THE TEMPORAL EVOLUTION OF THE RESEARCH IN CLIMATE CHANGE ADAPTATION

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Abstract

Research on climate change adaptation has increased in number and significance since the 1970s. Yet, the volume of information on adaptation is now difficult to manage given its vast scope and spread across journals, institutions, disciplines and themes. While an increasing number of researchers have used systematic literature reviews to analyse particular themes within this rapidly growing field of research, there is still missing an overall analysis of the current state of climate change adaptation science literature and its evolution. This paper provides a bibliometric review of climate change adaptation science literature that is focused on the human dimensions and how it has been constructed across time, disciplines, social relationships and geographies. Our novel review, spanning from 1978 to mid-2020, identifies the underpinning foundations of climate change adaptation literature, leading authors, countries and organisations as well as dominant research themes and priorities and explores how these have changed over time.

Keywords: *Climate change adaptation, Climate adaptation science, Bibliometric analysis, VOSviewer*

1. Introduction

Over the last two decades climate change adaptation has emerged as a central and now acknowledged component of the international climate change policy and research agenda (Klein et al., 2014; Owen, 2020; Swart et al., 2014). The Paris Agreement and its Article 7 have secured a prominent platform for climate adaptation as a key issue for global governance (Persson, 2019). Adaptation received its own ISO standard in 2019, cementing it further as a distinct area of research, policy and practice. Specific climate change adaptation conferences, such as the Adaptation Futures series, have been running since 2010 and new scientific degrees and professional certifications are being developed specifically for climate adaptation. That climate change adaptation literature is flourishing is evidenced also by the rapid expansion of the number of publications with a focus on climate adaptation. In fact, thousands of climate adaptation papers are now published each year (Noble, 2019).

Yet, to date, a focused analysis is still missing on the evolution of this literature, including its extent, growth and diversification over time. Adaptation science is both basic and applied (Moss et al., 2013) and includes knowledge about the processes of adaptation and knowledge generated about adaptation". This science however finds itself in a paradox: while it has quickly amassed a wealth of knowledge about the problem and potential solutions, it is "still characterized by an evolving epistemological base" (Eisenack and Stecker, 2012, p. 244). The field is plagued by "the dependent variable problem" (Biesbroek et al., 2018, p. 2) as to what counts as "adaptation" (Dupuis and Biesbroek, 2013). Large bodies of work exist that, even if not explicitly framed as climate change adaptation, still form a critical mass of knowledge that supports climate change adaptation ideas, theoretical development, and implementation (Biesbroek et al., 2018; Dupuis and Biesbroek, 2013; Keskitalo and Preston, 2019). The overall knowledge base remains fragmented (Cradock-Henry et al., 2019), including difficulties in capturing other forms of knowledge outside peer-reviewed literature such as the lived experiences in the Global South, and Indigenous knowledge in its different forms (Parsons et al., 2016). Method-focused reviews by Biesbroek et al. (2018) have focused on design, data and methods for adaptation policy reviews, Dupuis and Biesbroek (2013) reviewed underlying factors in conducting comparative studies on climate adaptation policies while Berrang-Ford et al. (2015) reviewed and synthesised methodologies for systematic reviews on adaptation. Lesnikowski et al. (2019) used topic modelling in adaptation governance research with UNFCCC COP (United Nations Framework Convention on Climate Change, Conference of the Parties) speeches and 25 Canadian municipalities as a methodological example of data analytics in adaptation research. Other recent review studies have looked at adaptation progress in Australia (Palutikof et al., 2019), public participation and engagement (Hügel and Davies, 2020), role of local knowledge (Klenk et al., 2017), and adaptive capacity (Siders, 2019). Others have used innovative methods to for example define generic trends across case studies such as adaptation finance archetypes that hold true across a range of local governments (Moser et al., 2019b). While these systematic reviews provide key insights into specific trends within particular themes and methodological advancements for adaptation science, they are limited by focusing on necessarily small sample sizes, specific topics and short time horizons. Complimentary methods, such as bibliometric analysis, provide therefore a significant opportunity to discover and examine broad trends through large datasets across long time periods (Hood and Wilson, 2001; Mingers and Leydesdorff, 2015; Mongeon and PaulHus, 2016). This broad scale analysis is particularly important since individual scientists do not operate in an intellectual vacuum but ideas are always intertwined with the "background knowledge of the time" (Chalmers, 1982, p. 56). Yet, to date the few papers that have attempted bibliometric reviews of climate change adaptation science literature have been too broad to provide robust explanations of the changes in research focus over time (e.g. Wang et al., 2018), not focused on climate adaptation per se (e.g. Di Matteo et al., 2018; Giupponi and Biscaro, 2015;

Haunschild et al., 2016) or are now outdated (e.g. Janssen, 2007; Janssen et al., 2006). Our aim therefore is to provide a novel analysis of the main trends in peer-reviewed literature that specifically focus on the human dimensions of climate change adaptation. We demonstrate the evolution of climate adaptation science, how the research topics have changed over time, the social networks of authors via co-authorship, and the most cited papers and the foundational literature that underpins the climate adaptation science literature. This broad overview is one of the first attempts to quantify the rapid growth of climate adaptation science literature, identify the geographical and institutional sources of this knowledge, and explain the evolution of adaptation science priorities over time. The paper is organised as follows: next, we explain the methodological choices in bibliometric analysis and the parameters that were used to search, include and exclude. Section 3 presents the result of the temporal evolution of the research (including core research topics and themes). This is followed by a discussion on what these underlying trends mean for the development of climate adaptation science and what they tell us at present how the field has and is behaving. We also reflect on the potential new areas that are likely to influence the field and discuss the intricacies of conducting large reviews given that these kinds of research methods are likely to increase in importance in the future.

2. Method

The production of knowledge within the field of climate change adaptation has exploded since the start of the century, with increases in both specialised and transdisciplinary research (Giupponi and Biscaro, 2015; Janssen, 2007; Janssen et al., 2006; Wang et al., 2018). These factors render it near impossible to stay on top all this literature and assess the collective developments made by J. Nalau and B. Verrall Climate Risk Management 32 (2021) 100290 3 this field. Thus, review methods that can assess massive and diverse sets of literature to track the rapidly evolving knowledge base are now more relevant than ever. Several literature review techniques exist such as narrative reviews (e.g. Baumeister and Leary, 1997; Wong et al., 2013), systematic reviews, and meta-analyses (e.g. Davis et al., 2014; Liberati et al., 2009; Moher et al., 2014) as well as bibliometric, visualisation and content analysis reviews (Mingers and Leydesdorff, 2015; Vinkler, 2010). While narrative, systematic and meta-analyses are well-established and explored review methods in this field, they are constrained by their ability to assess relatively small bodies of literature (e.g. less than 500 publications), whereas bibliometrics use statistical analysis of publication metadata and thus, can assess much larger literature sets (van Eck and Waltman, 2010). The current study employs a combination of bibliometric, visualisation and content analysis techniques to analyse the climate change adaptation science literature. And still, capturing all relevant publications related to a specific field is difficult (Buckland and Gey, 1994), especially with a rapidly developing, comprehensive and transdisciplinary research field like climate change adaptation. Historically, this field has been conceptualised

under several collective phrases as it has evolved (Wang et al., 2018). Thus, determining an appropriate query requires a systematic approach, such as iterative query reformulation (Wacholder, 2011) where analysis of preliminary search results of key papers inform renewed searches (Wang et al., 2014). This study implemented a similar query formulation method to search for climate change adaptation literature in the well-regarded, international databases Scopus and Web of Science Core Collection (Fig. 1), where these databases were selected to prevent geographic biases and increase publication coverage (Falagas et al., 2008). However, initial search results returned numerous publications concerning biological adaptation to climate change, as terminology is shared between these research fields. Therefore, irrelevant publications that lacked a societal dimension where iteratively filtered out by adding exclusion terms to the query. This process included successively adding exclusion terms (e.g. physiology, phenology, genes, genetic, plasticity, genus, species or molecular), which were determined using iterative query reformulation (Wacholder, 2011) and do not reflect the human dimensions of climate change adaptation. Search results were then limited to articles, reviews, book chapters and books in addition to limiting to 'topic section' (title, keywords and abstracts) to identify publications primarily focusing on climate change adaptation. While this may not identify all relevant publications, it selects the publications where authors have prioritised climate change adaptation as a core focus of their publication. Thus, bibliometric metadata were retrieved from the Scopus and Web of Science database on 16 June 2020 (Fig. 1). Scopus returned 10,274 publications while there were 8,586 publications extracted from Web of Science Core Collection. Publication metadata from these two sources were compiled into a database and duplicates were removed (N = 7,070). Although the query used in this study included exclusion terms to filter those publications that concerned biological adaptation to climate change, a further 284 publications were removed from the database after careful review of abstracts, keywords and titles by both authors. The final database contained 11,506 publications, where metadata were manipulated to identify temporal patterns in the literature including splitting into three broad time periods (early research 1978–2010, emerging research 2011–2015 and the latest research 2016–2020) as well as on an annual basis. The parameters of these time periods were selected based on temporal distribution of publications, ensuring there was enough data within each period to make sound comparisons (Verrall and Pickering, 2020), and to highlight the rapid expansion of publications after 2010. The number of publications were not normalised by population given that the number of researchers within a population is unlikely to explain why some countries fare better in adaptation science than others. Main authors, organisations, journals, subject areas (Web of Science Core Collection Categories) and spatial trends in the research were assessed. Since subject areas differ between Scopus and Web of Science, we coded publications from Scopus to the Web of Science Core Collection Categories based on abstracts, titles and keywords (Verrall and Pickering, 2020). Publications assigned to countries for spatial analysis were calculated in two ways: (a) by

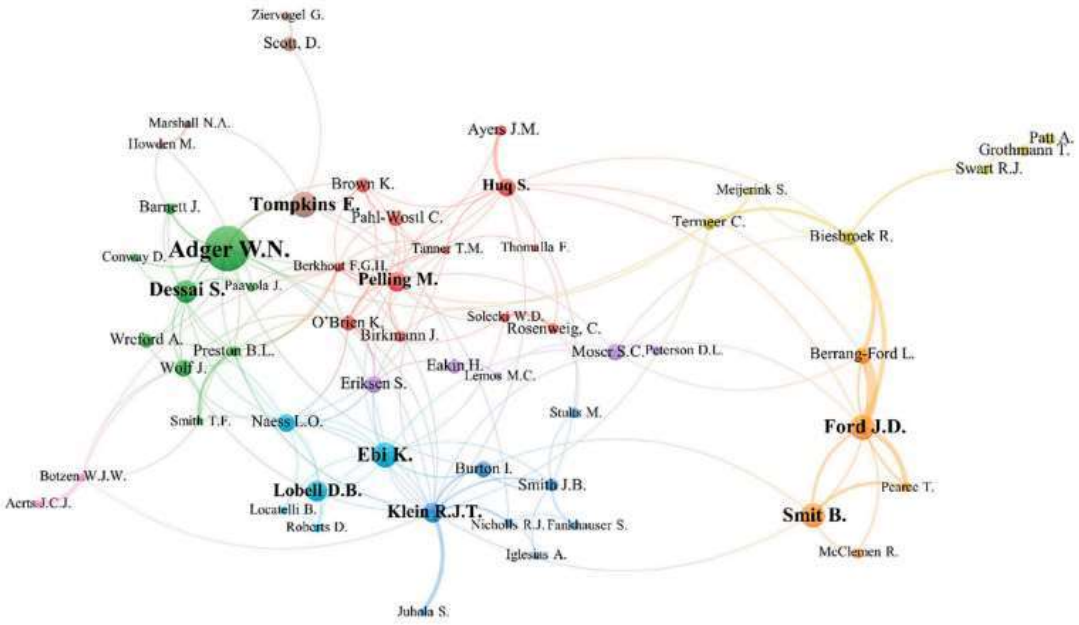
author affiliation and (b) by content analysis of 'topic sections' to determine where research was focused. Determining where the research was focused was calculated by analysing the abstracts for the frequency of occurrences for each country to provide a relative measure of research density (Verrall and Pickering, 2020). All contributing authors and subject areas are included, so some publications may be counted multiple times (Haunschild et al., 2016; Mingers and Leydesdorff, 2015). To identify dominant research topics and themes as well as co-author and co-citation interconnections, the bibliometric analysis package VOSviewer (van Eck and Waltman, 2010) was used to visualise and map the literature (see www.vosviewer.com). To reduce ambiguity, keywords, authors and reference titles were clustered using thesauri prior to analysis (Waltman et al., 2010). The distancebased maps produced here are generated by bibliographic coupling as a method to position nodes (e.g. keywords, authors, reference titles) and are weighted by number of documents/citations and link strength (Waltman et al., 2010). The distance between nodes is relative to the bibliographic similarity and nodes are allocated clusters which identify closely interrelated nodes. VOSviewer uses a modularity-based clustering method, which is comparable to multidimensional scaling and is generated by the smart local moving algorithm (Waltman and Van Eck, 2013; Waltman et al., 2010).

3. Results

3.1. Temporal evolution of the research

The first recorded publication from this literature was published in 1978 and assessed the relationship between climatic variations and horticultural trade flows in Europe (Folley, 1978). There were only 1,188 publications (10.3%) over the next 32 years (1978–2010), after which there has been a rapid increase in research on this topic with 4,035 publications (35.1%) over the following five years in the emerging period (2010–2015) and a further 6,283 publications (54.6%) in the latest five years. The greatest increase in publications on this topic occurred between the five-year period of 2006–2010 (540% increase from previous five years). Overall, this literature has seen an average annual growth rate of 28.5% and is thus set to double in size by early 2022.

Figure 1: Co-authorship of leading authors with at least 10 publications and 500 citations (60 authors) with the data displayed as distance maps, using VOSviewer software



Source: Van Eck and Waltman, 2019 (Lines are weighted by the number of links, with minimum line strength indicating one co-authored publication. Circles are weighted by the number of citations and top ten cited authors denoted by bold labels).

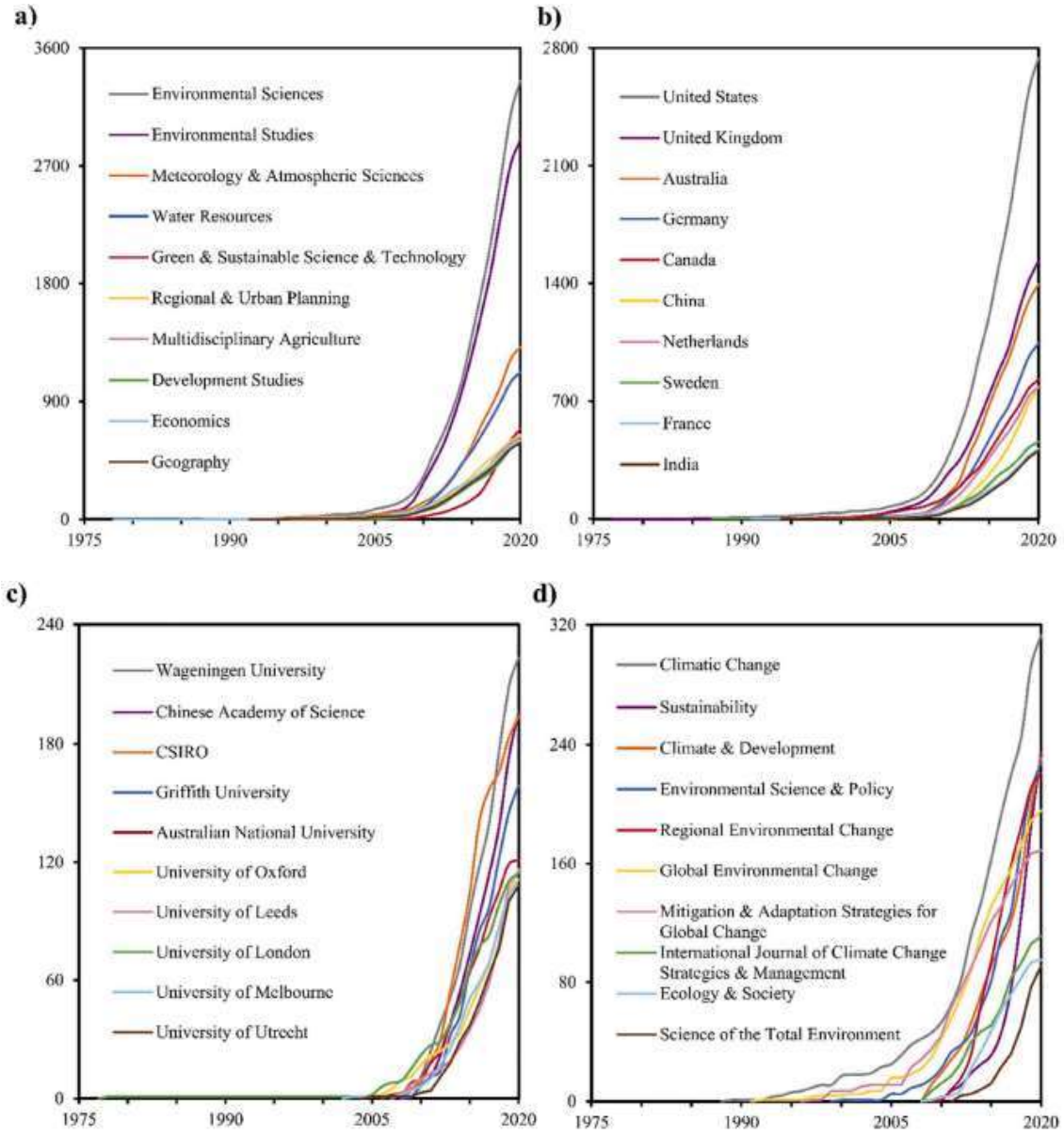
The diversity of subject areas covered by this literature has expanded considerably through time (Figure 2a). The first publications from this literature focused on 'economics', 'meteorology and atmospheric sciences' and 'multidisciplinary agriculture' but 'environmental sciences' and 'environmental studies' have become the dominant subject areas through time. Both 'multidisciplinary agriculture' and 'economics' were key subject areas until 1995, after which research on 'water resources' increased considerably. Research focus began to diversify from natural sciences to better encompass human dimensions such as 'regional and urban planning', 'development studies' and 'geography' from 2005 onwards, and most recently, 'green and sustainable science and technology' has become a key research area. Considering the temporal publication dynamics of countries, the United States and the United Kingdom have led this literature since its inception while Canada was also an important early contributor (Figure 2b). Since 2010, Australia has emerged as a research powerhouse, with Germany also considerably increasing its research output. The research of these leading countries has been excelled by a handful of research organisations (Figure 2c), with several organisations from Australia (CSIRO, Griffith University, Australian National University), the United Kingdom (University of Oxford, University of Leeds and University of London) and the Netherlands (Wageningen University and University of Utrecht). University of London and University of Oxford were leading contributions to this literature before 2010, but more recently, Wageningen University, CSIRO, the Chinese Academy of Science and Griffith University have emerged as the core organisations publishing on this topic. The leading journals that have published this literature

have also evolved over time (Figure 2d). Early work on climate change adaptation was naturally published in those journals that were forerunners in this area: Climatic Change (established 1978), Global Environmental Change (established 1990) and Mitigation and Adaptation Strategies for Global Change (established 1996). Regional Environmental Change (established 1999) has risen rapidly as a major publication outlet for climate adaptation since 2010. From 2004 onwards, journals such as Environmental Science and Policy (established 2001) have also increased their publication outputs on climate adaptation. After 2005, several newer journals began rapidly publishing on this topic including Sustainability (established 2009), International Journal of Climate Change Strategies and Management (established 2008) and Science of the Total Environment (established 2014). The overall strongest journal in this field remains Climatic Change.

3.2. Core research topics and themes

The most cited publications of this literature cover topics such as food security (Lobell et al., 2008; Pittelkow et al., 2015; Rosenzweig et al., 2013; Smit and Skinner, 2002), adaptive capacity (Adger et al., 2005, 2003; Bryan et al., 2009; Füssel, 2007; Grothmann and Patt, 2005; Kates et al., 2012; Pahl-Wostl, 2009; Pelling, 2010; Smit et al., 2000; Wilby and Dessai, 2010), health impacts (Costello et al., 2009), climatic extremes (Dore, 2005; Field et al., 2012; Littell et al., 2009; Taylor et al., 2013), social capital (Adger, 2003; Pelling and High, 2005), and limits (Adger et al., 2009; Riahi et al., 2017) and barriers (Moser and Ekstrom, 2010) to adaptation.

Figure 2: Temporal trends (1978–2020) of cumulative number of publications by leading subject areas (a), countries based on author affiliation (b), organisations (c), and journals (d). (All assigned subject areas and contributing authors are included, so some publications may be counted multiple times. Data from 2020 is incomplete as it was collected on June 16. Subject area categories are based on Web of Science Core Collection Categories).



Source: Author's statistic

4. Discussion and Conclusion

This paper has investigated the evolution of and current trends in peer-reviewed climate adaptation science. By using a bibliometric method, we have captured geographical representation, temporal trends in research priority topics and provided a review of the most cited papers, authors, foundational journals and research collaboration clusters. Overall, the subject of climate change adaptation is now truly global in its reach given its mainstreaming across journals, sectors and disciplines combined with rapid annual growth rate that is set to continue. The key topics have clearly diversified over time with new topics such as ecosystem-based adaptation and green infrastructure in particular in the last five years. Yet, despite this diversification and mainstreaming of climate adaptation science, the literature is

still heavily dominated by developed countries. This leads to a pressing need to increase especially developing country contributions to this vast literature so that it adequately reflects the diversity of climate adaptation insights and experiences. Future research could also look into similar trends in grey literature to capture the implementation experiences across the world and provide additional insights into how adaptation has evolved as a topic over time and identify future directions on emerging trends that are relevant to adaptation science, policy and practice.

5. References

1. Adger, W.N., (2003), *Social capital, collective action, and adaptation to climate change*, Economic Geography 79, 387–404. https://doi.org/10.1111/j.1944-8287.2003.tb00220.x.

2. Adger, W.N., Arnell, N.W., Tompkins, E.L., (2005), *Successful adaptation to climate change across scales*, Global Environ. Change 15, 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005.

3. Becken, S., (2013), *A review of tourism and climate change as an evolving knowledge domain*, Tourism Manage Perspectives 6, 53–62. https://doi.org/10.1016/j.tmp.2012.11.006.

4. Berrang-Ford, L., Ford, J.D., Paterson, J., (2011), *Are we adapting to climate change?*, Global Environ. Change 21, 25–33. https://doi.org/10.1016/j.gloenvcha.2010.09.012.

5. Biazin, B., Sterk, G., Temesgen, M., Abdulkedir, A., Stroosnijder, L., (2012), *Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa – a review*, Phys. Chem. Earth. 47–48, 139–151. https://doi.org/10.1016/j.pce.2011.08.015.

6. Boeckmann, M., Zeeb, H., (2016), *Justice and equity implications of climate change adaptation: A theoretical evaluation framework*, Healthcare 4 (3). https://doi.org/10.3390/healthcare4030065.

7. Bryan, E., Deressa, T.T., Gbetibouo, G.A., Ringler, C., (2009), *Adaptation to climate change in Ethiopia and South Africa: options and constraints*, Environ. Sci. Policy 12, 413–426. https://doi.org/10.1016/j.envsci.2008.11.002.

8. Conway, D., Schipper, E.L.F., (2011), *Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia*, Global Environ. Change 21, 227–237. https://doi.org/10.1016/j.gloenvcha.2010.07.013.

9. Gill, S.E., Handley, J.F., Ennos, A.R., Pauleit, S., Theuray, N., Lindley, S.J., (2008), *Characterising the urban environment of UK cities and towns: a template for*

landscape planning, Landscape Urban Plann. 87, 210–222. https://doi.org/10.1016/j.landurbplan.2008.06.008.

10. IPCC, (2013), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

11. IPCC, (2014b), Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, *Switzerland.*

12. Juhola, S., Westerhoff, L., (2011), *Challenges of adaptation to climate change across multiple scales: a case study of network governance in two European countries,* Environ. Sci. Policy 14, 239–247. https://doi.org/10.1016/j.envsci.2010.12.006.

13. Waltman, L., van Eck, N.J., Noyons, E.C.M., (2010), *A unified approach to mapping and clustering of bibliometric networks*, J. Informetrics 4, 629–635. https://doi.org/10.1016/j.joi.2010.07.002.