Resilience thinking: a bibliometric analysis of socio-ecological research

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Introduction

The concept of resilience was firstly introduced by Holling in 1973 in an ecological context. He defined resilience as: "A measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables…and it is concerned with persistence or probabilities of extinction" (Holling, 1973, p. 14). In recent decades, resilience thinking has been increasingly permeating sustainability debates in the context of social-ecological systems and the impact human activities have on the planet's physical environment. According to the Resilience Alliance, an interdisciplinary network of scientists and practitioners established in 1999, resilience in social-ecological systems has three defining characteristics: "the amount of change the system can undergo and still retain the same controls on function and structure, the degree to which the system is capable of self-organisation, and the ability to build and increase the capacity for learning and adaptation" (Resilience Alliance, 2002, n.p.). Resilience has also been identified as one of the most influential concepts in sustainability research (Quental and Lourenço, 2012).

The prevailing perspectives on sustainability and natural resources management focus on how to achieve stability, manage effectively and control change and economic growth (Adger et al., 2005; Folke, 2003 and 2006). However, this is not enough in a constantly changing globe and further research needs to allow for multidisciplinarity (McMichael et al., 2003), interdisciplinarity (Bjurström and Polk, 2011) and transdisciplinarity (Marinova and McGrath, 2005; Buns and Weaver, 2008) in order to better understand any occurring transformations. Jappe (2006) describes this as mutual task dependence of all scientific fields. Resilience as a new concept and way to look at the world was introduced in order to analyse how complex systems are adapting to climate change and human disturbance. Many argue that resilience thinking for social-ecological systems will be the optimal way to enhance the likelihood of sustainability in the uncertain future (Walker et al., 2004; Adger et al., 2005; Folke, 2006).

The main purpose of this study is to identify trends in resilience research using a bibliometric analysis. In particular, we identify the prevailing patterns of influence resilience research has in different contexts and the geographical distribution of this research output. The paper consists of four sections as follows. Section 2 describes the bibliometric analysis (procedures) used in the study, including data source, applied keywords, types of publications and limitations to data collection. Statistical analysis, ranking and distribution mapping of the resilience research outcomes are presented in section 3. The last section contains concluding remarks about the outcomes from this analysis.

Methodology and data

The study is based entirely on bibliographic desk-based research conducted in July-August 2012. It uses data sources available to almost all academic institutions in western countries. As the aim is to analyse the impact and importance of resilience research, we opted to investigate only publications that have been cited (instead of

providing a general description of all resilience publications irrespective as to how valuable they have been to other researchers). The main imperative that triggered this choice are the concerns of the scientific community associated with climate change and the need to see fast considerable real changes in order to address the deteriorating state of the planet. Despite the many questions and valid points raised around the use of citation analysis (MacRoberts and MacRoberts, 1996), the fact remains that cited research is a valid indicator for the influence of any work, at least on other researchers (Cole and Cole, 1972). Small's (2004) study identifies interest, novelty, utility and significance – all linked to research importance, as interrelated reasons stated by academic authors for their research to be cited.

Analysing only numbers of cited publications, rather than the actual number of cites they have attracted on the other hand, helps deal with problems associated with citation counts, such as biased over-citing, citing of a well-recognised body of literature, socio-psychologically motivated reasons to increase cites, different citation rates across disciplines as well as institutional and self-citations. More information about the methodology of the study is presented below.

Data sources

The data in this study was retrieved from three widely used databases, namely:

(1) Google Scholar – a freely available web-based tool in operation since 2006 that allows search for scholarly literature across disciplines and sources, including theses, books, papers and abstracts (Google Scholar, 2012, n.p.);

(2) Web of Science – an academic citation indexing and search service of Thompson Reuters' Web of Knowledge (formerly operated by the Institute for Scientific Information, ISI) launched in 2002 which claims to be "today's premier research platform for information in the sciences, social sciences, arts, and humanities" (Thompson Reuters, 2012, n.p.) and covers journals, conference papers, websites, patents and chemical structures; and

(3) Scopus – launched by SciVerse in 2004 to facilitate library searches around the world with an easy access to "the world's largest abstract and citation database of peer-reviewed literature" (Elsevier, 2012, n.p.) covering journals, trade publications, book series and conference papers.

The period of examination spans from 1973 to 2011, i.e. from the year when resilience was first introduced to the most recent year. The data from these different databases is analysed but also compared between the three sources with the aim to identify the general trends in resilience research. According to Aguillo (2012), Google Scholar provides the largest coverage of sources. Its free-of-charge availability also makes it accessible to all researchers, including outside the western academic system. These are the reasons why we opted to use Google Scholar to further analyse the geographical spatial distribution of research outputs related to resilience.

Keywords used

In order to identify resilience related publications, we applied keyword searches within the titles, keywords and abstracts of the various research outputs. The keywords used to search for such publications are mainly associated with the word "resilience" and also include the following combinations "ecological resilience", "economic resilience", "social resilience", "resilience & sustainability", "resilience & sustainable development", "resilience & social-ecological systems", "social-ecological resilience", "resilience & environment", "resilience & natural resources" and "resilience & assessment". The targeted coverage was intended to provide insights not

only about ecological resilience but also how the concept relates to sustainability and the integration of its social, economic and environmental tenants.

References selected

The publications selected in our study are those cited journal articles, books, conference papers, working papers, comments, theses and reports that list the word "resilience" in the title or as their keyword. In addition, if "resilience" does not appear in any of the above, we included the publication in the dataset only if "resilience" appears at least three times in the abstract. In other words, we have applied a very strict and generally limiting way of categorising a publication's belonging to our sample in order to accurately reflect the penetration of resilience thinking in academic research. A less restrictive approach would probably have expanded the size of the sample but would have raised questions as to how reliable any claims are.

Limitation of the data selection

It should be acknowledged that some limitations exist in the dataset used for this analysis. The publications counted in the study include only those containing "resilience" either in their title, keywords or abstract whilst publications based on possible synonyms, such as stability, adaptability, resistance, reliability and robustness, or antonyms, such as vulnerability, susceptibility and defencelessness, are excluded. Also, the selected publications include only documents in English which have been cited by other publications in English, and non-English publications were not considered.

Thus the publications counted in this paper do not include all publications in resilience research. The existing publications and research outcomes no doubt overweigh what we could find and access in this study. There are certainly other scholarly papers that are making their contribution to this area, particularly in languages such as Chinese, German, Spanish and French and this study is not trying to undermine the work done by these researchers. Any limitations should be seen as a deficiency in the current web-based data search engines rather than a deliberative decision by the authors. It will be interesting to compare the results from this study with any further work as the capacity of search tools expands.

Results and discussion

The analysis in this section is organised around five research directions. The first one is general statistics which describe the total number of cited publications on resilience and the particular context that has been the focus of this resilience research. In addition, we compare the data obtained from Google Scholar, Scopus and the Web of Science to illustrate the total trend in resilience thinking. Journal output and paper citation analyses of resilience publications represent the second research direction. The third direction engages with the spatial geographical distribution of the studies and particular case studies represented in the cited resilience publications. This is followed by an analysis of the national affiliations of the publications' authors and how different countries around the world are represented in resilience research. The last aspect shows the leading research institutes in the top 15 productive countries in the area of resilience.

General statistics

Resilience thinking has come a long way since its 1973 inception with the number of publications steadily on the increase. The annual numbers of cited publications for the 1973–2011 period are shown on Figure 1. In total 919, 939 and 942 cited publications were found through the respective databases of Google Scholar, Scopus and

Web of Science. It is interesting to observe that contrary to popular believes and earlier studies (e.g. Yang and Meho, 2006), the largest amount of resilience publications are captured by the Web of Science which is the most academically oriented database. In other words, there are many highly specialised scholarly publications that target the scientific community and are not necessarily captured by the more popular Google Scholar and Scopus search engines. On the other hand, the discrepancy between the three databases is relatively low, at around 2%. Most importantly, the overall trend and fluctuations appear to be very similar, irrespective as to which database is used. Hence, resilience research is very well represented by any of the three databases which does not seem to be the case in other research areas, such as for example medicine Falagas et al. (2007) or social sciences (Harzing, 2012).

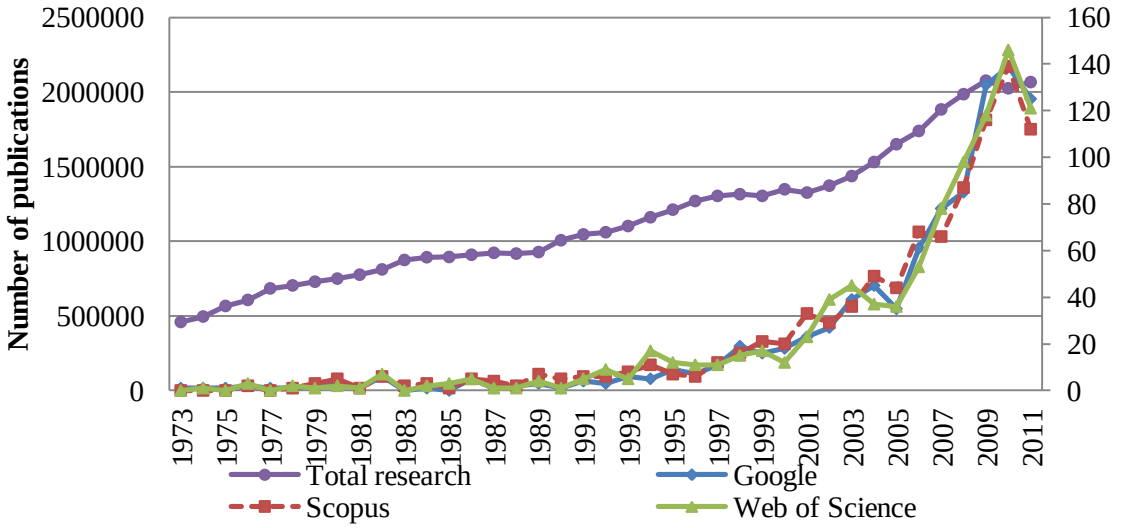

Fig. 1 Annual numbers of cited research publications in Web of Science and resilience publications in Scopus, Google Scholar and Web of Science, 1973–2011

In addition to resilience publications (right vertical axis), Figure 1 also shows the total number of cited publications for all research fields (left vertical axis) for the 1973–2011 period. Against the overall consistently increasing trend in total research outputs, resilience publications show a significant surge in relatively recent years. This indicates that resilience is becoming a robust research field.

The number of cited resilience publications reached a peak in 2010; however they seem to constantly fluctuate around a strong upwards trend and 2011 may just be one of these fluctuations, rather than a significant drop. Between 1973 and 1999, there was a stable increase in resilience publications, but this was followed by a very strong increase between 1999 and 2005 and an even further sharp increase since 2005. The study by Janssen et al. (2006, p. 10) already provided reliable evidence that the area of resilience has experienced "a major and still continuing increase in the number of published papers" (Janssen et al., 2006: 10). It is also encouraging to see the increasing trends in the uptake of these research findings as expressed in citations. The dramatic increase since 1999 in the number of cited publications has partly benefitted from the establishment of the outstanding global Resilience Alliance network with its academic journal *Ecology and Society* (Janssen et al., 2006) as well as from the increased interest in global environmental changes during 1990s. Activities on the global political arena since 2005, such as the release of the Millennium Ecosystem Assessment Reports in 2005,

the Stern Review in 2006, the Intergovernmental Panel on Climate Change (IPCC)'s 4th Assessment Report in 2007, as well as the continuing regular international climate change meetings and negotiations, all stimulated researcher interest in resilience.

Figure 2 breaks down the Google Scholar data to provide a more detailed overview of the specific areas of interest of resilience research as it relates to ecological (Eco-R), economic (Econ-R) and social systems (Soci-R) as well as to an integrated sustainability (Sust-R) approach. This original categorisation was done arbitrarily based on the research topics of the papers. Although we are not aware of any other similar classification, almost all resilience publications explicitly state their area of interest which varies vastly from conceptualisation to more narrowly oriented ecological, economic or social analysis. For instance, studies which are focused on conceptual development, such as "Resilience, adaptability and transformability in social-ecological systems" (Walker et al., 2003) and on ecological systems such as "Regime shifts and ecosystem services in Swedish coastal soft bottom habitats: when resilience is undesirable" (Troell et al., 2005) were classified as Eco-R; studies which stated economic perspectives, such as "Resilience in the dynamics of economy-environment systems" (Perrings, 1998), or which concentrate on economic resilience, such as "Economic resilience to natural and man-made disasters: multidisciplinary origins and contextual dimensions" (Rose, 2007) were categorised as Econ-R; research which mainly discusses resilience from social perspectives, such as "Social and ecological resilience: are they related?" (Adger, 2000), was categorised as Soci-R; while those studies which discuss resilience in terms of sustainability, such as "Resilience and sustainable development: building adaptive capacity in a world of transformations" (Folke et al., 2002), or in the context of integrated social, economic and ecological systems, such as "Incorporating resilience in the assessment of inclusive wealth: an example from South East Australia" (Walker et al., 2010) were classified as Sust-R.

The total number of 919 cited publications includes journal articles (661 or 71.9%), books (63 or 6.9%), conference papers (61 or 6.6%), working papers (54 or 5.9%), book chapters (41 or 4.5%), reports (23 or 2.5%), theses (9 or 1.0%), and short comments (7 or 0.8%).

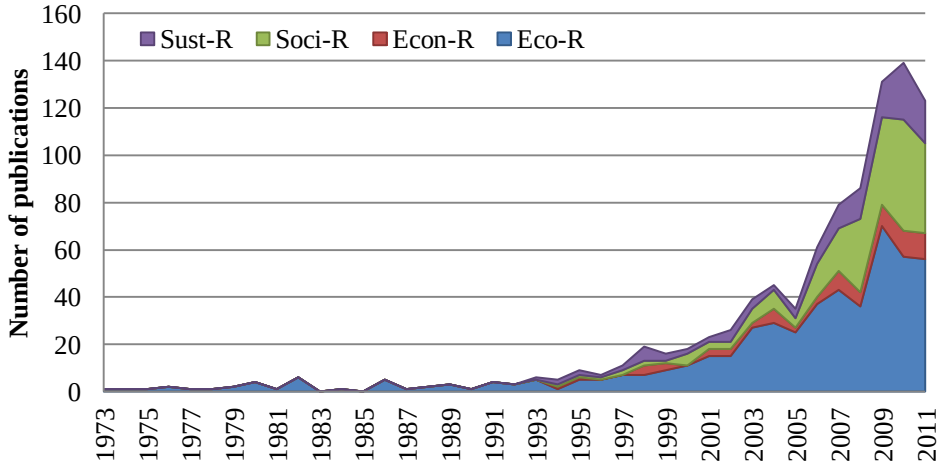

Fig. 2 Comparison of resilience research in different contexts

Note: Sust-R – resilience thinking in the context of sustainability; Scoi-R – resilience thinking for social systems; Econ-R – resilience thinking for economic systems; Eco-R – resilience thinking for ecological systems

The number of studies embracing resilience thinking in relation to ecological, economic and social resilience as well as in the context of integrated sustainability has been steadily growing since its emergence with a clear further increase since 1995. The majority of cited publications focus on ecological systems while social resilience has also grown significantly while resilience in relation to economic systems is still in the explorative stage. This situation largely differs from the area of sustainability research where economics (mainly through ecological economics) has been largely overrepresented (Quental and Lourenço, 2012). The number of cited publications that explore an integrated sustainability approach has also grown but it is still a very low share of all resilience output. With human induced climate change and other environmental problems, it is important to have the right perspective on any resilience research but we are yet to see more prominence of the integrated sustainability resilience research.

Resilience thinking for economic systems is a very important case and there needs to be a strong warning that such research can only be beneficial if it is based on interdisciplinarity. As the main external factor affecting the health of the planet's ecosystems, acceleration of human activities across the globe makes it difficult to continue to separate any ecological, social and economic impacts and "try to explain them independently, even for analytical purposes" (Folke et al., 2010, n.p.). Another warning is that while in isolation, socially and ecologically resilient systems have a very high probability to also be sustainable, a solely economically resilient system can be extremely detrimental to sustainability. In other words, we can learn how to efficiently and effectively destroy the environmental and social foundations of human life. Assessing and evaluating sustainability in the context of complex systems in a transforming world requires a shift in thinking and perspective (Ludwig et al., 2001) and resilience thinking seems to have started to deliver some changes but there is still a long way ahead.

Journal output and cited paper statistics

This part answers questions, such as: which journal is the most popular in the realm of resilience research, which articles are highly cited on the topic of resilience thinking, who has produced those articles and where have they been published. Hence the analysis here examines only the 661 cited journal articles according to Google Scholar. They have been published in 269 academic journals and Table 1 lists the top 10 journals in which they have appeared. The top journal with 85 cited papers in the area of resilience thinking is *Ecology and Society* (which replaced *Conservation Ecology* in 2004). This journal published by the Resilience Alliance is relatively new but has proven a strong outlet for resilience research. With a very significant drop in the number of articles cited, this is followed by *Global Environmental Change* (16 articles) and *Ecosystems* (15 articles).

Table 1 Top 10 journals with the largest number of articles (1973-2011)

Rank	Journal	Year of first publication	No. of articles
1	Ecology and Society (formerly Conservation Ecology)	2000	85
2	Global Environmental Change	1990	16
3	Ecosystems	1998	15
4	Ambio	1972	13
5	Ecological Economics	1989	12
	Ecology	1920	

6	Environmental Education Research	1995	11
	Water Resources Research	1965	
7	Environment and Development Economics	1996	10
	Natural Hazards	1988	
8	Environmental Hazards	2007	9
9	Climatic Change	1977	8
	Coral Reefs	1984	
	Ecological Applications	1991	
	American Naturalist	1972	
10	Ecological Modelling	1978	7
	Ecological Monographs	1972	
	Ecology Letters	1998	
	Human Ecology	1972	

We further looked at the actual number of Google Scholar citations that each cited resilience article has attracted. Table 2 presents the top 10 journal articles with the most citations and their authors, citation times, year of publishing, title of the journals and the context of the papers. It is not surprising that the top cited article is the original 1973 paper by Holling which for the first time introduced resilience thinking to ecological systems. The most prominent contributor in the area is Folke who comes from Sweden and is the author or co-author of the six of the top 10 cited journal articles. Similarly, Holling (Canada), Carpenter (USA) and Walker (Australia) have also achieved excellent recognition with their names appearing as authors or co-authors of five of the top 10 papers. This indicates that resilience thinking has produced a list of very noticeable and influential researchers and thinkers who have contributed to the shaping of ideas and research directions in this field. Furthermore, seven of the top ten cited articles are in the area of ecological systems with a strong interest in theory development. The economic context is represented with one article and so are the social and integrated sustainability approaches. Overall, it appears that since its inception the focus on the ecology continues to dominate resilience research. This has enabled it to produce a strong body of environmental findings but this knowledge still needs to be integrated with the socio-economic aspects of human presence on Earth.

Table 2 Top 10 articles with the most citations and the authors, year, journals and the context (1973-2011)

Rank	Title	Year	Author (s)	No. of citations	Journal	Context
1	Resilience and Stability of Ecological Systems	1973	Holling, C. S.	4216	Annual Review of Ecology and Systematics	T-E
2	Catastrophic shifts in ecosystems	2001	Scheffer, M., Carpenter, S., Foley, J.A., Folke, C. and Walker,B.	2348	Nature	T-E
3	Economic growth, carrying capacity, and the environment	1995	Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B., Levin, S., Maler, K., Perrings, C. and Pimentel, D.	1538	Science	ECO

4	Climate change, human impacts, and the resilience of coral reefs	2003	Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J., Kleypas, J., Lough, J. M., Marshall, P., Nystrom, M., Palumbi, S. R., Pandolfi, J. M., Rosen, B. and Roughgarden, J.	1437	Science	T-E
5	Resilience, adaptability and transformability in social-ecological systems	2004	Walker, B., Holling, C. S., Carpenter, S. and Kinzig, A.	975	Ecology and Society	T-E
6	Resilience and sustainable development: building adaptive capacity in a world of transformations	2002	Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S. and Walker, B.	940	Ambio	I-S
7	Regime shifts, resilience, and biodiversity in ecosystem management	2004	Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. and Holling, C. S.	902	Annual Review of Ecology Evolution and Systematics	T-E
8	Resilience: the emergence of a perspective for social-ecological systems analyses	2006	Folke, C.	888	Global Environmental Change	T-E
9	Social and ecological resilience: are they related?	2000	Adger, W. N.	856	Progress in Human Geography	SOC
10	From Metaphor to Measurement: Resilience of What to What?	2001	Carpenter, S., Walker, B., Anderies, J. M. and Abel, N.	834	Ecosystems	T-E

Note: T-E, ECO, SOC and I-S represent respectively that the research was conducted in the context of ecological systems or focused on theoretical studies, economic systems, social systems, and integrated ecological, social and economic systems or sustainability in terms of resilience.

Spatial distribution

In this part, we explore the geographical distribution of the 919 cited Google Scholar publications on the topic of resilience to analyse how much output has been generated in different countries, and which areas throughout the world have been used as case studies. Country performance in resilience research is represented through a mapping approach where the authors' affiliations in the publications were used as the criterion to locate the place of their origin. Publications were counted more than once if they had authors from more than one country. For instance, a paper with authors from USA and UK is counted twice – once for each country irrespective as to how many authors are form USA and UK as the main interest is to highlight the geographic spread of resilience thinking throughout the world (see Fig. 3). The most productive country in this respect is USA with 389 cited publications followed by Australia, UK, Sweden and Canada with 162, 135, 95 and 91

publications, respectively. Very few and even no authors come from Central Asia, the Middle East, North and Middle-West Africa. The spatial geographic distribution indicates the dominance of western researchers. Despite the evidence of China's growing contribution to the global scholarly knowledge (Veugelers, 2010), resilience thinking is yet to make its mark in influencing Chinese researchers as far as their publications in English are concerned.

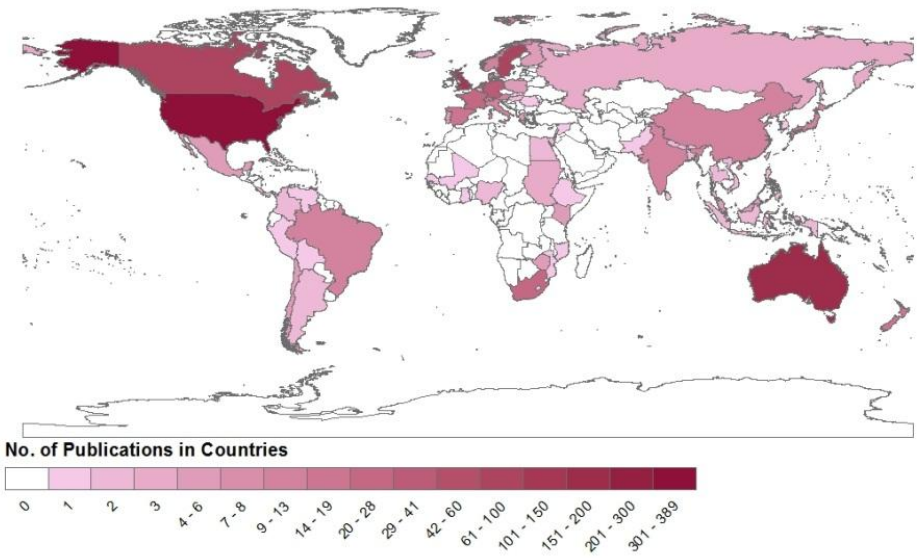

Fig. 3 Distribution of publications by country

Fig. 4 shows the areas which have been used as case studies in the cited publications on resilience thinking throughout the world. There are about 646 case studies within the 919 Google Scholar cited publications, which include 164 in North America (25.4%), 141 in Europe (21.8%), 104 in Oceania (16.1%), 89 in Africa (13.8%), 57 in South Asia (8.8%), 38 in South America (5.9%), 18 in Middle America (2.8%), 15 in East Asia (2.3%), 11 in West Asia (1.7%), 5 in the Arctic (0.8%) and 4 in Middle Asia (0.6%). This is a more balanced geographic spread but large areas of Central and West Africa, the Middle East, Central Asia and Eastern Europe continue to be underrepresented. In terms of specific countries, the largest number of case studies, namely 123, have been carried out in USA, followed by Australia – 85, Canada – 40 and UK – 26. It is interesting to note that Japan – one of the largest countries on earth in terms of population and the size of its economy, has not yet generated any case study for resilience research.

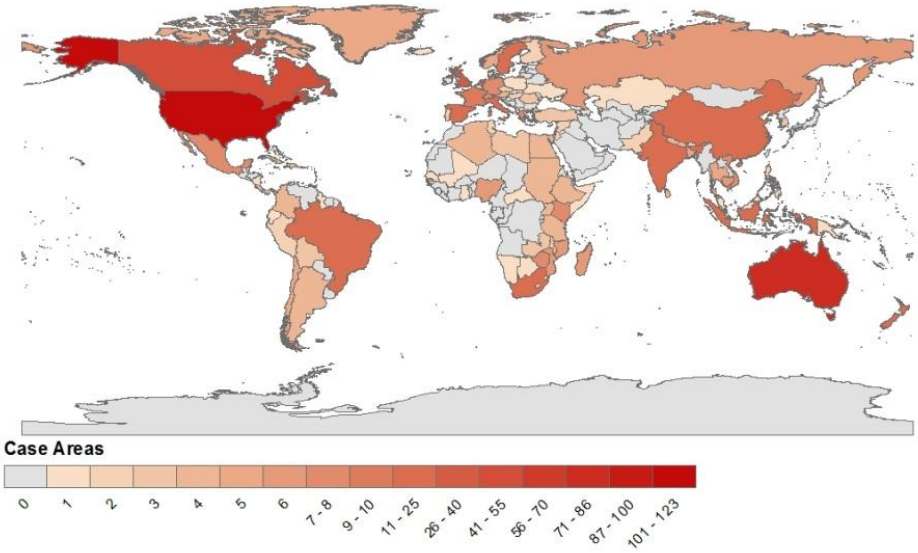

Fig. 4 Distribution of case areas covered in resilience publications

The spatial analysis demonstrates that USA, Australia, UK and Sweden are the scholarly leading countries in the realm of resilience research in social-ecological systems. The USA is both the most productive country and with the largest number of case areas, followed by Australia. However, not many studies have been undertaken in other large countries such as Russia, China and India. As resilience thinking seems to be an important, if not the main approach in adapting to climate change and human disturbances issues with the objective of sustainability in a highly uncertain future (Walker et al., 2004; Adger, 2005; Folke, 2006), more research is urgently needed. In particular, China and India which are currently experiencing high economic growth and already have large populations, are being ecologically threatened with serious environmental issues and resilience thinking may prove a useful way to re-examine such development. It may well be the case that Chinese researchers have resilience related publications in Chinese or other than English languages, which this research does not capture. Nevertheless, in order to respond to the urgent need for practically-oriented scholarly research, it is important to be able to easily communicate results, findings and exchange scientific ideas as well as understand the experiences of other countries. For the time being, English publications remain the main medium to achieve this.

Intensity of resilience research

This part examines the intensity of resilience research as represented by the share of resilience researchers within total researchers by country. This is indicative of the popularity of resilience thinking in the research arena of the various countries. Furthermore, the dominant resilience context is presented through the percentage of resilience researchers working respectively on ecological, economic, social and integrated systems (see Table 3).

The two African countries of Lesotho and Ghana appear to be at the top of the list according to resilience research intensity, however they both have relatively small numbers of researchers and the respective 1 and 3 cited resilience publications have drastically increased the share of researchers in this area to

respectively 21.6 per thousand and 7.2 per thousand. Among the remaining countries, resilience research is most popular in Australia and Sweden with about 2.6 and 1.8 per thousand researchers with cited publications in this area. The majority of researchers in most countries focus on resilience thinking in ecological systems and theoretical analysis. Among the countries with more than 10 cited resilience researchers, social resilience is dominant in South Africa and Japan, there is no country where economic resilience has attracted the highest interest and the integrated systems or sustainability approach is prevalent only in Columbia (where 100% of the studies fall in this category) and Austria.

Table 3 Numbers and shares of researchers with cited resilience publications (1973-2011)

Country	No. of researchers in resilience	Share in total researchers (‰)	Percentage of resilience researchers in different contexts (%)			
			T-E	ECO	SOC	I-S
USA	605	0.43	63.31	4.79	16.69	15.37
Australia	246	2.57	58.94	6.10	23.58	11.38
UK	218	0.93	57.80	6.42	22.48	13.30
Canada	99	0.65	57.58	2.02	25.25	15.15
Sweden	88	1.78	45.45	15.91	15.91	22.73
Netherlands	62	1.12	53.23	11.29	22.58	12.90
France	58	0.25	79.31	5.17	12.07	3.45
Germany	53	0.16	54.72	9.43	16.98	18.87
Spain	33	0.24	66.67	0	15.15	18.18
China	29	0.02	68.97	10.34	20.69	0
Switzerland	29	1.13	62.07	6.90	17.24	13.79
New Zealand	29	1.33	55.17	3.45	37.93	3.45
Italy	21	0.20	38.10	19.05	23.81	19.05
South Africa	21	1.07	38.10	4.76	42.86	14.29
Norway	18	0.68	50.00	27.78	16.67	5.56
Japan	17	0.03	35.29	0	47.06	17.65
India	16	0.10	31.25	18.75	31.25	18.75
Denmark	15	0.42	60.00	6.67	20.00	13.33
Israel	14	N/a	91.00	0	0	9.00
Austria	13	0.36	15.38	23.08	23.08	38.46
Brazil	12	0.09	83.33	8.33	8.33	0
Columbia	11	1.48	0	0	0	100.00
Sudan	11	N/a	9.00	0	54.56	36.36
Mexico	10	0.23	60.00	0	10.00	30.00
Finland	10	0.24	70.00	10.00	0	20.00
Portugal	9	0.20	44.44	22.22	33.33	0
Greece	8	0.36	75.00	0	12.50	12.50
Solomon Islands	7	N/a	100.00	0	0	0
Malaysia	6	0.58	100.00	0	0	0
Argentina	6	0.14	50.00	0	33.33	16.67
Hungary	6	0.28	0	16.67	83.33	0
Kenya	6	2.65	66.67	0	16.67	0
Poland	5	0.08	80.00	0	20.00	0

Chile	4	0.66	25.00	0	75.00	0
Singapore	4	0.13	75.00	0	25.00	0
Zimbabwe	4	N/a	50.00	0	50.00	0
Philippines	3	0.41	66.67	0	33.33	0
Indonesia	3	0.14	66.67	0	33.33	0
Nigeria	3	0.49	33.33	66.67	0	0
Russia	3	0.01	33.33	0	33.33	33.33
Romania	3	0.15	100.00	0	0	0
Ghana	3	7.23	0	0	0	100
Syria	3	N/a	100.00	0	0	0
Nepal	2	1.24	0	0	50.00	50.00
Senegal	2	0.42	100.00	0	0	0
Panama	2	4.88	100	0	0	0
Belgium	2	0.05	50.00	0	0	50.00
Egypt	2	0.06	50.00	0	50.00	0
South Korea	2	0.01	100.00	0	0	0
Iceland	2	0.74	100.00	0	0	0
Cuba	2	0.41	100.00	0	0	0
Slovenia	2	0.26	100.00	0	0	0
Slovakia	2	0.13	0	0	0	100.00
Pakistan	1	0.04	0	0	100.00	0
Mozambique	1	2.67	0	0	100.00	0
Peru	1	0.19	100.00	0	0	0
Sri Lanka	1	0.20	100.00	0	0	0
Bolivia	1	0.70	0	0	100.00	0
Venezuela	1	0.19	0	0	0	100.00
Costa Rica	1	0.64	100.00	0	0	0
Vietnam	1	0.10	0	0	0	100.00
Thailand	1	0.05	0	0	0	100.00
Lesotho	1	21.65	0	0	0	100.00
Ethiopia	1	0.27	0	100.00	0	0
Mali	1	1.71	100.00	0	0	0
Bangladesh	1	N/a	100.00	0	0	0
Belize	1	N/a	100.00	0	0	0
Bhutan	1	N/a	100.00	0	0	0
Fiji	1	N/a	100.00	0	0	0
Guam	1	N/a	100.00	0	0	0

Notes: 1. The source of data for research numbers is UNESCO's database (http://www.uis.unesco.org/Pages/default.aspx?SPSLanguage=EN).

2. T-E, ECO, SOC and I-S represent respectively that the research was conducted in the context of ecological systems or mainly on theoretical studies, economic systems, social systems and integrated ecological, social and economic systems or sustainability in terms of resilience.

3. N/a – information not available.

Overall, the geographic distribution of resilience thinking appears to indicate that despite very small numbers, this research is highly important for two categories of countries: (1) African (Lesotho, Mozambique, Ghana, Kenya, Mali and South Africa), a couple of Latin American (Panama and Columbia) countries and

Nepal, all of which are aspiring to improve the living standards of their people; and (2) strong western type small economies (Australia, Sweden, the Netherlands, Switzerland and New Zealand) which have already achieved higher living standards. It is a warning sign to see that resilience research communicated in English is yet to increase its importance for the world's largest and emerging economies, such as US, Japan, Germany, France, China, India, Brazil and Russia.

Research organisations

This final part looks at which research institutes or universities are leaders among the top 15 most productive resilience research countries (see Table 4). The research organisation with the largest number of author affiliations in the cited resilience papers is considered to be the leading institution for the respective country. Figure 5 shows the respective national shares that the leading resilience research holds.

Table 4 Leading institutes in top 15 most productive countries (1973-2011)

Rank	Country	Publications involved	Most productive institute		
			Name	Number	Percentage (%)
1	USA	389	University of California	40	10.3
2	Australia	162	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	52	32.1
3	UK	135	University of East Anglia	19	14.1
4	Sweden	95	Stockholm University	56	58.9
5	Canada	91	University of Manitoba	17	18.7
6	Germany	36	University of Kiel	6	16.7
7	Netherlands	35	Wageningen University	13	37.1
8	France	25	Laboratoire Ecologie	3	12.0
9	South Africa	21	University of Cape Town	6	28.6
10	New Zealand	17	University of Otago	6	35.3
11	Switzerland	16	Swiss Fuderal Institute for Environmental science and Technology	5	31.3
12	Spain	15	University of Autonoma de Barcelona	4	26.7
13	Norway	13	University of Oslo	7	53.8
	Austria		University of Natural Resources and Applied Life Sciences	5	38.5
14	Italy	12	University of Lecce	4	33.3
15	India	11	Indian Institute of Technology, Institute for Social and Economic Change	7	63.6

Notes: Because of multiple authorship the number of publications is higher than the total number of Google Scholar cited publications (919). Publications are counted more than once if their authors affiliate with more than one country (see main text for further explanation).

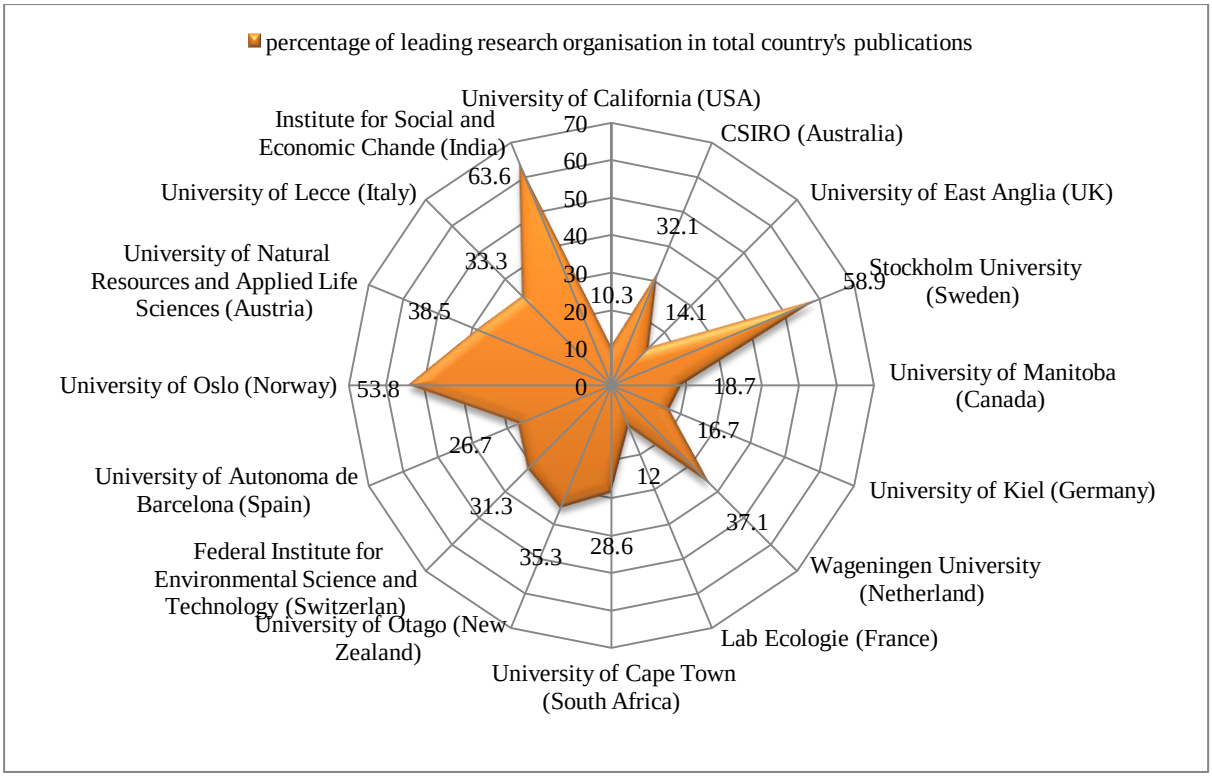

Fig. 5 Percentage of the leading resilience research organisation for the top 15 countries

The USA is overall the most productive country in resilience research, but its top institution – University of California, is responsible for 10% of the total research output in this area. This indicates that there is not a lot of concentration and resilience thinking has penetrated a larger number of American research organisations. The situation is very similar for the other larger developed economies, namely UK, Germany and France as well as for Canada where the shares of the respective leading organisations are below 20%. By comparison, the situation in India, Sweden and Norway is very different – the leading Institute for Social and Economic Change, Stockholm University and University of Oslo are respectively responsible for 64%, 59% and 54% of total national resilience output. In the remaining countries, the leading research organisations account for around a third of all cited resilience publications.

Conclusion

This paper examined the trends of resilience research using a bibliometric approach based on 919 cited English publications from 1973 to 2011 identified through Google Scholar. The analysis of resilience thinking shows that this area experienced a dramatic increase since it was introduced for ecological systems in 1973. This increasing trend substantially speeded up since 1999 with the establishment of the global Resilience Alliance network, which also publishes *Ecology and Society* – the top and most influential journal in this area, responsible for the largest number of cited resilience papers. Although the bulk of the research in resilience is conducted for ecological systems, there is an increasing interest in socio-economic systems and even more importantly, in integrated socio-ecological systems which facilitates sustainability research. How to incorporate resilience thinking to respond to sustainability challenges in the constantly changing world highly influenced by human activities, should be the main research direction of this area.

The paper also shows that resilience research is dominated in size by USA, Australia, UK and Sweden. In absolute numbers, USA is the most productive country in terms of resilience output; however, its importance is much higher for relatively smaller western economies, such as Australia and Sweden. Similarly, the case study areas covered in the cited publications demonstrate more attention to the parts of the world from where resilience research originates with many important areas attracting very little attention. Consequently, there is need for urgent practically-oriented scholarly research to concentrate on those particular regions where environmental issues have been seriously on the rise, such as in China.

Given the English language limitation of the study, it may be the case that there are other resilience publications, not captured by this analysis. Nevertheless, communication in English of environmental and sustainability concerns as well as resilience thinking remains highly important for the development of ideas and measures of adaptation to any future uncertain disturbances across the globe.

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References

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in Human Geography*, 24(3): 347–364.

Adger, N. W., Hughes, T.P., Folke, C., Carpenter, S.R. and Rockström, J. (2005). *Social-ecological resilience to coastal disasters. Science*, 309: 1036-1039.

Aguillo, I.F. (2012). Is Google Scholar useful for bibliometrics? A webometric analysis. *Scientometrics*, 91: 343–351.

Bjurström, A. and Polk, M. (2011). Climate change and interdisciplinarity: a co-citation analysis of IPCC Third Assessment Report. *Scientometrics*, 87: 525–550.

Burns, M. and Weaver, A. (eds) (2008). *Exploring sustainability science: a Southern African perspective*. Stellenbosch, South Africa: Sun Press.

Cole, J.R. and Cole, S. (1972). The Ortega hypothesis. *Science*, 178: 368–375. Online access http://www.sciencemag.org/content/178/4059/368.full.pdf (18.12.2012).

Elsevier (2012). SciVerse open to accelerate science: About Scopus. Online access http://www.info.sciverse.com/scopus/about (17.12.2012).

Falagas, M.E., Pitsouni, E.I., Malietzis, G.A. and Pappas, G. (2007). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. The FASEB Journal 22 (2): 338–342. doi:10.1096/fj.07-9492LSF

Folke, C. (2003). Freshwater for resilience: a shift in thinking. *Philosophical Transactions of the Royal Society: Biological Sciences*, 358: 2027-2036.

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*, 16: 253-267.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *Ambio*, 31(5), 437–440.

Folke, C., Carpenter, S.R., Walker, B.H., Scheffer, M., Chapin, T. and Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society*, 15(4): 20. Online access: http://www.ecologyandsociety.org/vol15/iss4/art20/ (25.01.2013).

Google Scholar (n.d.). Stand on the shoulders of giants. Online access http://scholar.google.com.au/intl/en/scholar/about.html (17.12.2012).

Anne-Wil Harzing, A.-W. (2012). Document categories in the ISI Web of Knowledge: Misunderstanding the Social Sciences? *Scientometrics*, DOI 10.1007/s11192-012-0738-1.

Holling, C.S. (1973) Resilience and stability of ecological systems. *Annual Review of Ecology Systematics*, 4: 1-23.

Janssen, M.A., Schoon, M.L., Ke, W. and Börner, K. (2006). Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Global Environmental Change*, (16): 240-252.

Jappe, A. (2007). Explaining international collaboration in global environmental change research. *Scientometrics*, 71(3): 367–390.

Ludwig, D., Mangel, M. and Haddad, B. (2001). Ecology, conservation and public policy. *Annual Review of Ecology and Systematics*, 32: 481-517.

MacRoberts, M.H. and MacRoberts, B. R. (1996). Problems of citation analysis. *Scientometrics*, 36(3): 435–444.

Marinova, D. and McGrath, N. (2005). Transdisciplinarity in teaching and learning sustainability. In G. Banse, I. Hronszky and G. Nelson (eds) *Rationality in an uncertain world* (pp. 275–285). Berlin: Edition Sigma.

McMichael, A.J., Butler, C.D. and Folke, C. (2003). New visions for addressing sustainability. *Science*. 302: 1919-1920.

Perrings, C. (1998). Resilience in the dynamics of economy-environment systems, *Environmental & Resource Economics*, 11(3): 503–520.

Quental, N. and Lourenço, J.M. (2012). References, authors, journals and scientific disciplines underlying the sustainable development literature: a citation analysis. *Scientometrics*, 90: 361–381.

Resilience Alliance (2012). Resilience. Online access: http://www.resalliance.org/index.php/resilience (17.12.2012).

Rose, A. (2007). Economic resilience to natural and man-made disasters: multidisciplinary origins and contextual dimensions. *Environmental Hazards*, 7(4): 383–398.

Small, H. (2004) Why authors think their papers are highly cited. *Scientometrics*, 60(3): 305–316.

Thompson Reuters (2012) Web of knowledge. Online access http://wokinfo.com/ (17.12.2012).

Troell, M., Pihl, L., Rönnbäck, P., Wennhage, H., Söderqvist, T. and Kautsky, N. (2005). Regime shifts and ecosystem services in Swedish coastal soft bottom habitats: when resilience is undesirable. *Ecology and Society*, 10(1): 30. Online access: http://www.ecologyandsociety.org/vol10/iss1/art30/ (25.01.2013).

Veugelers, R. (2010). Towards a multipolar science world: trends and impact. *Scientometrics*, 82(2): 439–456.

Walker, B., Holling, C.S., Carpenter, S.R. and Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society*, 9(2): 5. Online access: http://www.ecologyandsociety.org/vol9/iss2/art5/ (25.01.2013).

Walker, B., Pearson, L., Harris, M., Maler, K., Li, C., Biggs, R., & Baynes, T. (2010). Incorporating resilience in the assessment of inclusive wealth: an example from south east Australia. *Environmental and Resource Economics*, 45, 183–202.

Yang, K. and Meho, L.I. (2006). Citation Analysis: A Comparison of Google Scholar, Scopus, and Web of Science. In 69th Annual Meeting of the American Society for Information Science and Technology (ASIST), Austin, USA. Online access http://eprints.rclis.org/bitstream/10760/8605/1/Yang_citation.pdf (18.12.2012).