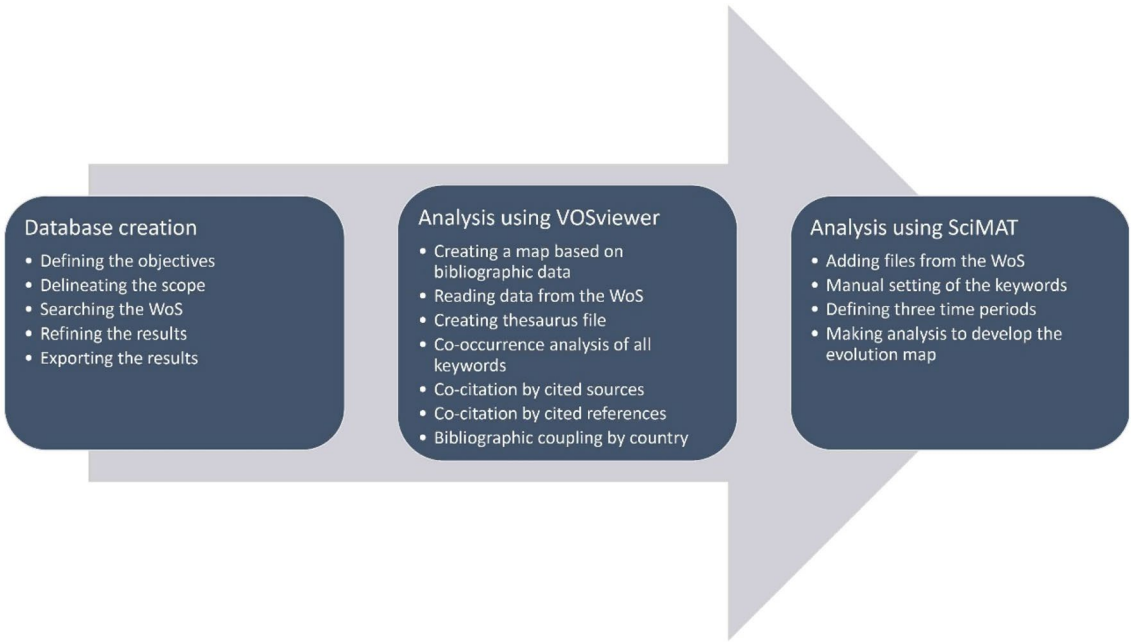

Fig. 1 Major steps taken for the purpose of this research

papers that may be only focused on positive peace. The initial search was conducted on February 2020 using the Web of Science (WoS) and returned 4405 articles. We used the filtering function of the WoS to exclude articles belonging to irrelevant categories such as Applied Mathematics, Mechanics, and Physics. At the end of this process, 2771 articles remained in the database. Next, we exported the 'Full Record and Cited References' of these articles to be used for analysis using SciMAT and VOSviewer. While checking the abstracts of these articles, we noticed that another round of cleaning is required because, in some articles, the search terms have been used for objectives different from those of this study. For instance, conflict could refer to intergenerational conflict in some studies. Therefore, we checked the titles and abstracts of all articles to only include relevant papers. At the end of this process, 1337 articles remained in the database for bibliometrics analysis in VOSviewer and SciMAT.

Performance analysis and science mapping using VOSviewer and SciMAT

With advances in text mining, there are now several software tools for bibliometrics analysis and science mapping (Cobo, López-Herrera et al. 2011a, b). What is common to all these tools is their ability to simplify the dynamic and complex linkages between different documents and their associated authors, journals, disciplines and countries. See Cobo, López-Herrera et al. (2011a, b) for more details about existing tools and their features.

VOSviewer is a frequently utilized tool for creating bibliometric networks of different items (e.g., authors, organizations, etc.) using various network analysis methods such as co-citation, term co-occurrence, and bibliographic coupling (Van Eck and Waltman 2009). In this review, we used the term co-occurrence analysis to identify major thematic clusters related to the nexus. As some terms may have different variants (e.g., Sustainable Development Goals and SDGs), before conducting the term co-occurrence analysis, we added a thesaurus file to the VOSviewer database to merge different term variants (for more information see Van Eck and Waltman (2020)). Other bibliometric network analyses used in this study are 'bibliographic coupling'[1] and 'co-citation'. The former was used to identify the most influential organizations and countries, and the latter to detect and categorize the most influential journals, publications, and authors. Interested readers are referred to the VOSviewer manual for more details about these different analyses (Van Eck and Waltman 2020). Outputs of these analyses are in the form of nodes and links, where the node size is proportional to the frequency of objects (i.e., terms, citation, etc.) and the link thickness represents link strength between two objects.

We used SciMAT to gain knowledge about the thematic and conceptual evolution of the nexus. For this purpose,

[1] "A bibliographic coupling link is a link between two items that both cite the same document. A co-citation link is a link between two items that are both cited by the same document" Van Eck N. and L. Waltman (2020). VOSviewer Manual for VOSviewer version 1.6.14. Leiden University, Leiden University.

it was necessary to divide the publication time span into several sub-periods, based on major milestones that may have influenced the conceptual evolution of the field. In the Introduction Section, it was discussed that the end of the Cold War in 1991 marks the beginning of a paradigm shift in peace and security studies. Based on this, we were interested in examining knowledge structure and trends of the nexus between climate change and events that undermine negative peace over the past three decades. Here, it should be mentioned that a few studies have been published on this nexus before 1990 that are not included in our database (Gleick 1989). However, since they are just a handful, we believe they do not affect the findings of the bibliometrics analysis. Accordingly, the time-span for Sci-MAT analysis is 1990–2020. Two key milestone reports can be identified during this 3-decade study period that may have affected the evolution of the field. The first one is the publication of the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC AR4) acknowledging climate change as a threat to global peace and security (IPCC 2007). The second milestone is the publication of the United Nations Sustainable Development Goals (SDGs) that has been extensively used to guide policy and/or research across different domains of development (UNSDG 2015). The framework includes specific SDGs related to climate change (SDG 13) and peace (SDG 16), indicating the increased recognition of their significance for achieving sustainable development. Considering these milestone events, the following sub-periods were used for analysis using SciMAT: 1990–2007, 2008–2014, and 2015–2020.

While SciMAT can be utilized for different types of bibliometrics analysis, in this study, we used its term co-occurrence features to identify closely linked concepts and explore thematic evolution of the nexus during the 3-decade study period. Detailed methodological information related to this software is presented in Cobo, Lopez-Herrera et al. (2012). Here, we only explain some major procedures and processes. Specifically, we used the keyword consolidation functions of the software (i.e., 'find similar words' and 'word group manual set') to clean the raw data and merge conceptually similar terms. We then ran the analysis—using all keywords—based on the settings recommended by the tool developers (Cobo, López-Herrera et al. 2011a, b). Accordingly, normalization of keyword co-occurrence was done using the 'equivalence index'; 'simple centers algorithm' was used for clustering algorithm; and 'h-index', 'average citations', and 'total citations' were used to identify the relative significance of different keyword clusters.

As shown in Fig. 2, analysis using SciMAT provides four types of outputs, namely, 'strategic diagram', 'thematic network', 'evolution map', and 'overlay graph'. A strategic diagram (Fig. 2a) is a graph with horizontal axis indicating network centrality and vertical axis showing network density (Cobo, López-Herrera et al. 2011a, b). Centrality is a measure of inter-network connections, that is, a higher value of centrality for a theme indicates that it has stronger linkages to other themes in the network and has played a relatively more important role in the development of the field. In contrast, density is a measure of intra-network connections. In other words, themes with higher values of density are highly developed and feature strong internal connections (Cobo, López-Herrera et al. 2011a, b). Overall, four different types of themes can be distinguished based on their positions on the graph: motor themes, highly developed and isolated themes, emerging or declining themes, and basic and transversal themes (Cobo, López-Herrera et al. 2011a, b). See the ESM for detailed definition of each theme.

Thematic networks are useful in explaining the results of the strategic diagram, (Fig. 2b). They provide more detailed information on how themes displayed on the strategic diagram are linked to other themes that have shaped to evolution of the field (Cobo, López-Herrera et al. 2011a, b). To complement these outputs, the evolution map illustrates how different themes are linked to each other across different sub-periods (Fig. 2c). When themes share completely or partially identical labels, they are connected by solid lines. In contrast, when two themes share some similar keywords (sub-themes) but their labels are different, they are connected by dotted links (Cobo, López-Herrera et al. 2011a, b). Finally, the overlay graph provides information about network entropy (Fig. 2d). Number of shared keywords is shown on the horizontal arrow. The outward directed arrow indicates the number of keywords from the first period that disappear in the subsequent period. Conversely, the inward arrow shows the number of newly emerged keywords.

Results and discussion

We first provide information related to the publication trends and present the results of the science mapping and bibliometrics analysis using VOSviewer. Next, we report the results of thematic evolution analysis using SciMAT.

Overall bibliometrics analysis

Publication trends

Figure 3 shows that until 2007, only a handful of studies have been annually published on this nexus. However, an overall increasing trend can be observed since 2007, suggesting that the publication of the IPCC AR4 has triggered

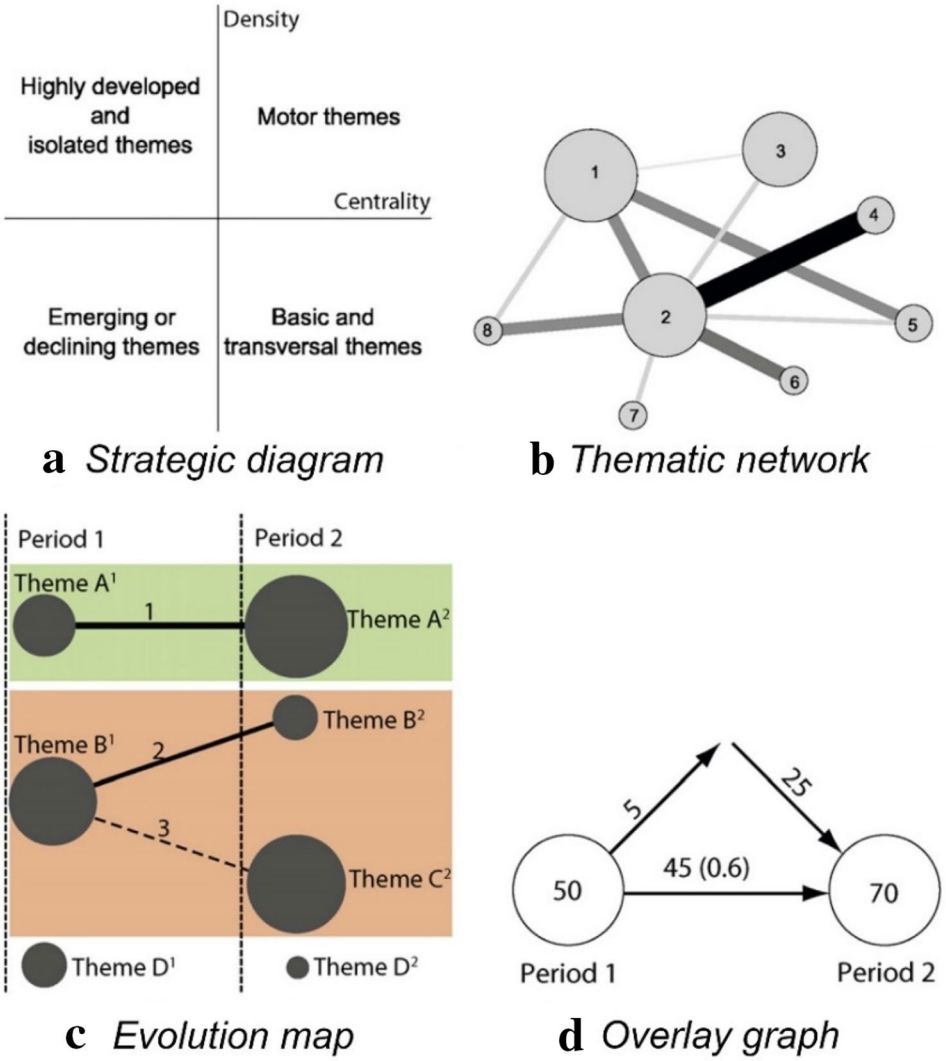

Fig. 2 Strategic diagram, thematic network, evolution map, and overlay graph (Cobo, López-Herrera et al. 2011a, b)

increased interest in the nexus (IPCC 2007). Also, it is clear that the number of publications has increased significantly over the past 5 years[2]. A possible explanation for this surge in interest could be the publication of the UN SDGs that emphasize the significance of peace and climate action for achieving sustainable development (UNSDG 2015).

This increasing trend can also be observed from the number of articles published per period that increased by factors of about 5.3 and 2.2 from the first period to the second period and the second period to the third period, respectively (Fig. 3).

[2] Note that the lower number of publications in 2020 compared to 2019 is because the initial search was done in early 2020. Also, the fact that more than 40 articles have already been published by Feb 2020 confirms an upward trend.

Term co-occurrence analysis

We used the term co-occurrence analysis to identify major thematic clusters. Each cluster is composed of several frequently co-occurring terms. The analysis output for a minimum threshold of 15 keywords is shown in Fig. 4. In this figure, node size and link thickness are proportional to the term frequency and link strength, respectively. Detailed quantitative data for the top-25 highly occurred terms is shown in Table 1 of the ESM. The following terms stand out in terms of occurrence frequency and total link strength: climate change, conflict, policy, adaptation, security, vulnerability, civil war, institutions, migration, and refugees. Higher occurrence and link strength values for the term climate change are unsurprising, since it was included in the search string and the review is focused on articles that examined its nexus with events that undermine peace. Regarding the terms related to events that erode negative peace, conflict

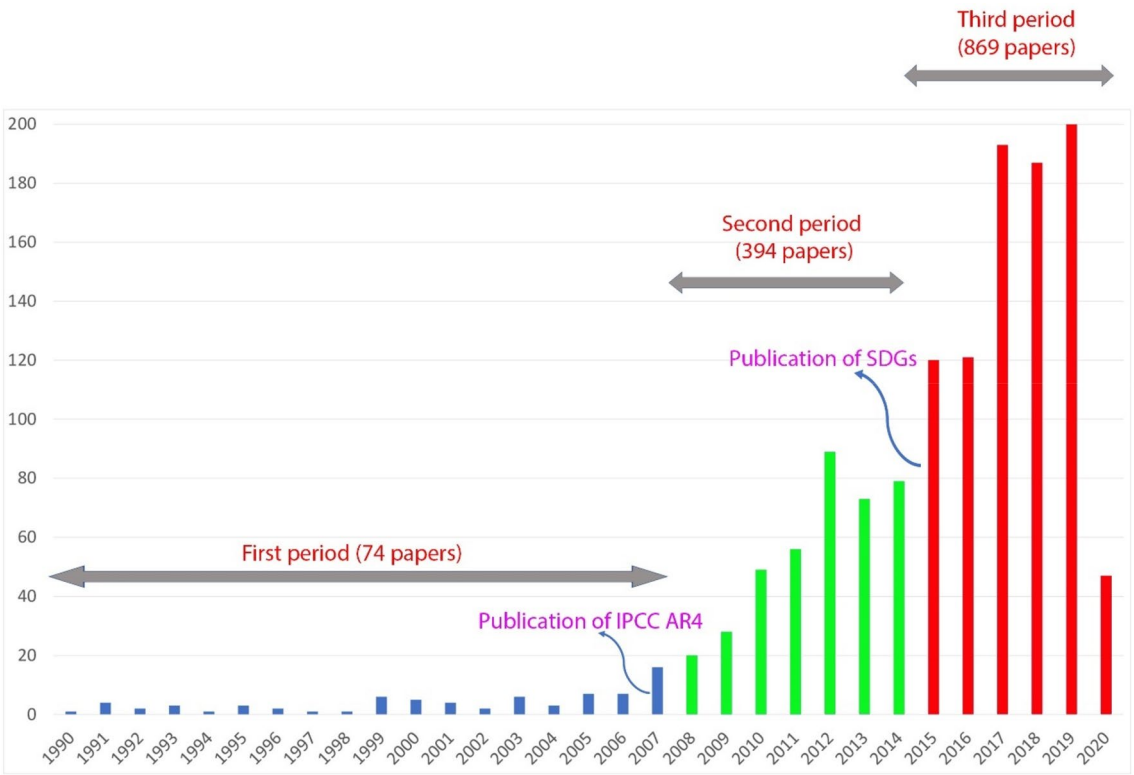

Fig. 3 The number of articles published per year and the three major periods of the study

and civil war feature higher values, indicating the relatively more attention they have received in the literature.

Four major thematic clusters can be distinguished in Fig. 4 (note that results related to influential journals, publications, and authors have also been presented in four clusters. Cluster colors remain consistent for all analyses. For instance, red clusters in Figs. 5–7, to a large extent, correspond to the red cluster discussed in Fig. 4). These clusters are focused on inter- and intra-state conflicts over climate policies, and institutional mechanisms (red cluster), violent conflict in Africa and the disaster-conflict nexus (green cluster), migration and adaptation (blue cluster), and resource management and environmental security (yellow cluster).

The red cluster has the largest number of terms, but most of them have not occurred frequently and do not have strong links to the other terms. The terms policy, management, and institutions are, however, exceptions. This cluster is mainly focused on two issues. The first one is about conflicts that typically occur between and/or within countries regarding climate policies and mitigation responsibilities. For instance, conflicts/tensions may arise when a government, local authority, or private company attempts to achieve climate change mitigation through implementing wind-based renewable energy initiatives (Lintz and Leibenath 2020), or carbon capture and storage schemes (Terwel and Daamen 2012). There is also evidence showing that some international mitigation initiatives such as REDD + may not lead to equitable benefit sharing, thereby causing social conflicts (Milne, Mahanty et al. 2019). The other issue is the importance of governance and institutional mechanisms for not only ensuring that tensions caused by climate policies are minimized, but also for reducing conflicts that may arise due to climate change impacts. The term institution has linkages to other clusters, showing the role that institutions can play in, for instance, reducing potential conflicts related to water scarcity or migration. In fact, the significance of functioning institutions for mitigating such conflicts is well evidenced in the literature (Hamed, Hadji et al. 2018; Koubi 2019).

Terms in the green cluster have received significant attention as demonstrated by their high frequency of occurrence as well as their strong interlinkages. This cluster has also two major thematic focus areas, namely, violent conflict in Africa and the disaster-conflict nexus. It is evident that linkages between risk factors such as drought and resource scarcity, induced by climate change/variability, and violent conflict, are well addressed in the literature. Terms in this cluster are closely linked to terms such as Africa and Sub-Saharan Africa, confirming earlier observations that research on the climate-conflict nexus has mainly been conducted in African countries, which raises concerns about sampling bias (Adams, Ide et al. 2018; Koubi 2019). Obviously, more research in other contexts affected by

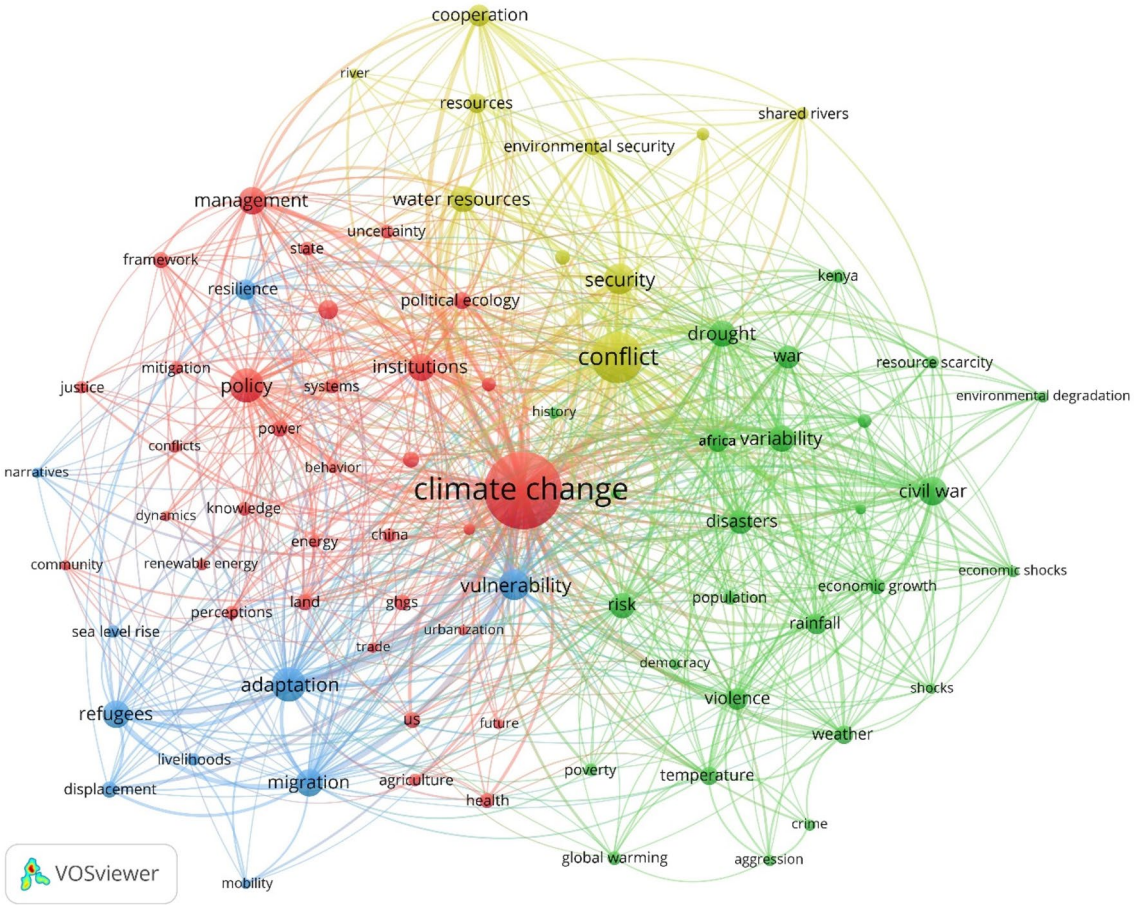

Fig. 4 The term co-occurrence map

climate impacts is needed to better unpack the complex relationships between climate and conflict. The other major focus area is related to possible interactions between disasters and conflict. A recent study shows that there is still a lack of empirical research on such interactions (Peters, Holloway et al. 2019). Mixed evidence has been reported on the effects of disasters on conflict outbreak, but conflict duration is likely to be increased due to natural disasters (Koubi 2019). This may result in massive migrations (Abel, Brottrager et al. 2019), which is the focus of the blue cluster. Disasters and other climate-induced stressors may also trigger large-scale migrations and displacements by eroding the livelihood security of people (Mbaye and Zimmermann 2016). In turn, these types of massive migration may result in social tensions and conflicts in the recipient communities (Connell and Lutkehaus 2017). This cluster also includes terms such as vulnerability and resilience, indicating the importance of resilience-building activities in minimizing vulnerabilities and improving response and adaptation capacities (Methmann and Oels 2015).

Finally, there is a separate thematic cluster focused on resource management and environmental security (yellow cluster). Here, there is a clear emphasis on water resources, highlighting the vast body of research on cooperation/conflict over water resources. This cluster is closely connected to the green cluster, and the linkages to Africa represent the large number of publications related to conflict over water resources in Africa (e.g., (Schilling, Hertig et al. 2020)). Presence of the term cooperation indicates that climate-induced resource scarcities may provide opportunities for cooperation rather than conflict (Tubi and Feitelson 2016). It also shows the importance of cooperation mechanisms and policies for avoiding conflicts (Link, Scheffran et al. 2016).

The most influential journals

We used 'co-citation by cited sources' to find out the relative importance of different journals in the development of the nexus. According to Van Eck and Waltman (2020), "a co-citation is a link between two items that are both cited by the same document". The analysis output, for a minimum number of 100 citations per source, is presented in Fig. 5.

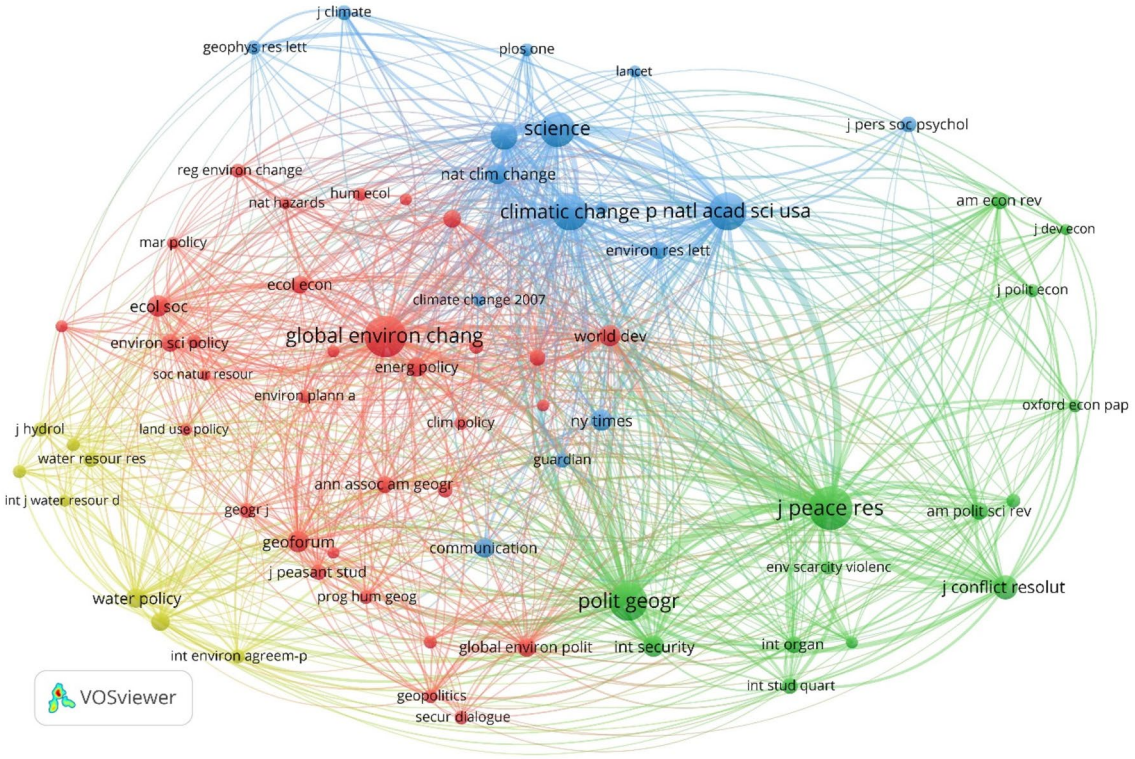

Fig. 5 Result of the co-citation analysis by cited sources

Quantitative details related to the top-25 most influential sources are available in Table 2 of ESM. Results show that journals such as Journal of Peace Research, Global Environmental Change, and Political Geography have been more influential. Interestingly, a high degree of correspondence between the clusters shown in Fig. 5 and those reported for the term co-occurrence analysis can be observed. Accordingly, in addition to general issues related to violent conflict, the red cluster mainly deals with issues related to conflicts induced by climate policies and institutional mechanisms for conflict mitigation. Prominent journals in this cluster are Global Environmental Change, Ecology and Society, World Development, Energy Policy, and Global Environmental Politics. As discussed in the previous section, the green cluster is mainly focused on violent conflicts in Africa that are linked to natural disasters and other climate change impacts. Prominent journals publishing on these issues are Journal of Peace Research, Political Geography, Journal of Conflict Resolution, International Security, and American Political Science Review. The blue cluster that represents terms such as vulnerability, resilience, and migration is mainly covered by influential journals such as the Proceedings of the National Academy of Sciences of the United States of America (PNAS), Climatic Change, Science, Nature, and Nature Climate Change. This cluster is closely linked to the red and green clusters, indicating that these journals have also covered issues related to climate policies and violent conflicts. Finally, the yellow cluster is clearly focused on issues related to (water) resources and their management. This corresponds well with the yellow cluster of the previous section. Major journals dealing with these issues are Water Policy, Water International, Water Resources Research, and Journal of Hydrology.

It should be noted that this analysis is not just based on the 1337 articles in our review database. In fact, documents cited by these articles have also been used in the analysis. Table 3 of the ESM lists the top journals based only on the 1337 articles and shows similar results, with Global Environmental Change, PNAS, and Journal of Peace Research as the top-3 journals.

Most influential publications

Co-citation analysis by cited references was used to identify the most influential publications. Result of the analysis for a minimum number of 25 citations is presented in Fig. 6. The quantitative details of this analysis are available in Table 4 of the ESM. The top-3 publications are Burke, Miguel et al. (2009), Homer-Dixon (1999), and Hsiang, Burke et al. (2013). Overall, there is a good correspondence between these clusters and those presented in the previous

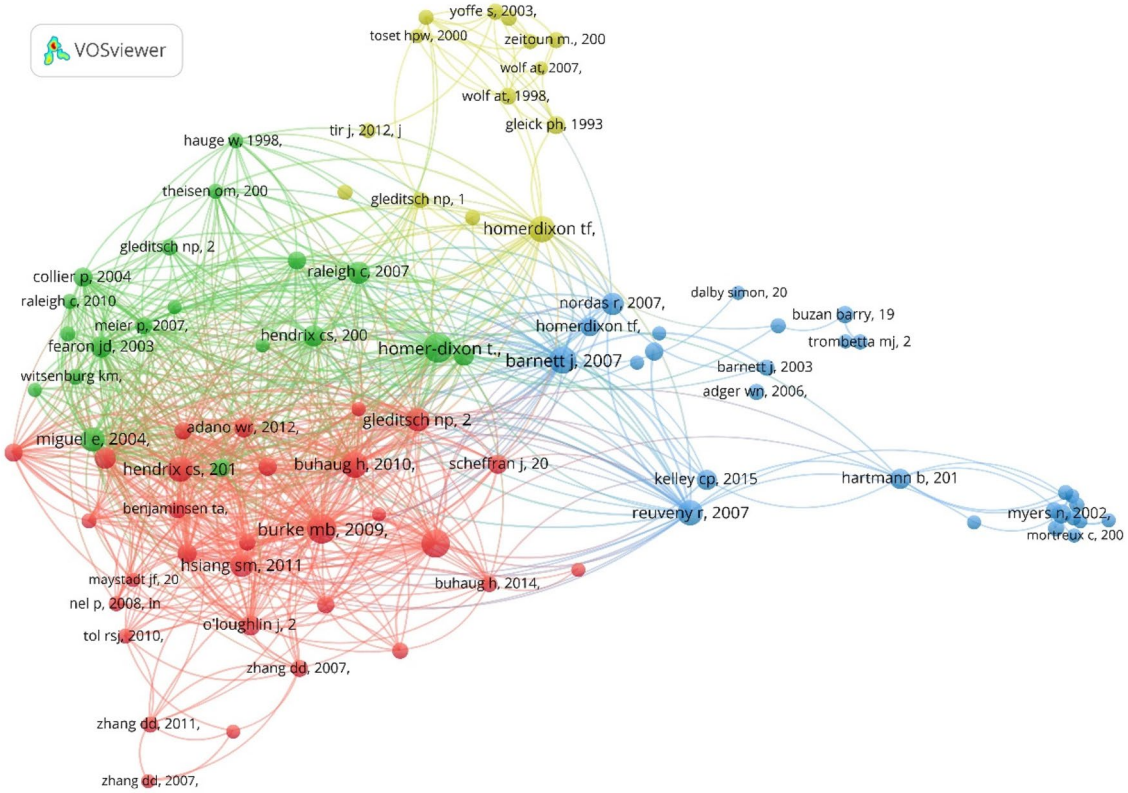

Fig. 6 Results of the co-citation analysis by cited references

sections. Results show that documents focused on interactions between climate change and violent conflicts (especially in the context of Africa) have been more influential. In Fig. 6, these are mainly publications belonging to the green and red clusters. In addition to the three publications mentioned above, noteworthy publications belonging to these clusters are Buhaug (2010), Hendrix and Salehyan (2012), Miguel, Satyanath et al. (2004), Hsiang, Meng et al. (2011), Gleditsch (2012), and Raleigh and Urdal (2007).

The other clusters also include several influential publications. For instance, in the blue cluster, which mainly consists of issues related to vulnerability, resilience, and migration, publications by Barnett and Adger (2007) and Reuveny (2007) are the most prominent. In the yellow cluster, which largely deals with issues related to (water) resource scarcity, the most noteworthy publications are by Homer-Dixon (1994) and Gleick (1993).

Influential authors and countries

We used co-citation analysis by 'cited authors' to identify the most influential authors. Result of this analysis for a minimum number of 70 total citations per author is presented in Fig. 7. The quantitative data for the top-25 authors are available in Table 5 of ESM. Based on these results, the following authors have had more influence in the development of the nexus: Halvard Buhaug, Clionadh Raleigh, and Thomas Homer-Dixon. The clusters presented in Fig. 7 are consistent with those reported in the previous sections. Prominent authors in the red and green clusters, that are mainly focused on the general climate-conflict interactions, are Halvard Buhaug, Clionadh Raleigh, Solomon Hsiang, Ole Magnus Theisen, Paul Collier, Cullen Hendrix, David Zhange, and Idean Salehyan. Most prominent authors related to adaptation and migration (blue cluster) are Jon Barnett, Neil Adger, Richard Black, Norman Myers, and Rafael Reuveny. Also, institutes such as World Bank and United Nations (IPCC) have been influential. Finally, the cluster related to the interactions of resource scarcity and conflict (yellow cluster) is represented by the following authors: Thomas Homer-Dixon, Nils Petter Gleditsch, Peter Gleick, Aaron Wolf, and Mark Zeitoun.

The influential authors can also be identified by considering only the authors of the 1337 articles in the database. This results in similar findings, but the order of the authors is different (see Table 1).

We used bibliographic coupling to find out which countries (based on the institutional addresses of the authors) have had more influence on the development of the nexus. "A bibliographic coupling link is a link between two items

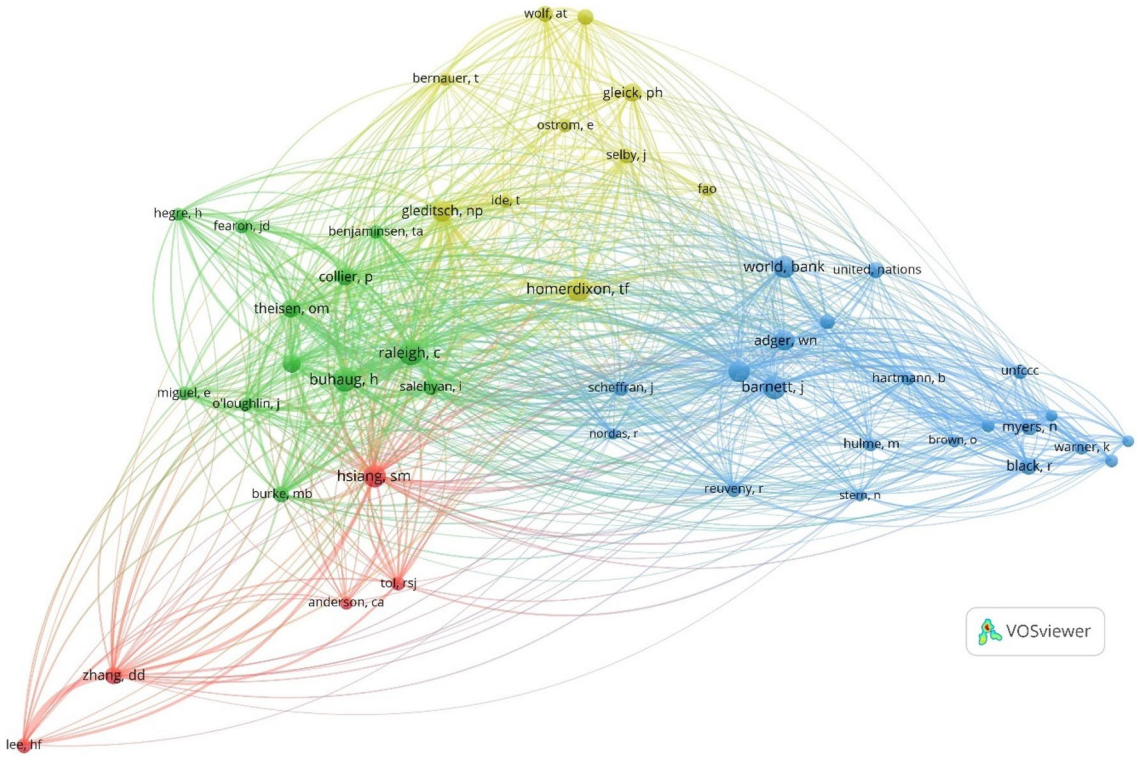

Fig. 7 Most influential authors

Table 1 Highly cited authors

ID	Author	Citations	Documents	Citation per document	Most cited document
1	Raleigh, Clionadh	759	5	152	(Raleigh, Linke et al. 2010)
2	Adger, W. Neil	717	4	179	(Brooks, Adger et al. 2005)
3	Buhaug, Halvard	582	9	65	(Buhaug 2010)
4	Lee, Harry F	577	11	52	(Zhang, Brecke et al. 2007)
5	Zhang, David D	564	8	71	(Zhang, Brecke et al. 2007)
6	Hendrix, Cullen S	451	6	75	(Hendrix and Salehyan 2012)
7	Tol, Richard S. J	432	4	108	(Tol 2009)
8	Scheffran, Juergen	311	10	31	(Scheffran, Brzoska et al. 2012)
9	Bernauer, Thomas	281	6	47	(Bernauer, Bohmelt et al. 2012)
10	Gleditsch, Nils Petter	254	4	64	(Nordas and Gleditsch 2007)

that both cite the same document" (Van Eck and Waltman 2020). Results of bibliographic coupling analysis for at least 10 documents per country are shown in Fig. 1 and Table 6 of the ESM. Most contributions have been made by authors from the USA, England, Germany, and Australia. These countries are closely linked to each other, indicating that they have been more involved in collaborative research projects, resulting in joint publications (e.g., Mach, Kraan et al. 2019). While existing research is highly reliant on evidence from Africa, as mentioned earlier, it is worth noting that the presence of African institutions in the literature is limited.

Conceptual structure and evolution of the field

Thematic structure

We used SciMAT to examine the thematic structure and evolution of the nexus. As discussed in the Methods Section, strategic diagrams are major outputs of the SciMAT analysis that provide information on the thematic structure of the nexus during each period. A strategic diagram divides important themes into four classes, namely, 'motor themes', 'basic and transversal themes', 'highly developed

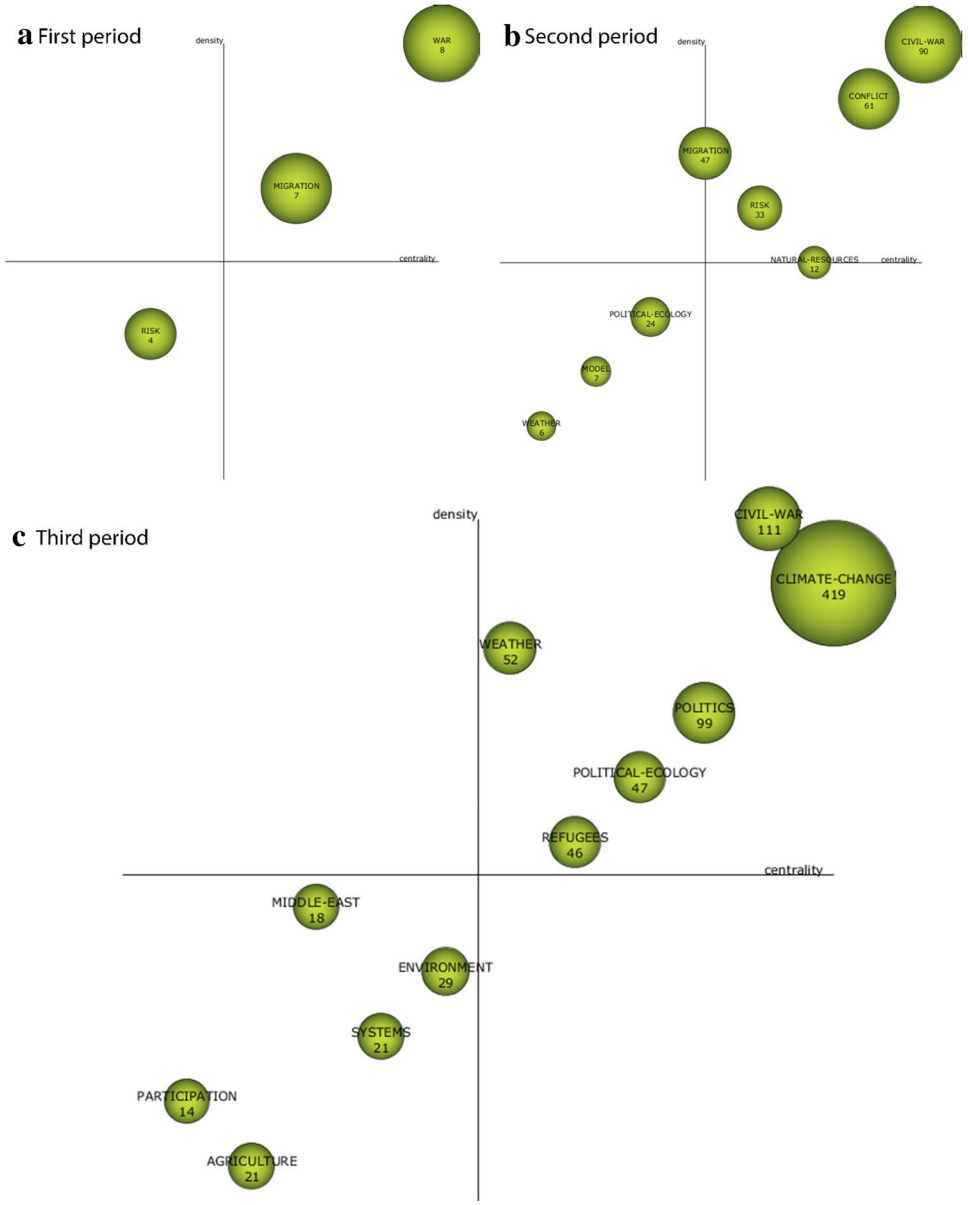

Fig. 8 Major themes during the three study periods

and isolated themes', and 'emerging or declining themes'. Based on this classification, we explain the thematic structure of the nexus for each period. The strategic diagrams are presented in Fig. 8. In these diagrams, the size of the nodes is proportional to the number of articles associated with each theme. Quantitative data on other performance measures related to these diagrams are available in Table 7 of the ESM.

First period (1990–2007): As shown in Fig. 8a, 3 major themes, namely, 'war', 'migration', and 'risk', shaped the structure of the field during this period. The limited number of themes is unsurprising since this is the formative period of this field of research. The motor themes that received more attention than others during this period were 'war' and 'migration'. The 'war' thematic area mainly dealt with the interactions between climate change, war, and human security and its focus was generally on African countries (see Fig. 2 of the ESM) (Barnett 2003; Barnett and Adger 2007; Brown, Hammill et al. 2007). 'Migration' was a relatively less developed thematic area, covering issues pertinent to climate-induced droughts and resource scarcities that trigger conflicts and may result in human migration. This thematic area had a specific emphasis on water resource scarcities (Yoffe and Ward 1999). Finally, results show that 'risk' was an emerging thematic area during this period. This implies that in the late 1990s and early 2000s, there had been significant debates over the implications of climate change impacts and their associated uncertainties for global peace and human security, including the actions

needed to address these impacts and uncertainties (Taylor and Buttel 1992; Edwards 1999; Knight 2005).

Second period (2008–2014): Fig. 8b shows that the thematic focus of the field has diversified during this period. Three major motor themes of this period are 'civil war', 'conflict', and 'risk'. 'Civil war' is the dominant thematic area in terms of all performance measures (see Table 7 of the ESM), which is closely linked to the 'war' theme of the previous period. A closer look at the strategic diagram (Fig. 2 of the ESM) shows that this thematic area has mainly focused on violent armed conflicts, in Africa, linked to climate change impacts and environmental degradation. In fact, several studies have been published during this period that examine linkages between climate change impacts and civil wars in Africa (Burke, Miguel et al. 2009; Dixon 2009; Raleigh 2010; Hsiang and Meng 2014). 'Conflict' is another important theme of this period, which is closely linked to another major theme—'natural resources'. These themes mainly deal with linkages between transboundary conflicts/cooperation and resource scarcity/abundance (Devlin and Hendrix 2014; Koubi, Spilker et al. 2014). The theme 'conflict' has a more diverse geographic focus and covers issues in other parts of the world, such as Southeast Asia (Jasparro and Taylor 2008; Kranz, Menniken et al. 2010) and Middle East (Brooks, Trottier et al. 2013). The other important themes are 'migration' and 'risks' that have received more scholarly attention compared to the preceding period (see Table 7 of the ESM). The 'risk' thematic area has evolved into a motor theme during this period, indicating that awareness about the human security risks of climate change has increased (Briggs 2012). Such risks were also emphasized in the IPCC AR4 published at the end of this period (IPCC 2007). 'Political ecology' is an emerging theme during this period that mainly deals with adaptation efforts and their potential linkages to peace and conflict. This becomes a motor theme during the third period.

Third period (2015–2020): During this period, the number of annual publications increased significantly as discussed earlier. Figure 8c shows that more themes have emerged in the past five years, indicating further expansion of the intellectual base of the field. The field has continued to consolidate around the following major motor themes during this period: 'climate change' and 'civil war'. 'Climate change' is the dominant theme based on all performance measures (Table 7 of the ESM). It is closely related to the themes 'conflict' and 'migration' from the previous period. The dominance of this theme is a clear indication of the increasing recognition of the urgency of climate threats and is in line with arguments regarding the paradigm shift in the traditional notion of security (O'Sullivan 2015; Koubi 2019). It also shows that more emphasis has been placed on the need to adopt appropriate resilience and adaptation measures for reducing vulnerabilities and managing conflicts triggered by drought and water scarcity (Schilling, Nash et al. 2017). Furthermore, the issue of climate-induced migration as an adaptation measure has also received special attention (Bettini 2017).

The focus of 'civil war', the other important motor theme, has not changed much since the previous period. Here, too, the emphasis is on possible linkages between armed conflicts and climatic impacts. In terms of geographic focus, Africa is still dominant (van Weezel 2019, 2020), but the Syrian crisis has also received attention (Kelley, Mohtadi et al. 2015; Karnieli, Shtein et al. 2019). A major change compared to the previous period is, however, the emergence of 'natural disasters' as a sub-theme that covers issues such as possible linkages between disasters and the outbreak/duration of conflicts (Schleussner, Donges et al. 2016), and the impacts of war and conflicts on efforts aimed at disaster risk reduction (Walch 2018).

Figure 8c also shows that 'politics' and 'political ecology' (an emerging theme during the second period) have evolved into motor themes during this period. This is consistent with recent arguments that challenge the existence of direct causal linkages between climate change and conflict/violence and emphasize the significance of pre-existing conditions and other interacting factors related to governance, institutions, and policy making (Abrahams and Carr 2017). Furthermore, these themes deal with other issues concerned with environmental security that are not just relevant to specific regions (e.g., Africa) and indicate further shifts in attention away from traditional notions of security (Hassan, Afridi et al. 2017; Schilling, Nash et al. 2017). This includes, for instance, policy discourses that frame climate change as a threat multiplier and aim to rally political support for climate actions by emphasizing the geopolitical and national security implications of climatic impacts, such as sea level rise and the Arctic sea ice decline (Titley and St. John 2010; Abrahams 2019). Also, it entails dealing with new types of conflict that may emerge following the implementation of climate mitigation policies that may undermine climate justice (Hoang, Satyal et al. 2019).

There are also several themes that can be categorized as either emerging or declining. It is too early to make definitive judgements about these themes. However, some speculations can be made based on the structure of the strategic diagrams. For instance, the theme 'environment' includes sub-themes such as 'United States', 'trade', and 'cooperation'. This can be interpreted as an emerging theme considering that, for example, the recent trade war between US and China may have implications for climate mitigation (Fang 2020), or the climate policies of the Trump administration may cause serious conflicts (Mayer and Phillips 2019). 'Middle East', 'participation', and 'agriculture' are also likely to be emerging themes. Major sub-themes of 'Middle East' are 'transboundary water', 'irrigation', and

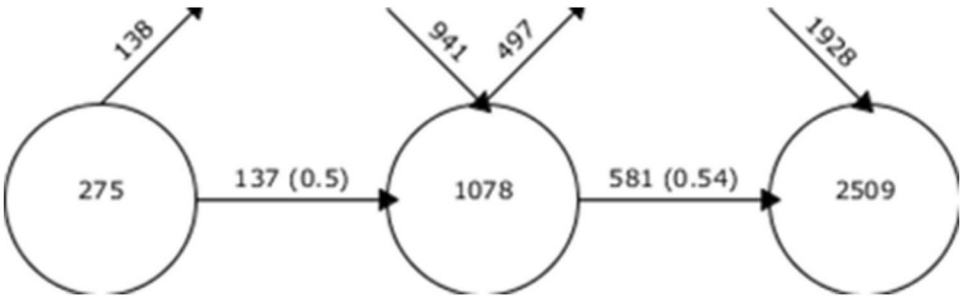

Fig. 9 The overlay graph

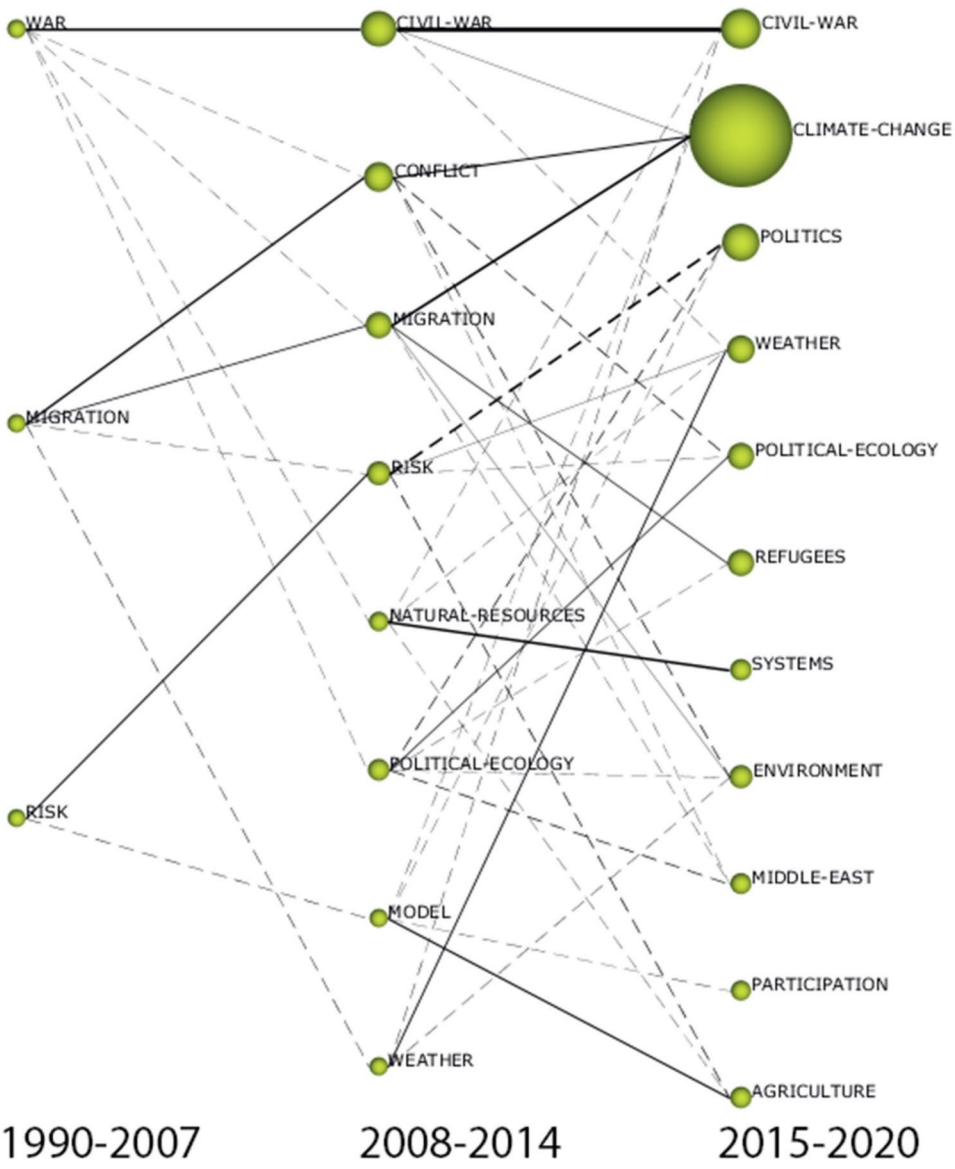

Fig. 10 The thematic evolution of the field

'Syria'. These sub-themes reflect issues related to the long civil war in Syria and the water stress challenges the region is facing (Feitelson and Tubi 2017). The theme 'participation' is composed of sub-themes such as 'gender', 'rights', and 'social movement', referring to the increasing awareness of the importance of participatory approaches and climate justice (Kalabamu 2019). Finally, 'agriculture' could also be an emerging theme since it is composed of sub-themes such as 'food', 'uncertainty', and 'urbanization'. This may indicate concerns about the security implications of rapid

Table 2 Performance of the thematic areas

Thematic areas	Periods	Number of documents	Number of citations	h-Index
War	P1	8	1,284	8
	P2	90	5,689	38
	P3	530	4,395	44
	Total	628	11,368	90
Migration/conflict	P1	7	646	7
	P2	108	4,866	52
	P3	465	3,654	37
	Total	580	9,166	96
Risk	P1	4	494	4
	P2	33	1,230	22
	P3	52	328	10
	Total	89	2,052	36

urbanization in certain regional contexts, such as Africa and Asia (Roth, Khan et al. 2019).

Conceptual evolution map

We use the keyword overlay graph (Fig. 9) and the thematic evolution map (Fig. 10) to explain the conceptual evolution of the field (see the Methods section for details on how to interpret these figures). Figure 9 shows that, over time, the number of keywords has increased significantly (numbers inside the circles). This is consistent with our earlier discussions about the expansion of the intellectual base of the field over time. Also, the number of shared keywords between consecutive periods has increased from 137 to 581, indicating some degree of consolidation in the keywords used across different periods. At the same time, the number of disappearing (outward arrow) and newly emerging (inward arrow) themes is also high, implying that the field is constantly evolving. This is an expected trend given the complex, dynamic, and uncertain nature of climate change (impacts).

The evolution map (Fig. 10) supports our earlier arguments that issues related to war, conflict and migration, and (security) risks and vulnerabilities have received relatively more attention in the literature. In fact, these issues constitute 3 major persistent thematic areas over the study period. Table 2 presents performance measures for these three thematic areas. Related illustrations are also shown in Figs. 2–4 of the ESM. One important observation is how the thematic areas, in some cases, overlap and are not always mutually exclusive. Some noteworthy points regarding the 3 persistent thematic areas are as follows:

- As the dominant thematic area, 'war' has mainly been focused on issues related to national security and inter-state interactions during the first period. Since the second period, however, more attention has been paid to civil war. Also, in the last period, there has been a clear emphasis on non-conventional security threats that may exacerbate environmental problems and function as risk factors for inter- and intra-state wars. The major geographic focus during all periods has been Africa (Fig. 2 of the ESM).
- The second prominent thematic area is focused on migration and conflict. During the first period, the primary focus has been on climate-induced migration and potential associated conflicts. Since the second period, however, its scope has expanded to also deal with interactions between conflict and various factors, such as resource scarcity, transboundary water management, and natural disasters (Fig. 3 of the ESM).
- Finally, the third thematic area is focused on risks. Although it is less prominent in terms of performance measures (see Table 2), it has maintained a stable position as an important theme throughout the study period. This thematic area mainly deals with risks related to national and human security. It also covers issues such as crime and terrorism (Fig. 4 of the ESM).

Conclusions

Since the early 1990s, it has been recognized that climate change can have significant implications for global peace and security. Consequently, a large body of research has been published on this topic. The main purpose of this article was to provide a bibliometrics analysis of this vast literature using text mining and science mapping tools. The article, therefore, differs from traditional systematic reviews that explore causal linkages between climate change and peace. Instead, it complements existing reviews by mapping existing science and providing performance analysis. In addition, the overall conceptual evolution of the field is also explored.

Regarding the publication trends, it was found that until 2007 only a handful of articles have been published annually. However, the field has been burgeoning since 2008. While this may reflect the overall increase in scholarly publications regardless of the field and topic over the past decade or so, we discussed that this may also indicate the success of the IPCC AR4 report in raising awareness about the urgency of the issue. While our search string and database included terms related to different factors and events that undermine negative peace, results showed that existing research is mainly focused on certain events, namely, war and violent conflict. Others such as crime and other forms of social tensions and direct conflicts have received limited attention.

The bibliometrics analysis and science mapping using VOSviewer showed that four major topical clusters can be identified. The dominant category is focused on the interactions between climate change impacts and violent conflicts in the context of Africa. The other three clusters are political tensions over climate policies and institutional mechanisms for addressing such conflicts, disasters and other climate-induced stressors that may trigger large scale migrations and cause conflicts, and conflicts/cooperation related to scarce (water) resources. This analysis also provided information on influential journals, authors, and countries related to each of these four clusters. A noteworthy finding related to these analyses is the lack of institutional and geographical diversity based on the authors' institutional affiliations. Specifically, while the geographic focus of existing research is mainly on Africa, only a limited share of the research has been conducted by scholars based in the continent. Also, a clear gender imbalance in the list of influential authors was observed.

Regarding the conceptual evolution of the field, results of the SciMAT analysis for three sub-periods (1990–2007, 2008–2014, and 2015–2020) showed that themes related to war, conflict and migration, and security risks have been persistent throughout the study period. This analysis revealed that, over time, the intellectual base of the field has expanded. There has also been a growing recognition of the significance of dealing with climate-induced threats and environmental security issues. These results are, to a large extent, in line with those drawn from the VOSviewer analysis. In particular, they also confirm the dominance of studies focusing on violent conflicts in Africa.

Overall, this study has gone some way towards providing a better understanding of the research landscape on the nexus. It complements existing systematic reviews through bibliometrics and science mapping analyses that can inform interested researchers and policy makers of major interactions occurring at the interface of climate change and peace. Although the nature of causal linkages was not explored here, some useful information can be gained by referring to the influential articles highlighted in the bibliometrics analysis. Given the rapid evolution of the field, however, more detailed and updated analysis of the causal linkages is warranted. This review also showed that existing research is mainly focused on few events that undermine negative peace, namely, violent conflict and war. Future research should, therefore, also pay more attention to other events, such as crime and other forms of social conflict and violence. Finally, it needs to be acknowledged that only peer-reviewed literature was analyzed in this research. It is necessary to also analyze grey literature in future research. This could include any documents not indexed in scientific databases, such as the WoS, and would allow a more comprehensive scoping of knowledge about recent policy discourses and local knowledge (e.g., in the context of Africa) that are not always published in peer-reviewed journals.

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