

Synthesis

An Update on the Scholarly Networks on Resilience, Vulnerability, and Adaptation within the Human Dimensions of Global Environmental Change

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ABSTRACT. In Janssen et al. (2006), we presented a bibliometric analysis of the resilience, vulnerability, and adaptation knowledge domains within the research activities on human dimensions of global environmental change. We have updated the analysis because 2 years have gone by since the original analysis, and 1113 more publications can now be added to the database. We analyzed how the resulting 3399 publications between 1967 and 2007 are related in terms of co-authorship and citations. The rapid increase in the number of publications in the three knowledge domains continued over the last 2 years, and we still see an overlap between the knowledge domains. We were also able to identify the “hot” publications of the last 2 years.

Key Words: *adaptation; bibliometric analysis; citations; resilience; vulnerability*

INTRODUCTION

In Janssen et al. (2006), a study was presented that aimed at identifying the structure and dynamics of major fields contributing to the concepts of resilience, vulnerability, and adaptation within the research on the human dimensions of global environmental change. We identified the most influential scholars, publications, and journals in these three knowledge domains.

The basic finding of Janssen et al. (2006) was that the resilience knowledge domain was only weakly connected with the two other domains in terms of co-authorship and citations. The resilience knowledge domain has a background in ecology and mathematics, with a focus on theoretical models, whereas the vulnerability and adaptation knowledge domains have a background in geography and natural hazards research, with a focus on case studies and climate change research.

The data retrieval for the 2006 article was performed in March 2005. In this brief note, we present an update of the original analysis using data retrieved in April 2007. By adding 1113 new publications to the database, we continue to see a rapid increase in

the field, as well as its integration of knowledge domains. For more in-depth discussion of the procedures of the bibliometric analysis, we refer the reader to Janssen et al. (2006) and the supplemental website <http://www.public.asu.edu/~majansse/pubs/SupplementIHDP.htm>.

We present a bibliometric analysis of the three knowledge domains using tools and techniques developed for the large-scale mapping of knowledge domains (Börner et al. 2003). This analysis requires the acquisition of a high quality, comprehensive data set of relevant papers; the analysis and correlation of these paper records; and the visualization of the results for means of communication. This paper presents the results of analyzing 3399 publications related to the study of resilience, vulnerability, and adaptation published between 1967 and 2007. Because of the way we collect our data, these publications are mainly international journal articles in English. General statistics are provided; major journals, most productive authors, and best connected authors are identified; and co-author and paper citation networks for the three areas as well as for the complete data set are presented and discussed.

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DATA COLLECTION

Most research results in the domains of resilience, vulnerability, and adaptation are published in journals. The Arts and Humanities Index, the Social Science Citation Index, and the Science Citation Index as provided by the Institute of Scientific Information (ISI) were used to acquire the raw material for the bibliometric analysis. A manual check of ISI's journal coverage confirmed that all relevant journals are covered. The data were retrieved from ISI's Web of Science online interface (<http://www.isiknowledge.com>) between 14–20 March 2005 for Janssen et al. (2006). In this paper, we updated the database by retrieving additional material on 14–15 April 2007. For each paper, the complete author, title, language, abstract, keywords, address, cited references, times cited, publisher information, and subject category were saved. Two types of searches were performed: (1) a keyword-based search and (2) a cited reference search using seminal papers. The complete list of keywords and seminal papers can be found at <http://www.public.asu.edu/~majansse/pubs/SupplementIHDP.htm>.

Although we aimed for the best and most complete set of relevant publications, we may have missed important contributions. Still, we believe we have a comprehensive data set that covers the three areas well and can be used to analyze the structure and dynamics of research on resilience, vulnerability, and adaptation within the area of human dimensions of global environmental change.

DATA ANALYSIS AND VISUALIZATION

General Statistics

The final data set contains 3379 unique journal papers and 20 books and other non-journal publications published between 1967–2007. Of those, 1559 report research on resilience, 1543 are related to research in vulnerability, and 1033 discuss research on adaptation. Some papers are classified into two or all three knowledge domains. Compared with Janssen et al. (2006), 1113 unique publications were added.

Figure 1 shows the number of papers in the three knowledge domains between 1977 and 2007. There appears to be a stable number of papers for all three areas until the early 1990s, after which the number

of papers increases rapidly. The trend found in Janssen et al. (2006) continues in the 2 most recent years.

Journal Statistics

Which journals have published many articles in the various knowledge domains and which journals were cited the most? When we exclude the 20 books and other non-journal publications, we have 3379 papers that have been published in about 690 different journals. This shows the diverse nature of the research topics covered in this paper.

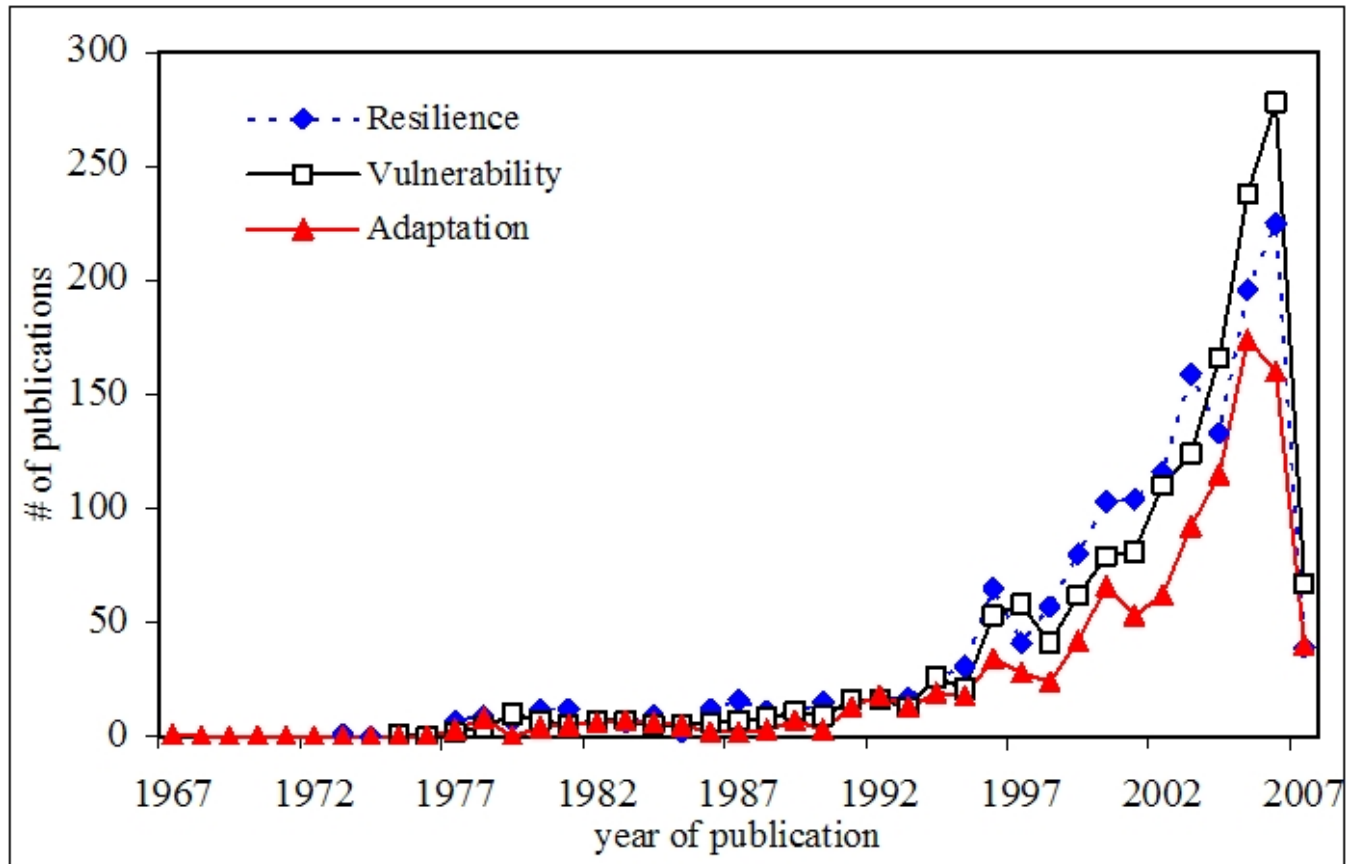
Table 1 lists the top ten journals in which most papers have been published. At the top of the list are climatic change-oriented journals, followed by ecology and ecosystem management-oriented journals. Note that a number of these journals (e.g., *Global Environmental Change*, *Ecology and Society* (renamed from *Conservation Ecology* in 2004), and *Ecosystems*) were founded since 1990.

Table 1 also gives citation counts per journal compiled using the HistCite™ software (Garfield 2004). Note that these counts represent citations by and to publications within the set of 3399 papers. The most cited journals are *Global Environmental Change* and *Climate Change*.

We also explored which publications are the most cited, and especially which publications are most cited in the articles newly added to the database in order to identify “hot publications” (Table 2). The “hot publications” are the International Panel on Climate Change (IPCC) *Report on Impacts, Adaptation and Vulnerability of Climatic Change* (McCarthy et al. 2001) and the *Panarchy* book capturing the main achievements of the Resilience Network (Gunderson and Holling 2002).

Table 3 shows the top ten journals that have the greatest number of papers published in each of the three knowledge domains. Resilience-oriented papers are mainly published in ecology and ecosystem management-oriented journals, which is quite different from the other two knowledge domains. Papers relating to both adaptation and vulnerability are published in climate change and global environmental change-oriented journals. Furthermore, vulnerability papers also are published in geography (*Annals of the American*

Fig. 1. Number of papers published in the three knowledge domains per year. Data for 2006 and 2007 are incomplete.



Association for Geography (AAAG)) and natural hazard research (*Disasters*, *Natural Hazards*) journals. Adaptation papers are published also in anthropology journals such as *American Anthropology* and *Human Ecology*.

Using HistCite™, we ranked the journals according to their citation counts (analogous to Table 1) separately for each knowledge domain. Table 4 shows the dominance of ecology journals for the resilience domain, and geography and climate change for the vulnerability and adaptation domains. We also see two journals on development studies in the domain of vulnerability (*World Development* and the *Institute for Development Studies (IDS) Bulletin*) as well as the *Proceedings of the National Academy of Sciences of the United States of America* (PNAS).

Author Statistics

Next, we were interested in identifying and analyzing the most productive and most collaborative authors within our database (including the 20 publications we excluded in the journal analysis). Table 5 shows the top ten authors who have the greatest number of publications and the greatest number of citations in our data set. Professor Folke (Beijer Institute and Stockholm Resilience Centre, Stockholm University) leads with the greatest number of publications. We used HistCite™ to calculate the number of times authors are cited. C. S. Holling, currently emeritus Professor at the University of Florida, and previously at the University of British Columbia (Canada) and the International Institute for Applied Systems Analysis (Austria), is by far the most cited author, followed by Folke.

Table 1. The top ten journals with the greatest number of papers (left) and the greatest number of citations (right) within the whole database over the period 1977–2007.

Papers published, 1977–2007			Papers cited, 1977–2007	
Rank	Journal	No. of articles	Journal	No. of citations (No. of articles)
1	Climatic Change	152	Global Environmental Change	669 (118)
2	Global Environmental Change	118	Climatic Change	639 (152)
3	Ecology and Society	109	Annual Review of Ecology	531 (8)
4	Ecological Economics	74	Nature	530 (21)
5	Environmental Management	74	Ecosystems	450 (42)
6	Ambio	67	Science	384 (27)
7	Climate Research	65	Ecology and Society	316 (109)
8	Human Ecology	44	Ecological Applications	253 (42)
9	Ecological Applications	42	Ambio	219 (67)
10	Ecosystems	42	Journal of Rangeland Management	196 (11)

Table 6 presents the most productive institutions and countries. Papers are allocated to institutions and countries based on the affiliations of the first author. The most productive institution is Stockholm University, where Folke is professor. Next on the list are the University of East Anglia (Adger), Wisconsin University (Carpenter), and CSIRO (Walker). The most productive countries (as measured by affiliation of first author) are USA, UK, and Canada. As 97% of the papers are published in English, it is no surprise that the most productive countries are native English-speaking countries.

Co-Author Networks

Next, we were interested in understanding the scholarly interactions and the structure of the research community based on co-authorship

relations. A total of 6293 unique authors were identified in the complete data set. By representing authors as nodes and their co-authorship relations as edges, the links between nodes and co-author networks can be analyzed and visualized. This visualization is of interest, because it may help us to identify structures of collaboration between authors.

Different thresholds were applied to identify and map the most productive authors, the best connected authors and the strongest co-authorship relations. In particular, we identified two authors who had at least 100 unique co-authors. Next, we selected the 16 most productive authors with a minimum of 15 papers. Both sets make up the set of 17 authors who are very productive and/or collaborative. Next, we determined all co-authors for those 17 authors, but kept only the 69 authors who had published a

Table 2. The top ten cited publications in the database over the period 1977–2007 (left) and the period 2005–2007 (right).

Citations between 1977–2007			Citations between 2005–2007	
Rank	Publication (Author, date)	No. of citations	Publication (Author, date)	No. of citations
1	Holling (1973)	458	McCarthy et al. (2001)	171
2	Holling (1986)	298	Gunderson and Holling (2002)	125
3	McCarthy et al. (2001)	290	Scheffer et al. (2001)	96
4	Gunderson et al. (1995)	256	Holling (1973)	96
5	Berkes and Folke (1998)	233	Berkes and Folke (1998)	82
6	Gunderson and Holling (2002)	189	Berkes et al. (2003)	81
7	Burton et al. (1978)	176	Kates et al. (2001)	68
8	Scheffer et al. (2001)	169	Blaikie et al. (1994)	58
9	Blaikie et al. (1994)	147	Holling (1986)	52
10	Kates et al. (2001)	112	Carpenter et al. (2001)	47

minimum of six papers. The thresholds were manually selected such that the number of authors and their co-authorships was sufficiently large to derive meaningful structures. We balanced the desire to provide a lot of data points, but not too much in order to be identifiable nodes. We acknowledge that this procedure is somewhat subjective, but small changes in the thresholds had no significant impact on the structure of the network, only the visual transparency.

The resulting network was laid out using the Pajek (Batagelj and Mrvar 1997) network visualization package (see Fig. 2). The most densely linked group of authors around the Folke node publishes in the domain of resilience.

Paper-citation Networks

To analyze and communicate the paper-citation network, we imported the complete data set (citations in the 20 publications that were not in the ISI database were entered manually) into HistCite™ (Garfield 2004). The resulting graph for the complete data set is given in Fig. 3. The graphs for each of the three domains are shown in Figs. 4–6. In all graphs, nodes represent highly cited papers and edges denote citation links. The nodes are sorted in time with old papers on the top and young papers at the bottom.

Figure 3 shows papers which are cited at least 60 times within the whole database, and if one of these highly papers cites another highly cited paper, they are linked. Holling (1973) is the most cited paper (458 times). Papers from very different knowledge

Table 3. The top ten journals with the greatest number of papers in resilience, vulnerability, and adaptation over the period 1977–2007. (The # symbol refers to the number of papers).

Rank	Resilience		Vulnerability		Adaptation	
	Journal	#	Journal	#	Journal	#
1	Ecology and Society	104	Climatic Change	98	Climatic Change	102
2	Ecological Economics	61	Global Environmental Change	88	Global Environmental Change	80
3	Environmental Management	52	Climate Research	48	Climate Research	36
4	Ambio	47	Disasters	36	Climate Policy	23
5	Ecosystems	40	AAAG	27	Human Ecology	19
6	Ecological Applications	37	Ambio	24	American Anthropology	17
			Natural Hazards	24	Energy Policy	17
7	Global Environmental Change	29	Climate Policy	22	IDS Bulletin	15
8	Conservation Biology	25	Environmental Management	20	Ambio	14
9	Ecological Modeling	23	Environmental Monitoring and Assessment	20	Disaster	14
10	Human Ecology	22	IDS Bulletin	20	Environmental Science and Policy	14

domains cite Holling (1973). Another major publication that is highly cited across disciplinary boundaries is Burton et al. (1978). Interestingly, as we identified in Janssen et al. (2006), the resilience knowledge domain develops quite separately from the vulnerability and adaptation knowledge domains. Very few cross citations exist. Only Holling (1986) cited Burton et al. (1978), and a few “vulnerability/adaptation” papers and books refer to major resilience publications. Berkes et al. (2003) appears as a new highly cited publication in the citation network.

We also generated citation networks for the separate knowledge domains (Figs. 4–6). For the resilience knowledge domain, we used a threshold of 40 citations, and this figure is similar to the left side of Fig. 3. New publications that appear in the citation network since Janssen et al. (2006) are Holling (2001) and Walker et al. (2002)

The vulnerability knowledge domain, mapped using a threshold of 30 citations, shows the centrality of Burton et al.’s (1978) research on the environment as a natural hazard and McCarthy et al. (2001) as the recent focus on climate change and

Table 4. The top ten journals with the greatest number of citations in resilience, vulnerability, and adaptation over the period 1977–2007. (The # symbol refers to the number of received citations, the figures between parentheses are the number of articles in that journal in that knowledge domain.)

Rank	Resilience		Vulnerability		Adaptation	
	Journal	#	Journal	#	Journal	#
1	Annual Review of Ecology	526 (8)	Global Environmental Change	437 (88)	Climatic Change	391 (102)
2	Nature	443 (10)	Climatic Change	332 (98)	Global Environmental Change	383 (80)
3	Ecosystems	423 (40)	Science	158 (13)	Climatic Research	60 (36)
4	Ecology and Society	296 (28)	Progress in Human Geography	143 (10)	Climate Policy	49 (23)
5	Ecological Applications	211 (37)	AAAG	124 (27)	Progress in Human Geography	44 (4)
6	Journal of Rangeland Management	186 (11)	IDS Bulletin	112 (20)	Agricultural and Forest Meteorology	35 (9)
7	Science	182 (16)	PNAS	79 (15)	PNAS	32 (2)
8	Ambio	167 (47)	World Development	74 (13)	Building Research and Information	29 (12)
9	Conservation Biology	135 (25)	Climate Research	70 (48)	AAAG	28 (14)
10	Ecological Economics	130 (61)	Ambio	50 (24)	Ambio	28 (6)

vulnerability. Since Janssen et al. (2006) was published, Kelly and Adger (2000), O'Brien and Leichenko (2000), Yohe and Tol (2002), and Turner et al. (2003) have been added.

In the adaptation knowledge domain, the McCarthy et al. (2001) report has a central position. Compared with Janssen et al. (2006), Burton et al. (2002), Yohe and Tol (2003), and Turner et al. (2003) have been added.

Next, we analyzed the complete database to see whether there is a general trend for papers to fall into multiple knowledge domains. If each publication could be uniquely classified into one

knowledge domain, the value of the index would be 1. Figure 7 shows that the relative number of categories per paper is steadily increasing over time. It appears that scholars more frequently use keywords from different knowledge domains or cite seminal papers from various knowledge domains. It would be difficult to draw conclusions from this, but it suggests that the knowledge domains are starting to overlap more than in the past.

Table 5. Top-ranked authors of the complete data set. The left side of the table ranks authors (by lead author) according to number of publications. The right side of the table ranks authors (by lead author) according to number of citations.

Rank	Number of publications		Number of times cited	
	Author	No. of Publications	Author	No. of Citations
1	C. Folke	69	C. S. Holling	1865
2	S. R. Carpenter	35	C. Folke	1156
3	F. Berkes	30	B. H. Walker	673
4	W. N. Adger	28	S. R. Carpenter	596
5	C. S. Holling	26	L. H. Gunderson	589
	B. H. Walker	26	F. Berkes	507
7	L. H. Gunderson	20	J. J. McCarthy	454
8	R. J. Nichols	19	R. W. Kates	360
	C. Perrings	19	W. N. Adger	297
	B. Smith	19	O. F. Canziani D. J. Dokken N. A. Leary K. S. White	290

Table 6. The top ten most productive institutions (left) and countries (right). The publications are distributed according to the institutions and countries of the lead author. For 121 publications, this information was not available.

Rank	Institution	Number of publications	Country	Number of publications
1	Stockholm University	103	USA	1461
2	University of East Anglia	92	UK	461
3	University of Wisconsin	85	Canada	393
4	CSIRO	83	Australia	247
5	University of British Columbia	71	Netherlands	182
6	Wageningen University	55	Sweden	177
7	University of Florida	52	Germany	150
8	University of Colorado	48	France	95
9	Vrije Universiteit Amsterdam	48	South Africa	93
10	Arizona State University	46	India	63

Fig. 2. Co-author network of the most productive and best connected authors with the strongest co-authorship relations. Circles denote author nodes, and are labeled by the author's last name and initials. Legend: Node – author; Node area size—# of publications; Node area color—# of unique co-authors

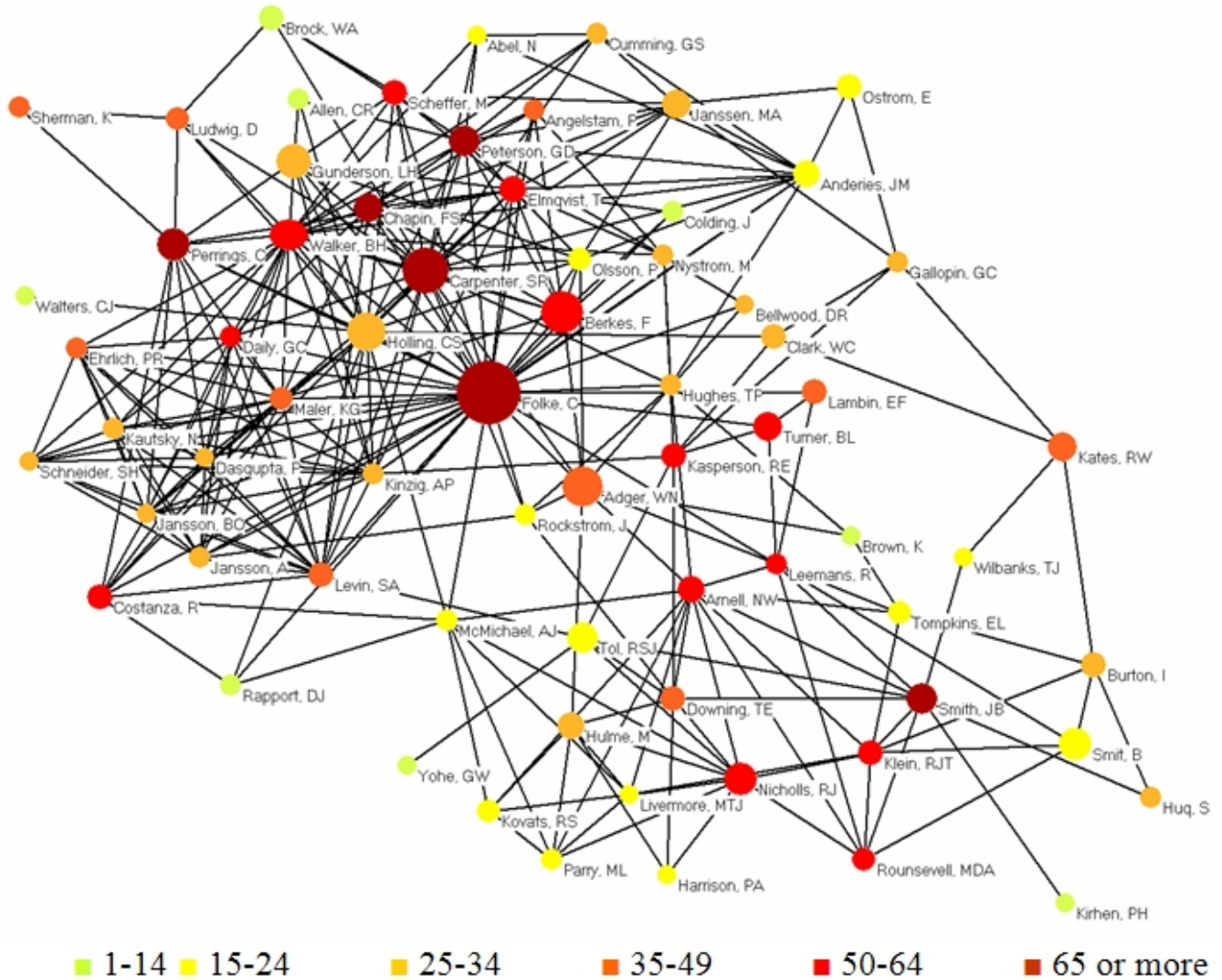


Fig. 3. Paper citation network of the most highly cited papers within the whole data set (Threshold 60 citations within the data set). The node size denotes the number of citations, the arrows refer to citations.

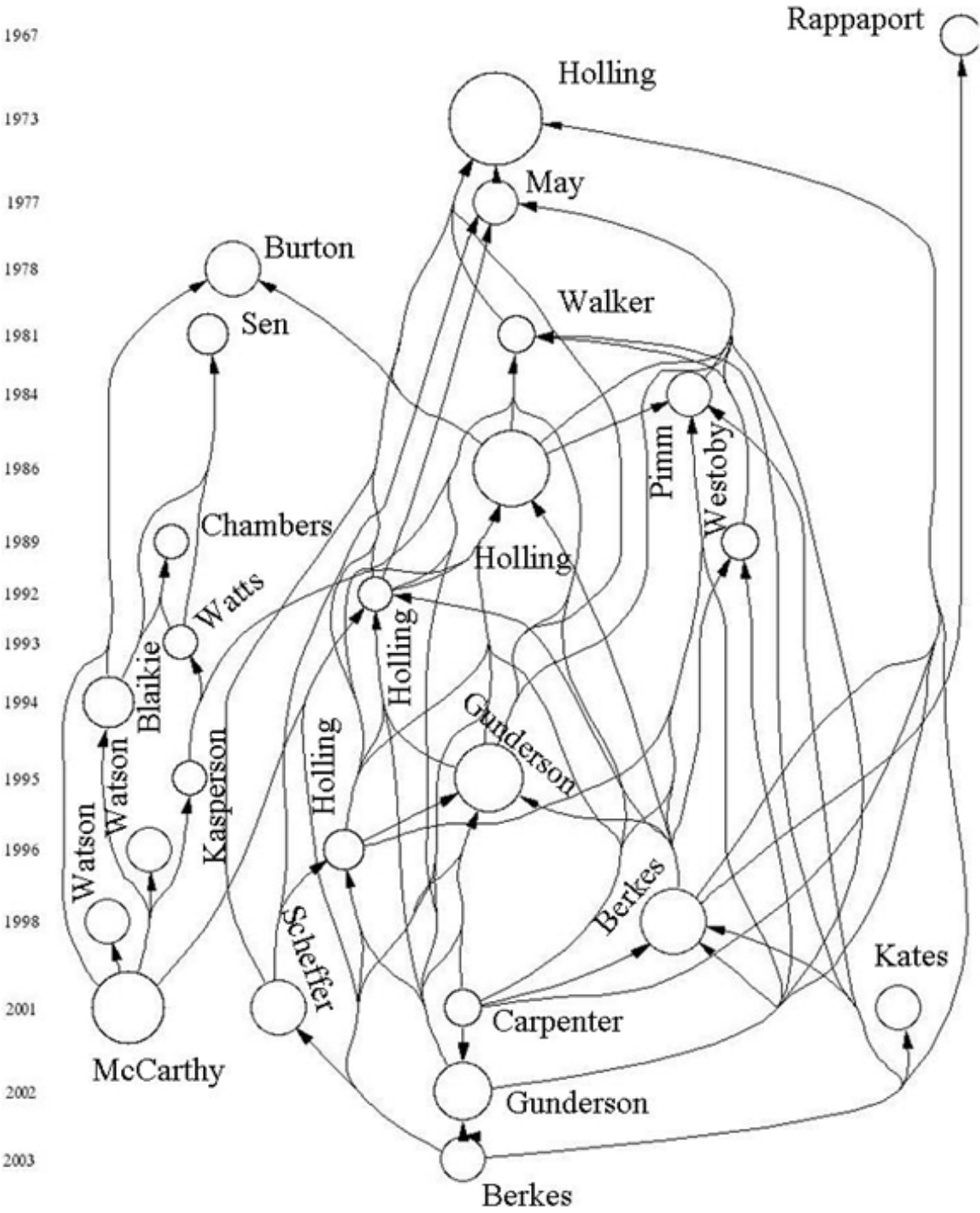


Fig. 4. Paper citation network of the most highly cited papers within the resilience knowledge domain (Threshold 40 citations within the data set). The node size denotes the number of citations, the arrows refer to citations.

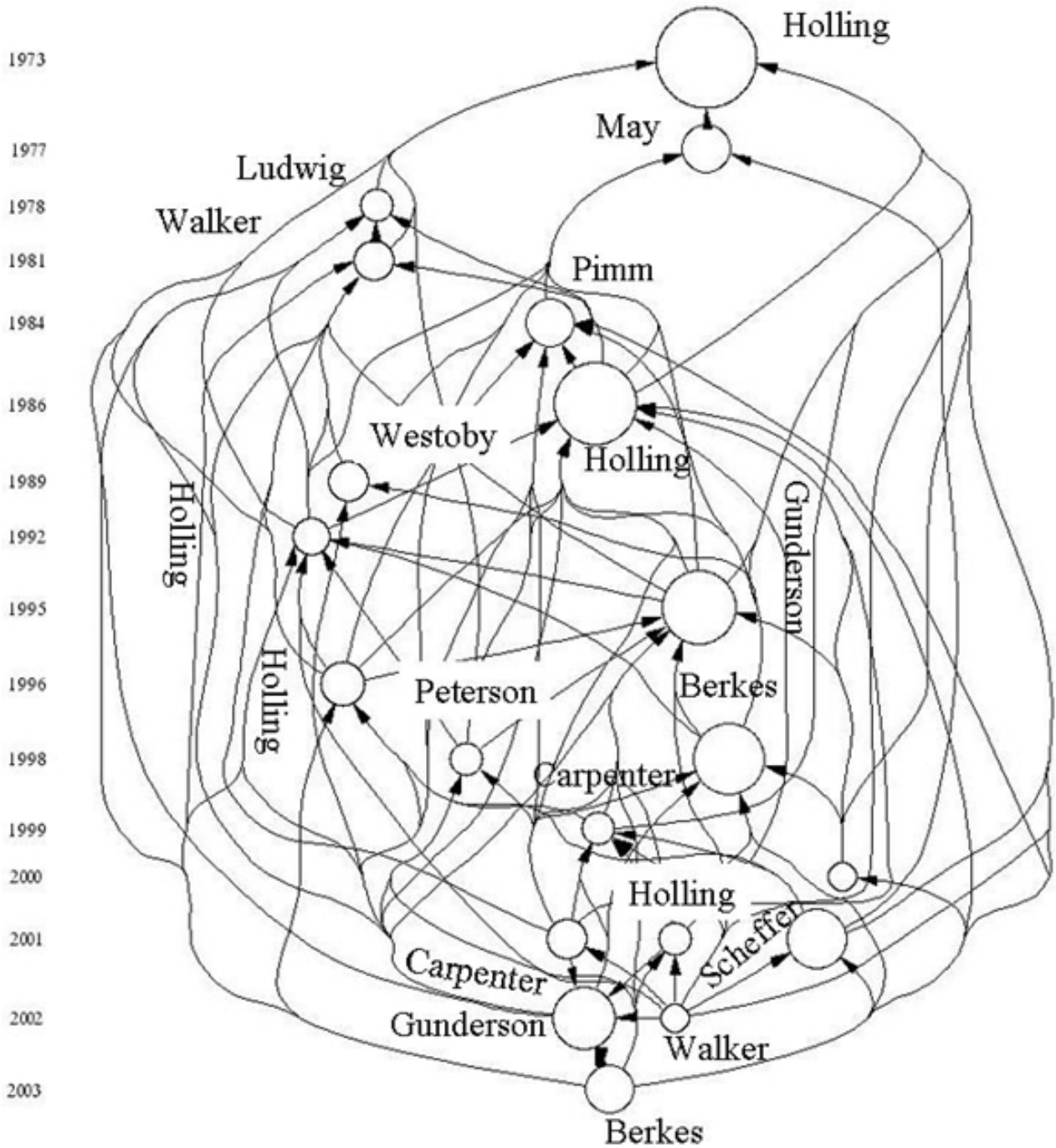


Fig. 5. Paper citation network of the most highly cited papers within the vulnerability knowledge domain (Threshold 30 citations within the data set). The node size denotes the number of citations, the arrows refer to citations.

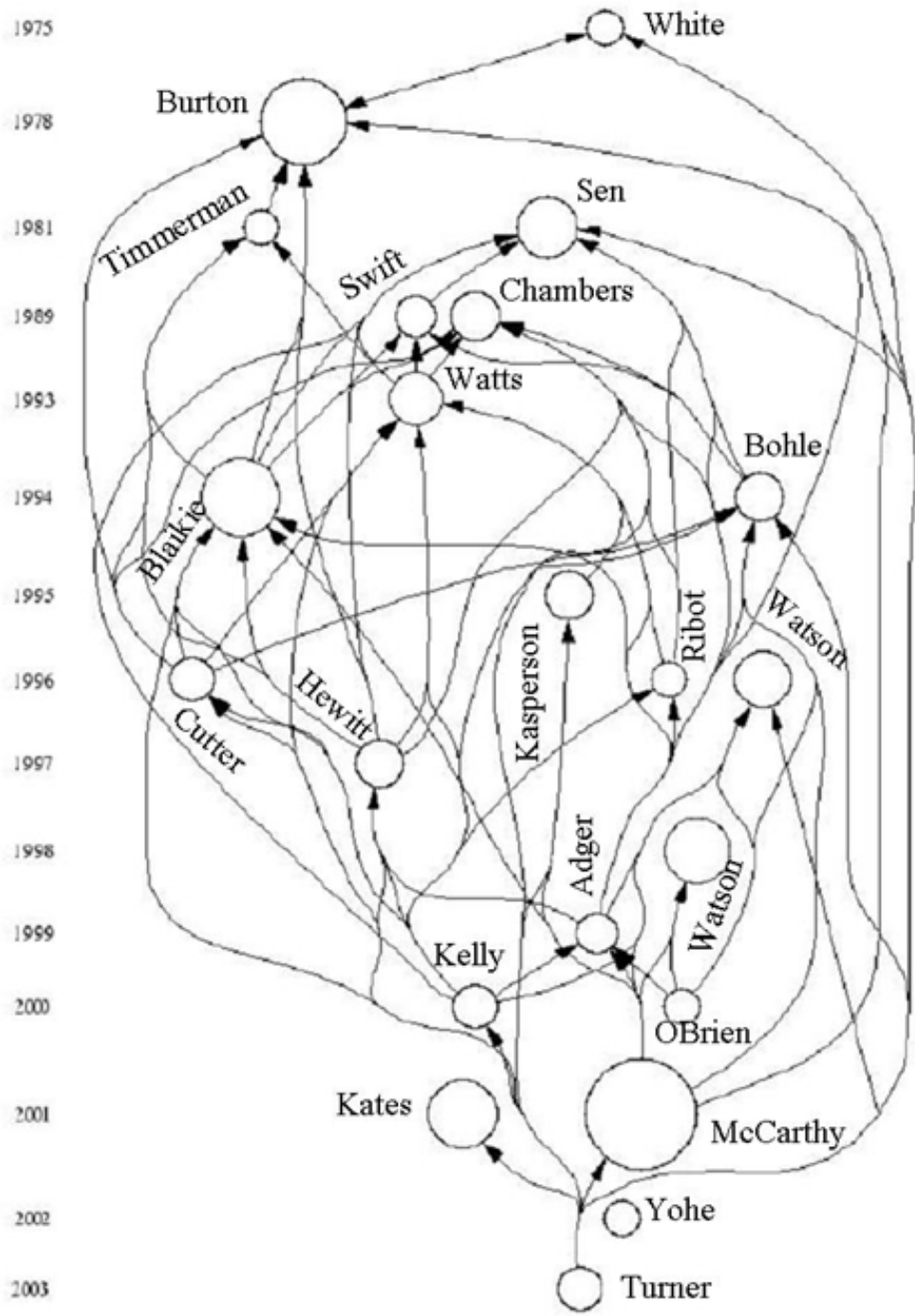


Fig. 6. Paper citation network of the most highly cited papers within the adaptation knowledge domain (Threshold 20 citations within the data set). The node size denotes the number of citations, the arrows refer to citations.

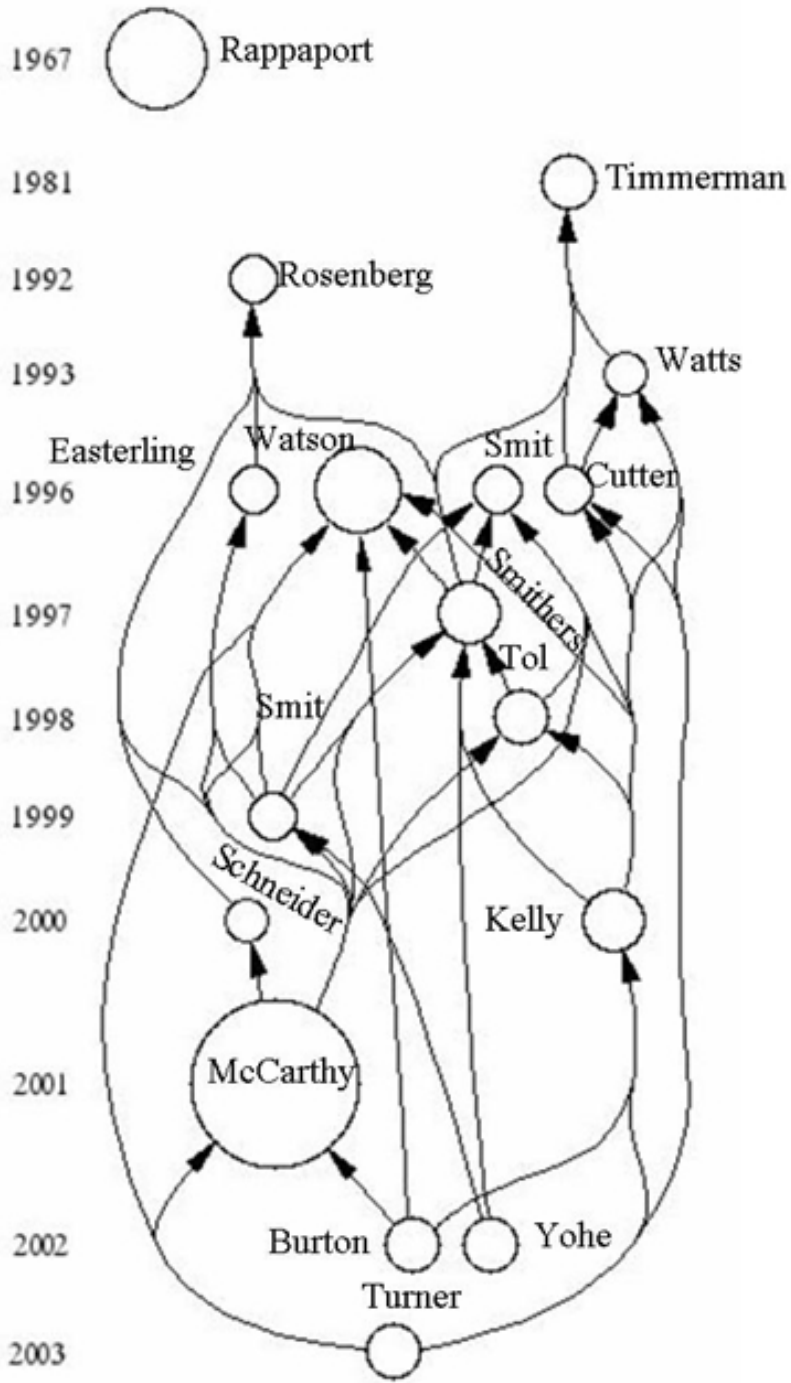
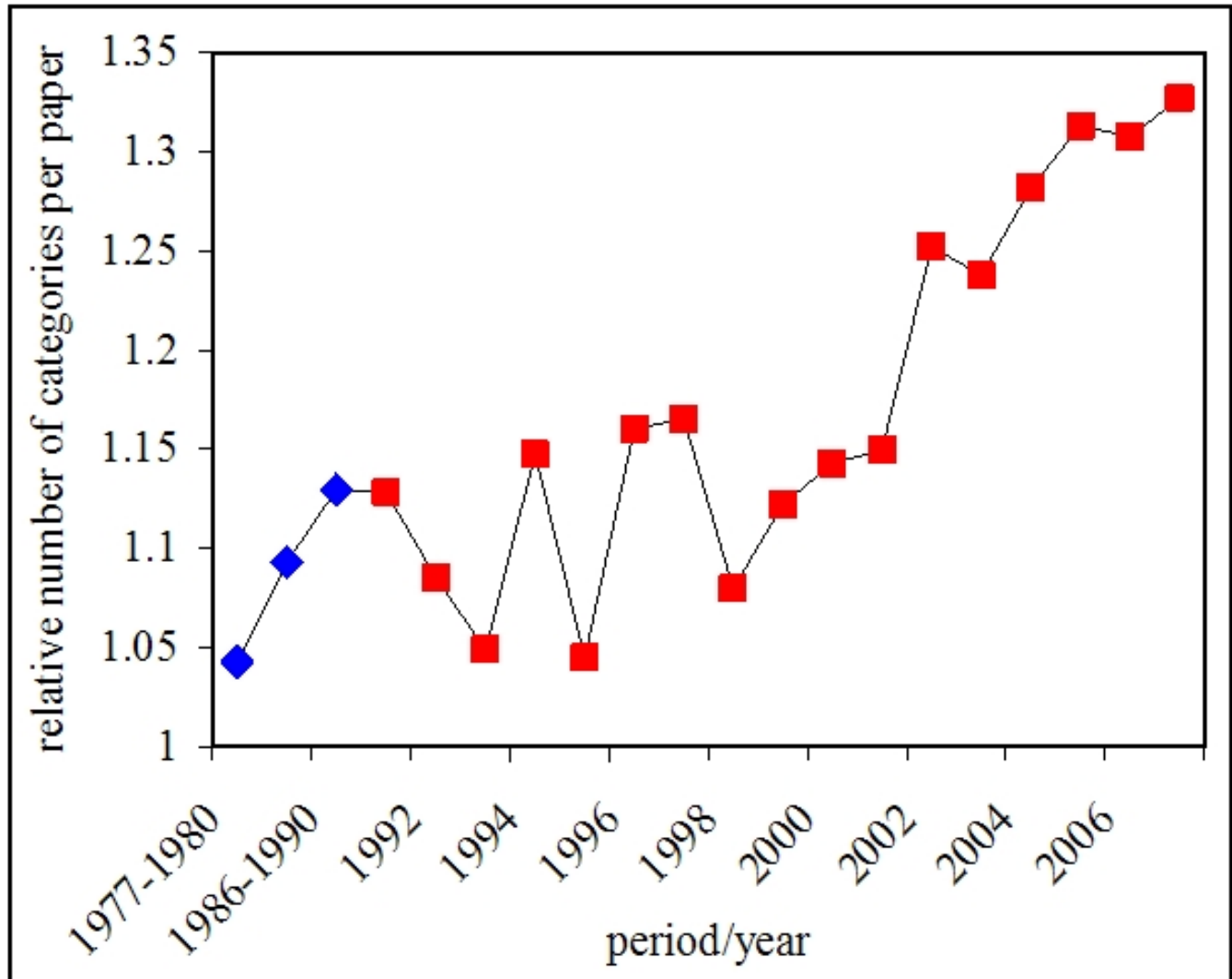


Fig. 7. The average number of knowledge domains that publications issued in one year or period belong to. For earlier years, 5-year periods are used as only small numbers of publications are available.



CONCLUSION

We updated the analysis of the publications related to resilience, vulnerability, and adaptation of human dimensions of global environmental change. Our analysis shows that this research area continues to experience a major increase in the number of published papers. It also shows that there is an increased overlap among the three knowledge domains.

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