Ecosystem Services 59 (2023) 101501

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Full Length Article

Changes in authorship, networks, and research topics in ecosystem services

Ida Kubiszewski [a,*], Luke Concollato [b], Robert Costanza [a], David I. Stern [c]

[a] Institute for Global Prosperity, University College London, UK
[b] Ecolora LTD, UK
[c] Crawford School of Public Policy, Australian National University, Australia

ARTICLE INFO

Keywords:
Citation analysis
Transdisciplinary
Social capital
Network analysis

ABSTRACT

A large network of researchers and practitioners have been working on ecosystem services (ES) for decades. In the inaugural issue of this journal, in 2012, we analysed the authorship structure, citations, topics, and journals publishing on ES. Here we update and expand that analysis and compare results with those we found in our previous analysis. We also analyse the influence that the journal *Ecosystem Services* has had on these variables over its first 10 years. We look at which articles have had the most influence on the field (as measured by the number of citations in *Ecosystem Services*) and on the broader scientific literature (as measured by total citations). We also look at how authorship networks, topics through keywords, and the types of journals publishing on the topic have changed. Results show that between the two time periods (before and after the establishment of the journal *Ecosystem Services* in 2012) there has been significant growth in the number of authors (12,795 to 91,051) and number of articles published (4,948 to 33,973) on ES. Authorship networks have also expanded significantly, and the patterns of co-authorship have evolved in interesting ways. The journal *Ecosystem Services* is now the most prolific publisher of articles on ES among the 4,286 journals that have published in the area. There is a cluster of 9 top journals that cite, and are cited by each other, within this rapidly expanding policy-relevant research area.

1. Introduction

The concept of ecosystem services (ES)[1] has been increasingly used not only in academia, but also for analysis and decision-making in the business and policy sectors (Costanza and Kubiszewski, 2012; Costanza et al., 2017). ES was conceived to provide a common language which could be used to communicate between various disciplines about the complex connections between humans and the rest of nature (Braat and de Groot, 2012). More importantly, its goal was to allow for holistic decision-making around the development of trade-offs, land-use planning, collaborative management, investments, and the provision of public goods and services (Millennium Ecosystem Assessment (MEA), 2005; Fisher et al., 2008; Kubiszewski et al., 2021). It provides a means to include the public goods characteristics of the environment in economic thinking and planning, without commodification (Costanza et al., 2017).

Since this journal, *Ecosystem Services*, was first published in 2012, interest in this topic has significantly increased, in large part due to The Economics of Ecosystems and Biodiversity (TEEB), the Ecosystem Services Partnership (ESP), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Parallel to the Intergovernmental Panel on Climate Change (IPCC), IPBES was established to facilitate the connection between science and policy around the topics of biodiversity and ecosystem services. IPBES noted an accelerating decline of biodiversity and ecosystem services (Costanza et al., 2014; Sutton et al., 2016; Ruckelshaus et al., 2020). This, and other work, shows the importance of the connection between science, policy, and business in integrating ecosystem services and natural capital into mainstream economic policy (Costanza et al., 2017; Kubiszewski et al., 2022).

Traditionally, the ES field has been dominated by economists and ecologists (Lakerveld, 2012). Over the years, it has grown to include more social and political scholars and issues (Pagiola, 2008). As the field has grown and become more diverse, authors from new fields have begun using the concept and creating new questions and challenges (Chaudhary et al., 2015). However, this diversity also brings new ideas, collaborations, avenues of research, and innovative results. As the field continues to grow and expand, so will the opportunities it has to create

* Corresponding author.
E-mail address: ida.kub@gmail.com (I. Kubiszewski).

[1] In this article, the abbreviation ES always refers to the field while the name of the journal *Ecosystem Services* is always written out in full and italicized.

https://doi.org/10.1016/j.ecoser.2022.101501
Received 8 June 2022; Received in revised form 28 November 2022; Accepted 10 December 2022

positive change. Now, the ES framework brings together multiple disciplines to address pressing world problems (Steger et al., 2018). It requires social, environmental, and economic knowledge, as well as interaction with on-the-ground stakeholders (Sarkki et al., 2013). This means that extensive collaboration has developed around the idea of ES.

In this paper, we look at the networks of scholars that have been working in this inherently transdisciplinary field. We compare these results with those we found in our previous analysis of this topic in the first issue of this journal (Costanza and Kubiszewski, 2012). We also analyse the influence that the journal *Ecosystem Services* has itself had over the past 10 years, specifically looking at which of its articles have had the most influence on the field.

2. Methods

The past decade has seen a major increase in ecosystem services (ES) authors and publications, and the field overall. We compare our results to those we published in Costanza and Kubiszewski (2012), where we analysed publications up until the end of 2011. The analyses performed in the current paper are either on all ES papers up until the end of 2021, or they compare the past decade (2012–2021) with the earlier period (1984–2011).

Data for the analysis of authors and journals publishing in the area of ES was collected around 7 April 2022 from *Scopus*. *Scopus* is a citation database that includes the majority of articles from peer-reviewed academic journals, books, and book chapters. *Scopus* was chosen over the *Web of Science* or *Google Scholar* (the two other major citation databases) because it is more comprehensive than the *Web of Science* and provides more reliable data about articles and authors than *Google Scholar*.

The publications included in this analysis included the term "ecosystem services" in either their title, abstract, or key words. It is irrelevant whether the plural "ecosystem services" or the singular "ecosystem service" is used as the search term since both produce identical search results. All articles with an English abstract, regardless of the language of the body of the paper, were picked up in our search. The core data used in this paper are author names, co-authors, number of publications, citations, author h-index, and the country of current institution. Data was collected for papers published from the first mention of ES in a published academic paper in *Scopus* (Pearsall, 1984) up until the end of 2021.

We created a Python script to analyse authorship data from *Scopus*. This script uses the Python data analysis library pandas[2] and the matplotlib[3] library to visualise the data. We also used SciPy to parse keyword stems, as well as to identify duplicates and words of similar meaning. The analysis involved filtering the data by year, author, and keywords to produce tables and plots.

To find the most prolific authors, we select all authors with more than 30 ES publications. The data was formatted and imported into Kumu.[4] This online software created a network visualisation of authors and their connections to other co-authors. Using Kumu's built-in organisational algorithm, as well as manual reorganisation, we arranged the authors into organised groups. Plots were also produced using the plotly[5] Python library.

We also carry out analyses of articles and journals. To find the most influential articles we identify: 1) the articles published in the journal *Ecosystem Services* that were cited most (in all journals including *Ecosystem Services*) – outwardly influential articles and 2) the articles indexed in *Scopus* that were cited most by articles in the *Ecosystem Services* journal – inwardly influential articles. To do this, we downloaded data on all articles published in the journal together with their number of citations and their reference lists on 19 May 2022.

Table 1
Summary of totals between the two time periods.

	1984–2011	2012–2021	Entire period (1984–2021)
Total # of ES papers published	4,948	33,973	38,921
Total # of ES authors	12,795	91,051	97,868
Authors who published ≥5 papers	396	5085	6,672
Authors who published ≥30 papers	4	116	163
Total # of journals publishing ES papers	1,276	3,692	4,286

We identified the most influential individual articles published in the journal based on their number of citations in *Scopus*. To deal with the varying age of articles and their corresponding variation in potential to be cited, following Costanza et al. (2016), we selected the top three articles in each year of publication apart from 2022. Though this selects papers in recent years that have low numbers of citations so far, Stern (2014) shows that early citations are quite strongly correlated with long-run cumulative citations and so many of these papers will turn out to be very influential. In 2021, the third position was shared by three articles with the same number of citations. We chose the article with the most *Google Scholar* citations of the three.

We identified the journal articles with the most influence on articles published in *Ecosystem Services* by first aggregating the reference lists of all the articles published in *Ecosystem Services* itself. This data required pre-processing before analysis because references were occasionally entered incorrectly by authors into their reference lists and/or they may have been recorded incorrectly in *Scopus*. Using this data, we identified articles with 46 or more citations. This results in a list of highly cited articles that is larger than we ultimately needed. We then searched for these articles on *Scopus* and downloaded their number of total citations to ensure accurate numbers of citations. We selected the 30 most cited articles from this list. We also downloaded the number of citations that these most outwardly influential articles received from articles published in *Ecosystem Services*.

To find the journals that most frequently cited *Ecosystem Services,* we searched for all articles published in the journal using *Scopus*. We then requested the list of all articles citing those articles and counted the number of times each journal was cited. To find the journals most cited by *Ecosystem Services*, we downloaded the references in all articles published in the journal from the *Web of Science* (also on 19th May). We then searched for all journal titles with more than 100 *Ecosystem Services* citations, which turned out to generate far more journals than we needed for our final list. We used the *Web of Science* for this exercise as its reference lists are better formatted and more accurate. Note that, apart from issues of noise, there should be no difference, in principle, between the number of citations either an article or a journal receives from *Ecosystem Services* according to *Scopus* or the *Web of Science*.

3. Results

Our results show that over the past 10 years (from 2012 to 2021) academic activity around the topic of ES has grown significantly. Before 2012, there were 4,948 papers published by a total of 12,795 authors. Between 2012 and 2021, there were 33,973 papers published by 91,051 authors (Table 1).

In Table 1, in the rows showing the number of authors that have published 5 or more and 30 or more papers, the number of authors in the column for the entire period (1984–2021) is much larger than the total of the two separate periods. This is because when looking at the two separate periods, author publication numbers may be split. For example, for the line that shows 'Authors who published ≥30 papers', an author may have published 10 papers before 2011 and 25 papers after 2011. They would, therefore, not be included in either of the two separate time periods, but they would be included in the calculation for the entire

[2] https://pandas.pydata.org/.
[3] https://matplotlib.org/.
[4] https://kumu.io/.
[5] https://plotly.com/.

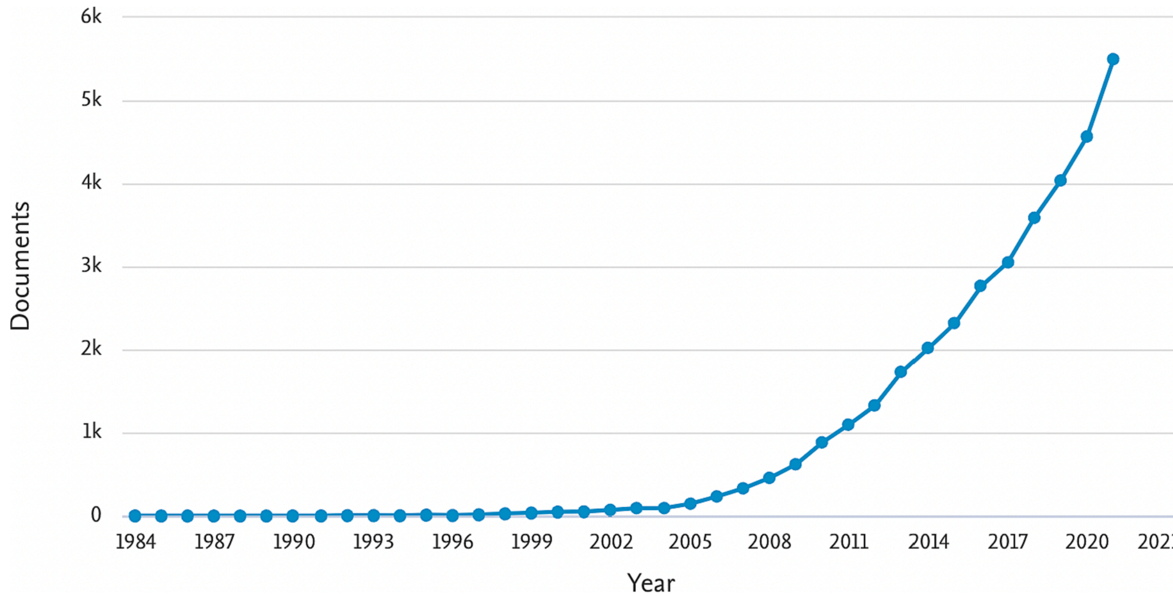

Fig. 1. The number of papers on ecosystem services published each year as noted in Scopus.

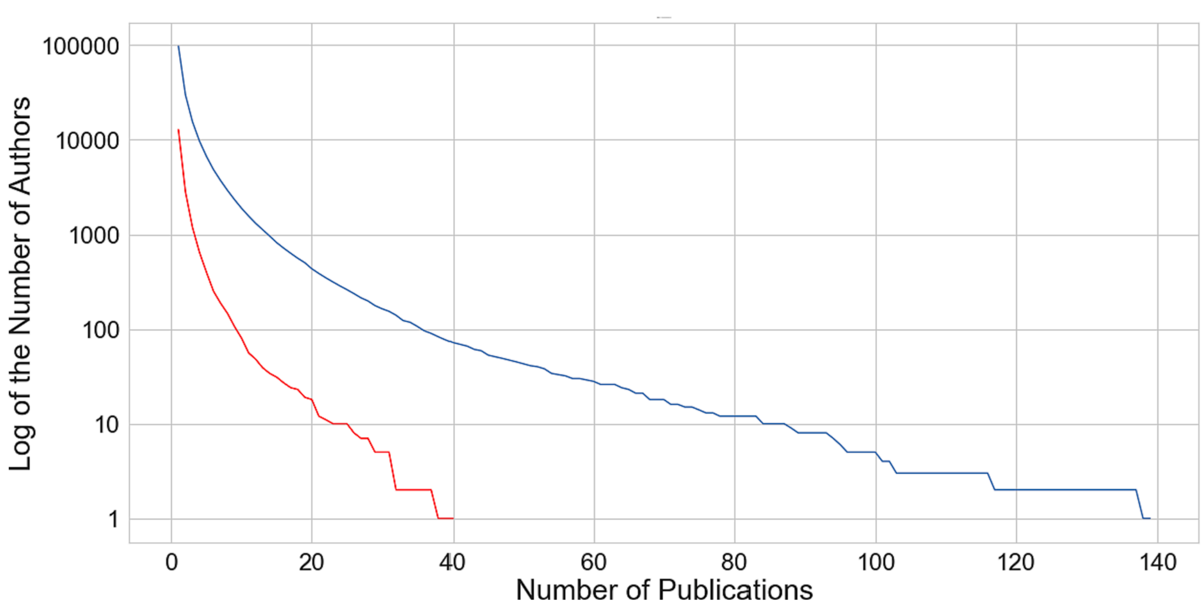

Fig. 2. The number of ES publications per author versus the number of authors with that many publications. The red line shows publications before 2012, the blue line shows publications before 2022. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

period.

In the rows stating the total numbers of authors and journals, the number for the entire period is less than the total of the two separate time periods. This is because a significant number of authors and journals published articles in both time periods, and they are not double-counted in the final column.

The number of journal articles published on ES has been growing exponentially, with more than 5,000 papers published in 2021 alone (Fig. 1).

We also compare the publication rate of authors up to 2012 and for the entire period (1984–2021) (Fig. 2). We find that the number of prolific authors increased significantly in the 10 years from 2012 to 2021. Fig. 2 shows that up to 2012, the most prolific author had published 40 papers on ES and just over 10,000 authors had published at least 1 paper on ES. By 2021the most prolific author had published almost 140 papers and around 100,000 authors had published at least 1 paper.

These two periods also show a change in the primary keywords listed by authors in articles on ES. Table 2 shows the 20 most used keywords in the two time periods with their relative frequency and the change in that relative frequency. Many of the top keywords appear in both time periods (14 keywords). The ones that do not make the top 20 list in the first period (1984–2011) include 'urban', 'green infrastructure', 'cultural ecosystem services', 'trade-offs', 'protected area', and 'payments for ecosystem services'. In the second period (2012–2021), the keywords that no longer made the top 20 list include 'ecosystems', 'economic value', 'valuation', 'sustainable development', 'ecosystem service value', and 'biodiversity conservation'.

The greatest positive change in relative frequency was for the keywords 'cultural ecosystem services', 'green infrastructure', 'trade-offs', 'payment for ecosystem services', 'urban', 'climate change,' and 'remote sensing'. The greatest decrease in relative frequency was for the

Table 2
The 20 most used keywords in the two time periods, with their relative frequency and change in relative frequency sorted from highest to lowest change in relative frequency.

Topic	1984–2011 # of uses	1984–2011 Relative frequency	2012–2021 # of uses	2012–2021 Relative frequency	Change in relative frequency
Total papers	**4,948**		**33,973**		
Cultural Ecosystem Services	2	0.0 %	436	1.3 %	3075.1 %
Green Infrastructure	7	0.1 %	455	1.3 %	846.7 %
Trade-Offs	27	0.5 %	426	1.3 %	129.8 %
Payments For Ecosystem Services	36	0.7 %	361	1.1 %	46.0 %
Urban	48	1.0 %	459	1.4 %	39.3 %
Climate Change	171	3.5 %	1,606	4.7 %	36.8 %
Remote Sensing	56	1.1 %	506	1.5 %	31.6 %
Protected Area	44	0.9 %	378	1.1 %	25.1 %
Land Use Change	60	1.2 %	446	1.3 %	8.3 %
Carbon Sequestration	67	1.4 %	422	1.2 %	−8.3 %
Agriculture	79	1.6 %	476	1.4 %	−12.2 %
Sustainability	125	2.5 %	753	2.2 %	−12.3 %
Conservation	126	2.5 %	750	2.2 %	−13.3 %
Restoration	72	1.5 %	403	1.2 %	−18.5 %
Resilience	74	1.5 %	409	1.2 %	−19.5 %
Pollinators	87	1.8 %	480	1.4 %	−19.6 %
Ecosystem Service Value	65	1.3 %	354	1.0 %	−20.7 %
Biodiversity	346	7.0 %	1,856	5.5 %	−21.9 %
Land Use	123	2.5 %	590	1.7 %	−30.1 %
Biodiversity Conservation	64	1.3 %	302	0.9 %	−31.3 %
Sustainable Development	80	1.6 %	351	1.0 %	−36.1 %
Wetlands	112	2.3 %	449	1.3 %	−41.6 %
Economic Value	90	1.8 %	338	1.0 %	−45.3 %
Ecosystem Functions	113	2.3 %	405	1.2 %	−47.8 %
Valuation	82	1.7 %	269	0.8 %	−52.2 %
Ecosystems	90	1.8 %	290	0.9 %	−53.1 %

keywords 'wetlands', 'economic value', 'ecosystem functions', 'valuation', and 'ecosystems'. But 'biodiversity' and 'climate change' have the highest relative keyword frequency in both time periods.

Next, we examine the 163 most prolific ES authors – those that have published at least 30 ES papers over the entire period (Table 3). These authors come from 29 countries, spanning 6 continents. They have authored, or co-authored, 5,152 papers on ES, 13 % of the total 38,921 ES papers.

We also look at the number of co-authors that these 163 authors had within this group of 163, since this is the basis for the interconnection strengths in the network diagram in Fig. 4. The ratio of their co-authorships with the 163 most prolific authors to their total co-authorships indicates the degree to which each author is publishing with younger authors or those newer to the field (i.e. not among the 163). These ratios range from 1 % to 19 %.

We find that there is a relationship between authors' number of co-authors and authors' citations ($R^2 = 0.26$) (Fig. 3). If the 12,554 citations for Costanza et al. (1997) are taken out, as this paper is an outlier in terms of citations, the R^2 increases to 0.29. This relationship is partially due to the fact that with more co-authors, the quality of the paper tends to increase. However, it is also partially due to the fact that with more co-authors, a paper will be disseminated to a greater extent by the authors themselves and its number of citations and self-citations will increase.

Fig. 4 presents a network diagram for these 163 authors.[6] Within this diagram, each bubble represents one of the authors, with the number in the circle matching the author number in Table 2. The size of each circle represents the author's number of ES publications, its colour represents their continent, and the thickness of the line connecting any two authors represents the number of ES papers the two authors published together. The circles are organised by continent, and within that, organised by smaller co-authorship clusters.

The distribution of authors (Fig. 4) shows that, by far, most of the authors are from Europe (90 authors), representing 15 countries: Austria (2), Belgium (4), Denmark (1), Finland (2), France (3), Germany (25), Hungary (1), Italy (3), Lithuania (1), Netherlands (8), Norway (3), Spain (6), Sweden (7), Switzerland, (2), and the United Kingdom (22). North America has about a third of the number of the authors as Europe with 31 authors from three countries: Canada (3), Mexico (1), and the United States (27). Asia has a similar number of authors as North America (24) with 21 of those from China. The other three countries are Indonesia (2), Israel (1), and Singapore (1). The least represented continents are Oceania (7), South America (5), and Africa (5). Oceania is only represented by Australia (3) and New Zealand (4). South America is represented by Argentina (1), Brazil (2), Chile (1), and Uruguay (1). Africa is represented by South Africa (5) alone.

In Asia, there are two independent clusters that never co-author with each other. They are each centred around one of the two most prolific authors in the field. One of these clusters rarely publishes with any of the other authors on this list, with a few minor exceptions. The other cluster publishes extensively with North American authors, but rarely with authors from any other continents. Asia also has several authors that do not publish with any of the other authors in our list.

In North America, one loose cluster of authors is evident. However, the rest of the authors publish papers mainly with authors from other continents. In Europe, there are three loose clusters. However, extensive collaboration seems to occur among most of the authors in Europe. In Africa, Oceania, and South America there is no apparent clustering among their limited number of prolific authors. The authors from these continents mostly publish with authors from other continents, and rarely with each other. Outside of China, none of the clusters is centred around a specific individual. On the other continents, publishing happens in groups, with extensive links between these groups, both within and outside their own continent.

In the past decade, the number of journals that have published in this field has also increased significantly. Before 2012, only 1,276 journals had published on ES. By the end of 2021, that increased to 3,693 journals. We select the 10 journals that published the most ES articles in each year from 2001 to 2021. We then delete journals that have less than 25 cumulative ES articles. There are 59 journals remaining. The heat map (Fig. 5) shows the number of ES publications that these 59 journals had in each year.

We also analyse the articles published in the journal *Ecosystem Services*. We found a total of 1,350 articles published in *Ecosystem Services* as of 19th May 2022, which is cumulatively the largest number of papers on ES published in any journal. These were cited a total of 42,620 times and made a total of more than 91,000 citations.

Table 4 shows the three most cited articles published in each year in *Ecosystem Services*, which we call 'outwardly influential'. These articles received about a fifth of the total number of citations received by the journal. About half of them (16 out of 30) were published as open access. Out of the 30 papers in Table 3, eight are review articles.

The article that has had the most citations per year is Costanza et al. (2017), with 189 citations per year, followed by de Groot et al. (2012) with 128 citations per year (Table 4). These two articles are the only articles that have over 100 citations per year, and about 13 % and 10 %,

[6] An interactive version of this figure can be found at https://kumu.io/lukeconcollato/es#es-map-with-names/condensed-view-ida.

Table 3
List of the 163 most prolific ES authors. The first column (#) corresponds to the author's number in the network diagram shown in Fig. 3. The table includes each author's h-index, number of co-authors, co-authors among the 163 most prolific authors, total citations and total publications in Scopus, and country of current affiliation. Green highlighted authors had more than 30 ES papers before 2012. (Abbreviations: NZ – New Zealand, SA – South Africa, UK – United Kingdom, US – United States).

#	Name	ES h-index	Total Co-authors	Average Co-authors	Co-authors among these 163	163 co-authors/Total Co-authors	Total Cites	Ave. Cites	Total Pubs	Country
1	Albert C.	17	170	4.59	19	11 %	904	24.4	37	Germany
2	Andersson E.	19	104	3.35	13	13 %	2860	92.3	31	SA
3	Angelstam P.	17	197	5.63	10	5 %	1264	36.1	35	Norway
4	Aronson J.	20	131	4.23	17	13 %	2840	91.6	31	US
5	Bagstad K.J.	20	187	4.07	18	10 %	2069	45	46	US
6	Bai Y.	16	55	1.57	5	9 %	890	25.4	35	China
7	Bakshi B.R.	17	48	1.07	1	2 %	1165	25.9	45	US
8	Balmford A.	25	197	5.47	9	5 %	3688	102.4	36	UK
9	Balvanera P.	28	351	7.8	35	10 %	6874	152.8	45	Mexico
10	Baral H.	19	120	3.87	7	6 %	1031	33.3	31	Indonesia
11	Barbier E.B.	24	158	3.29	10	6 %	8880	185	48	US
12	Barton D.N.	25	349	7.93	32	9 %	2843	64.6	44	Norway
13	Bastian O.	15	78	2.52	7	9 %	855	27.6	31	Germany
14	Batáry P.	19	434	13.56	21	5 %	3280	102.5	32	Hungary
15	Beaumont N.	16	178	4.68	10	6 %	3711	97.7	38	UK
16	Bengtsson J.	24	201	6.28	24	12 %	5941	185.7	32	Sweden
17	Bennett E.M.	32	314	4.91	35	11 %	6892	107.7	64	US
18	Birkhofer K.	21	402	11.82	19	5 %	2277	67	34	Germany
19	Bommarco R.	37	461	8.87	22	5 %	6560	126.2	52	Sweden
20	Bonn A.	20	358	9.68	34	9 %	1101	29.8	37	Germany
21	Bouma T.J.	15	185	5.61	1	1 %	962	29.2	33	Netherlands
22	Brancalion P.H.S.	19	196	5.44	5	3 %	1766	49.1	36	Brazil
23	Brander L.M.	16	214	6.69	24	11 %	2219	69.3	32	Netherlands
24	Bremer L.L.	13	196	6.53	8	4 %	791	26.4	30	US
25	Bryan B.A.	26	121	2.57	6	5 %	2136	45.4	47	Australia
26	Bugmann H.	16	150	4.84	6	4 %	2883	93	31	Switzerland
27	Bullock J.M.	21	210	4.2	23	11 %	3669	73.4	50	UK
28	Burgess N.D.	19	286	7.94	8	3 %	1352	37.6	36	UK
29	Burkhard B.	34	420	4.52	42	10 %	5769	62	93	Germany
30	Carpenter S.R.	27	156	4.88	14	9 %	9269	289.7	32	US
31	Chan K.M.A.	31	336	5.33	34	10 %	9135	145	63	Canada
32	Chaplin-Kramer R.	22	508	13.37	39	8 %	3049	80.2	38	US
33	Cheung W.W.L.	18	344	10.75	14	4 %	3764	117.6	32	Canada
34	Clough Y.	19	337	9.11	16	5 %	4151	112.2	37	Sweden
35	Costanza R.	45	392	3.92	27	7 %	25,572	255.7	100	UK
36	Crossman N.D.	22	208	5.2	24	12 %	3177	79.4	40	Australia
37	Cumming G.S.	21	128	3.46	21	16 %	3022	81.7	37	Australia
38	Daily G.C.	45	313	4.06	35	11 %	13,274	172.4	77	US
39	de Groot R.	33	305	4.55	49	16 %	23,786	355	67	Netherlands
40	Deng X.	17	71	2.22	1	1 %	1052	32.9	32	China
41	Dick J.M.	17	269	8.68	37	14 %	854	27.5	31	UK
42	Díaz S.	21	333	11.1	20	6 %	9356	311.9	30	Argentina
43	Egoh B.	24	245	7	34	14 %	4723	134.9	35	US
44	Ehrlich P.R.	25	76	2.45	8	11 %	6825	220.2	31	US
45	Eigenbrod F.	18	174	4.58	29	17 %	2386	62.8	38	UK
46	Eisenhauer N.	18	426	13.31	17	4 %	2538	79.3	32	Germany
47	Elmqvist T.	36	246	4.82	35	14 %	9895	194	51	Sweden
48	Escobedo F.J.	23	111	2.09	2	2 %	2178	41.1	53	US
49	Everard M.	16	130	1.76	5	4 %	1163	15.7	74	UK
50	Fisher B.	20	150	4.29	14	9 %	4465	127.6	35	US
51	Folke C.	44	205	3.73	22	11 %	17,792	323.5	55	Sweden
52	Friess D.A.	18	234	5.09	6	3 %	1444	31.4	46	Singapore
53	Fu B.	32	286	2.47	17	6 %	5135	44.3	116	China
54	Fürst C.	21	140	3.18	17	12 %	1373	31.2	44	Germany
55	Gao J.-X.	7	101	3.06	2	2 %	216	6.5	33	China
56	García-Llorente M.	30	244	4.52	20	8 %	3681	68.2	54	Spain
57	Gaston K.J.	38	124	1.97	4	3 %	6083	96.6	63	UK
58	Geneletti D.	25	268	4.12	28	10 %	2529	38.9	65	Italy
59	Ghermandi A.	17	70	2.26	7	10 %	1829	59	31	Israel
60	Gómez-Baggethun E.	43	407	5.81	36	9 %	8576	122.5	70	Norway
61	Gratton C.	19	321	10.7	19	6 %	2545	84.8	30	US
62	Grêt-Regamey A.	30	315	4.38	39	12 %	3575	49.7	72	Switzerland
63	Grunewald K.	17	169	3.19	16	9 %	1013	19.1	53	Germany
64	Haase D.	32	208	2.97	22	11 %	3822	54.6	70	Germany
65	Haines-Young R.	19	245	7.42	33	13 %	2820	85.5	33	UK
66	Halpern B.S.	21	220	7.33	11	5 %	6871	229	30	US
67	Hanley N.	15	96	3	5	5 %	797	24.9	32	UK
68	Harrison P.A.	23	246	6.31	25	10 %	2787	71.5	39	UK

(continued on next page)

Table 3 (*continued*)

#	Name	ES h-index	Total Co-authors	Average Co-authors	Co-authors among these 163	163 co-authors/Total Co-authors	Total Cites	Ave. Cites	Total Pubs	Country
69	Hein L.	27	96	1.78	14	15 %	5694	105.4	54	Netherlands
70	Jacobs S.	18	252	7.41	29	12 %	1304	38.4	34	Belgium
71	Jiang B.	16	56	1.47	7	13 %	926	24.4	38	China
72	Jones L.	17	264	8	9	3 %	1295	39.2	33	UK
73	Kleijn D.	24	307	8.77	18	6 %	4812	137.5	35	Netherlands
74	Klein A.-M.	34	463	7.72	24	5 %	10,185	169.8	60	Germany
75	Koellner T.	20	159	3.24	19	12 %	1412	28.8	49	Germany
76	Kremen C.	48	391	5.84	29	7 %	17,303	258.3	67	Canada
77	Kubiszewski I.	17	168	4.94	6	4 %	4185	123.1	34	UK
78	Lal R.	29	121	1.61	2	2 %	2789	37.2	75	US
79	Landis D.A.	27	342	8.55	20	6 %	4693	117.3	40	US
80	Langemeyer J.	20	198	5.82	19	10 %	1633	48	34	Spain
81	Lavorel S.	44	596	6.85	50	8 %	14,625	168.1	87	NZ
82	Li F.	18	57	1.46	2	4 %	1371	35.2	39	China
83	Li J.	13	52	1.24	3	6 %	462	11	42	China
84	Liu J.	26	99	2.91	17	17 %	4047	119	34	US
85	Liu Y.	18	93	1.9	6	6 %	1363	27.8	49	China
86	Locatelli B.	22	146	4.29	20	14 %	1310	38.5	34	France
87	Loreau M.	17	170	4.86	11	6 %	8229	235.1	35	France
88	Lovelock C.E.	15	159	4.54	4	3 %	1138	32.5	35	Australia
89	Lü Y.-H.	19	91	1.82	5	5 %	1909	38.2	50	China
90	Mace G.M.	25	328	8.63	30	9 %	6946	182.8	38	UK
91	Maes J.	31	326	5.02	44	13 %	4328	66.6	65	Italy
92	Martín-López B.	48	583	5.72	57	10 %	9090	89.1	102	Germany
93	Matzdorf B.	15	93	2.74	11	12 %	1233	36.3	34	Germany
94	McPhearson T.	18	98	3.16	14	14 %	2120	68.4	31	US
95	Meire P.	15	81	2.31	5	6 %	699	20	35	Belgium
96	Metzger J.P.	13	257	7.14	16	6 %	1738	48.3	36	Brazil
97	Metzger M.J.	16	158	5.27	13	8 %	2581	86	30	UK
98	Min Q.-W.	8	50	1.67	3	6 %	244	8.1	30	China
99	Montes C.	29	82	1.74	11	13 %	4385	93.3	47	Spain
100	Mooney H.A.	22	232	7.25	33	14 %	8246	257.7	32	US
101	Müller F.	21	284	4.9	28	10 %	3850	66.4	58	Germany
102	Mulligan M.	13	225	7.26	18	8 %	1404	45.3	31	UK
103	Muys B.	18	308	7.33	4	1 %	876	20.9	42	Belgium
104	Nahuelhual L.	16	85	2.66	3	4 %	994	31.1	32	Chile
105	Nowak D.J.	21	119	2.7	11	9 %	2765	62.8	44	US
106	O'Farrell P.J.	21	191	5.62	22	12 %	2600	76.5	34	SA
107	Ouyang Z.	30	309	2.26	18	6 %	5021	36.6	137	China
108	Palomo I.	27	295	6.86	33	11 %	3194	74.3	43	France
109	Paruelo J.	13	103	3.22	5	5 %	12,419	388.1	32	Uruguay
110	Pascual U.	32	411	7.34	32	8 %	6755	120.6	56	Spain
111	Pauleit S.	19	114	3.35	10	9 %	1742	51.2	34	Germany
112	Peng J.	20	95	1.98	4	4 %	1453	30.3	48	China
113	Pereira H.	21	349	9.18	30	9 %	4609	121.3	38	Germany
114	Pereira P.	9	136	4.25	18	13 %	302	9.4	32	Lithuania
115	Perrings C.	17	154	4.81	23	15 %	3013	94.2	32	US
116	Peterson G.D.	28	201	5.74	39	19 %	7394	211.3	35	Sweden
117	Philpott S.M.	20	258	7.59	14	5 %	2292	67.4	34	US
118	Plieninger T.	32	285	4.25	33	12 %	3593	53.6	67	Germany
119	Polasky S.	48	433	5.22	41	9 %	17,428	210	83	US
120	Potts S.G.	44	687	8.28	25	4 %	12,258	147.7	83	UK
121	Pretzsch H.	15	225	5.49	4	2 %	916	22.3	41	Germany
122	Reed M.S.	20	165	5.5	7	4 %	1512	50.4	30	UK
123	Reyers B.	30	218	5.19	36	17 %	5401	128.6	42	SA
124	Richards D.R.	15	95	2.97	3	3 %	1104	34.5	32	NZ
125	Richardson D.M.	31	190	4.32	8	4 %	4075	92.6	44	SA
126	Ricketts T.H.	35	332	5.63	45	14 %	13,168	223.2	59	US
127	Ruckelshaus M.	24	251	6.28	19	8 %	5271	131.8	40	US
128	Schirpke U.	18	84	1.95	9	11 %	1057	24.6	43	Austria
129	Schröter M.	18	205	5.86	39	19 %	1862	53.2	35	Germany
130	Schulp C.J.E.	20	110	3.24	16	15 %	1724	50.7	34	Netherlands
131	Seppelt R.	22	352	8.19	38	11 %	3005	69.9	43	Germany
132	Setälä H.	20	138	4.31	10	7 %	6867	214.6	32	Finland
133	Settele J.	28	353	6.79	23	7 %	5043	97	52	Germany
134	Shackleton C.M.	17	125	3.38	8	6 %	1102	29.8	37	SA
135	Smith H.G.	14	355	11.45	23	6 %	1091	35.2	31	Sweden
136	Smith P.	18	266	8.58	6	2 %	4017	129.6	31	UK
137	Steffan-Dewenter I.	39	431	7.18	19	4 %	11,077	184.6	60	Germany
138	Syrbe R.-U.	11	73	2.28	8	11 %	841	26.3	32	Germany
139	Tallis H.	23	228	6.33	21	9 %	5770	160.3	36	US
140	Tappeiner U.	26	183	3.45	15	8 %	2003	37.8	53	Austria
141	Tasser E.	18	73	2.03	3	4 %	1093	30.4	36	Italy

(*continued on next page*)

Table 3 (*continued*)

#	Name	ES h-index	Total Co-authors	Average Co-authors	Co-authors among these 163	163 co-authors/Total Co-authors	Total Cites	Ave. Cites	Total Pubs	Country
142	Termansen M.	21	321	9.73	20	6 %	2523	76.5	33	Denmark
143	Tscharntke T.	53	780	8.3	36	5 %	14,512	154.4	94	Germany
144	Turner R.K.	23	125	3.38	13	10 %	7078	191.3	37	UK
145	Van Beukering P.	11	166	5.53	23	14 %	1516	50.5	30	Netherlands
146	Van Noordwijk M.	20	187	4.45	11	6 %	1657	39.5	42	Indonesia
147	Verburg P.H.	42	306	3.48	30	10 %	5564	63.2	88	Netherlands
148	Verheyen K.	18	281	7.21	5	2 %	1095	28.1	39	Belgium
149	Vihervaara P.	16	242	8.07	21	9 %	1412	47.1	30	Finland
150	Villa F.	16	153	4.14	13	8 %	1431	38.7	37	Spain
151	Wang S.	14	54	1.69	5	9 %	1103	34.5	32	China
152	Weisser W.W.	25	498	12.15	27	5 %	5089	124.1	41	Germany
153	Woodcock B.A.	17	348	11.23	20	6 %	2011	64.9	31	UK
154	Wratten S.D.	26	363	6.48	18	5 %	3077	54.9	56	NZ
155	Wu J.	19	129	2.93	2	2 %	2543	57.8	44	China
156	Wunder S.	19	112	3.61	7	6 %	4090	131.9	31	Spain
157	Xiao Y.	14	98	2.23	9	9 %	1338	30.4	44	China
158	Xie G.	12	84	2.15	5	6 %	658	16.9	39	China
159	Xu W.-H.	18	118	2.88	10	8 %	1572	38.3	41	China
160	Yang Z.-F.	12	59	1.97	1	2 %	651	21.7	30	China
161	Zhao W.-W.	11	59	1.51	5	8 %	515	13.2	39	China
162	Zhen L.	14	81	2.31	5	6 %	591	16.9	35	China
163	Zheng H.	25	204	2.15	12	6 %	2673	28.1	95	China

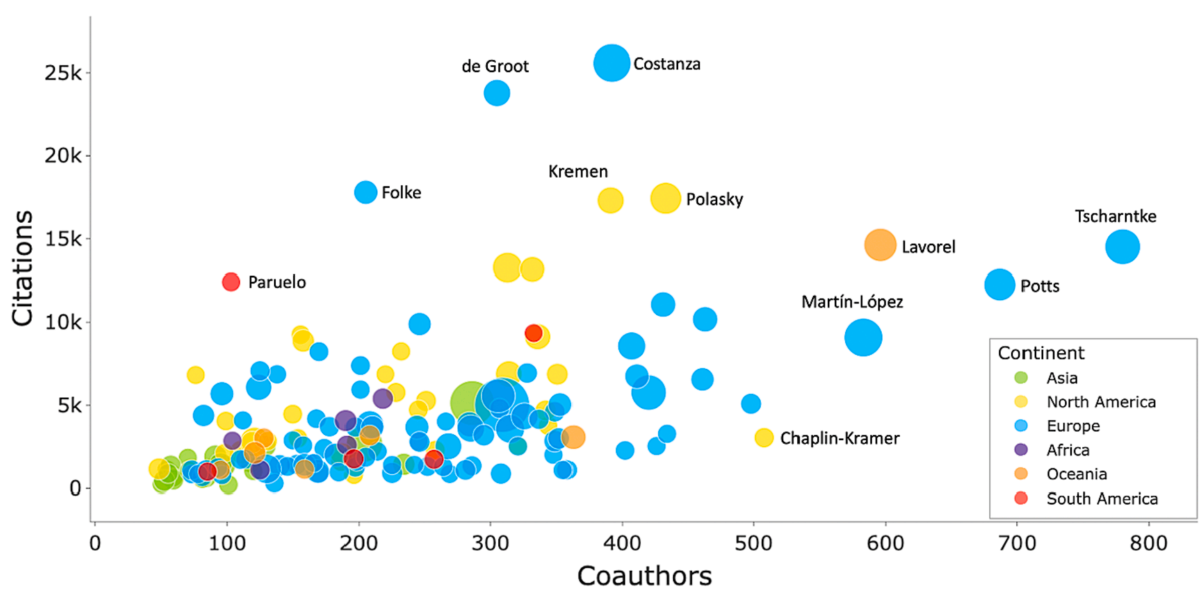

Fig. 3. Relationship between the number of co-authors and citations to papers by those authors. Each circle indicates one of the 163 authors. The colour of each circle indicates the author's current continent, and its size indicates the number of papers that person has published.

respectively, of these citations come from other articles in *Ecosystem Services*. Across the 30 articles, the share of total citations that come from the journal *Ecosystem Services* ranges from 0 to 24 %.

Table 5 provides a list of the top 30 ES articles published in all journals, ranked by their citations in the *Ecosystem Services* journal – the inwardly influential articles. The most cited article is Costanza et al. (1997) with 12,554 citations in total. Only 2.4 % of these citations are by articles in *Ecosystem Services*. Foley et al. (2005) is the second most cited paper with 7,660 citations in total (Table 5). Only 0.7 % of these citations come from articles published in *Ecosystem Services*. It makes sense that the more cited papers in the table are older as they have had more time to accumulate citations.

Table 6 presents a list of the 20 journals that most cite articles in *Ecosystem Services* as well as the top 20 journals that are cited by articles in *Ecosystem Services*. For the citing journals, the table displays the number of their articles that cite *Ecosystem Services*. Each citing article could cite more than one *Ecosystem Services* article. For the cited journals, the table shows the number of citations they received from *Ecosystem Services*. Nine journals appear in both lists: *Ecosystem Services, Ecological Economics, Ecological Indicators, Science of the Total Environment, Land Use Policy, Journal of Environmental Management, PloS ONE, Ecology and Society,* and *Environmental Science & Policy*.

4. Discussion

The data for the years 1984 to 2011 in this paper do not exactly match the data we presented in Costanza and Kubiszewski (2012). This is because: (1) we use *Scopus* in this paper, while our 2012 paper used the *Web of Science*, (2) both *Scopus* and the *Web of Science* have diversified the types of publications they carry to include reports, books, and book chapters, and (3) over the past decade, *Scopus* and the *Web of Science* have digitised earlier work, which has been added to both

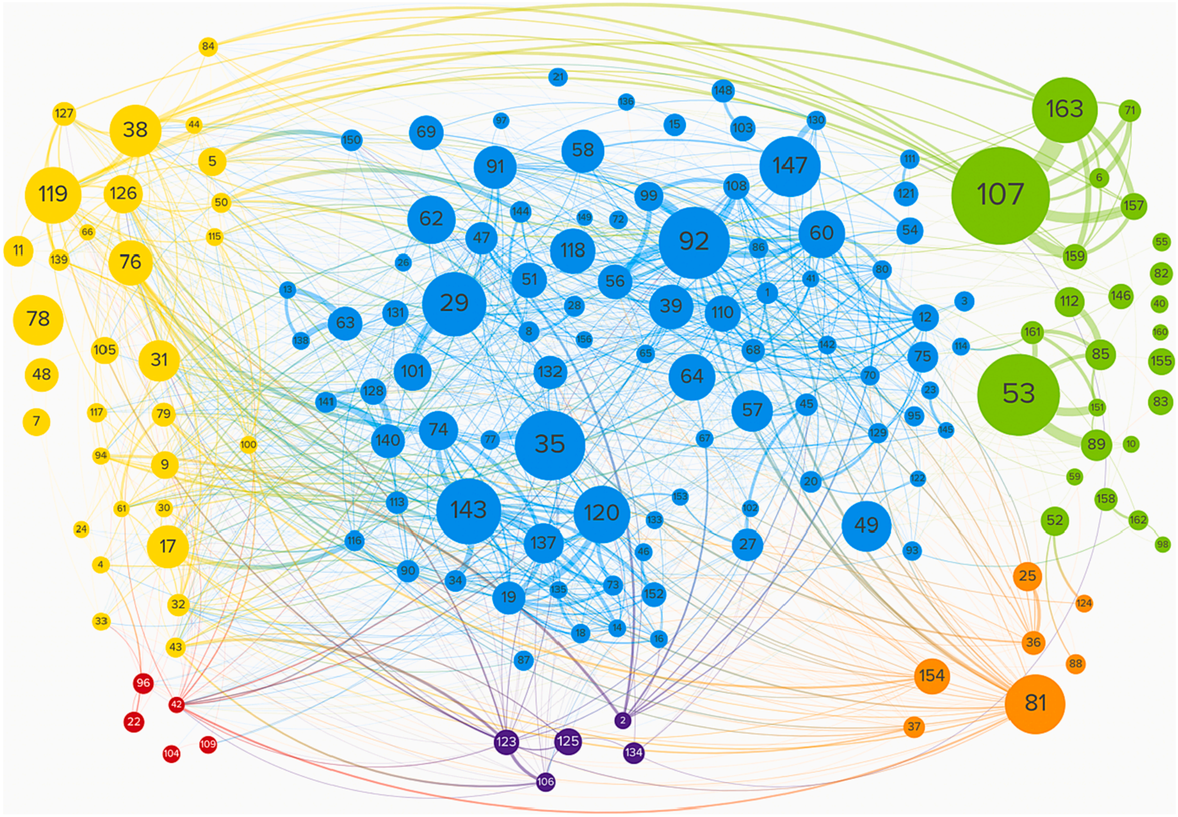

Fig. 4. Network diagram of the most prolific 163 authors in the field of ecosystem services. The number in each circle is keyed to the authors listed in the first column (#) of Table 3. The size of each circle represents the number of publications of each author, the colour represents the continent, and the thickness of the line connecting them represents the number of ES papers the two authors published together. Colour legend is the same as in Fig. 3 (yellow = North America, red = South America, blue = Europe, purple – Africa, green = Asia, and orange = Oceania). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

databases.

We must acknowledge that the number of publications and citations does not measure an author's or publication's full impact. For example, the relative influence of academic publications in a world of blogs, websites, big reports, and social media is decreasing. The policy and practice communities have become less reliant on academic publications for their work. However, publication and citation analysis of academic literature is still the most quantitative and objective way to assess impact within the academic research community. We acknowledge both its benefits and limitations.

Before 2012, there were only 396 authors that had published 5 or more papers on ES and 4 that had published 30 or more (highlighted in green in Table 3). However, if we look at papers published in just the last decade, there were 5,085 authors that published 5 or more papers and there were 116 that had 30 or more. This is more than an order of magnitude increase in the number of authors publishing in this field. Looking at all papers published on ES over the full period (1984–2021), 6,672 authors have published 5 or more papers and 163 authors have published 30 or more papers. These numbers are much larger than the sums of authors from the two time periods. This is because there are authors that published some papers before 2012 and then some papers after 2012. However, because their publications are split between the two time periods, they did not make the 5 or 30 paper cut-offs in either individual period but do meet them when those time periods are combined.

Co-authorship patterns have also changed in the past decade. With significantly more authors publishing on the topic of ES, the most prolific authors are no longer in as tight clusters as they were 10 years ago (Costanza and Kubiszewski, 2012). This seems like a natural evolution. As more authors, from varying backgrounds and fields, have begun to publish on ES, these 163 authors have more opportunities to publish with others entering the field. This creates the opportunity for new ideas to enter the field, and for the field to grow and evolve. It is important to remember, that the co-authorship patterns, shown in Fig. 4, are only those among the 163 most prolific authors out of the total of 97,868 authors who have published on ES. These 163 authors may publish extensively with others that are not on this list. They are often in research groups that frequently co-author papers together. For example, Table 3 shows the total number of co-authors for each author, along with the number of co-authors that are also among the 163 most prolific authors. The ratio of these two, ranging from 1 % to 19 %, indicates the extent to which authors are publishing with other prolific authors rather than with authors who are younger or newer to the field and have not published many papers yet. These 163 authors publish mostly with authors external to this list, many having hundreds of co-authors only a handful of which come from this prolific group.

Fig. 4 shows the geographic distribution of the most prolific authors and their connections with other prolific authors. Europe is obviously the home of most of these authors, but there are strong nodes in North America and Asia and emerging nodes in South America, Africa, and Oceania. Comparing Fig. 4 with the analogous network diagram (Fig. 5) in Costanza and Kubiszewski (2012), it is clear that the network of prolific authors has become much less clustered around a few key authors or groups and much more interconnected globally. This is consistent with the maturing of the field and the rapidly increasing number of papers, authors, and collaborations.

Significant growth has occurred in the number of journals that have published on the topic of ES, rising from 1,276 at the end of 2011 to 3,692 at the end of 2021. However, it is important to keep in mind that the overall number of journals, on all topics, has also increased. It is

Fig. 5. A heat map showing the top 10 journals, in each year, that published in the field of ecosystem services. Journals are organised in alphabetical order. The number in parentheses after the journal title is the cumulative number of ES articles published in the journal.

estimated that at least 30,000 academic journals exist, with a growth rate of 5–7 % a year (Musa, 2021) – *Scopus* catalogues more than 27,000 active journals. The diversity of journals publishing articles in the ES field has also increased. In addition, more general journals, such as *PLoS ONE* and *Proceedings of the National Academy of Sciences of the United States of America* (*PNAS*), have published significant numbers of ES articles (Fig. 3).

The types of articles in the ES field have also shifted. In both time periods, 1984–2011 and 2012–2021, the two keywords most used in ES papers were 'biodiversity' and 'climate change' (Table 2). Even though the problems that these two keywords represent remain critical, the relative frequency of their usage in the later period has decreased as more articles on a wider range of topics have been published. Changes in the relative usage of keywords show how topics of interest have shifted within the field of ES. For example, the keywords 'cultural ecosystem services' and 'green infrastructure' show the largest increase in relative frequency. Other keywords, such as 'ecosystems' and 'valuation', have seen the greatest decrease in relative frequency. Unsurprisingly, as the field of ES has developed and matured, more specific topics have become more frequently studied. For example, 'cultural ecosystem services' are more difficult to adequately assess, hence they were relatively understudied in the early years but have become increasingly studied more recently. Likewise, 'green infrastructure', along with the synonym 'nature-based solutions', has become more popular, and as a result has

Table 4
The top three articles published each year in the journal Ecosystem Services that were most cited, or outwardly influential.

Yr.	Publication	Total cites	Ecosystem Services cites	Ecosystem Services/Total cites	Total cites per year
2012	(de Groot et al., 2012)	1283	128	10 %	128
	(Maes et al., 2012)	622	88	14 %	62
	(Braat and de Groot 2012)	588	125	21 %	59
2013	(Crossman et al., 2013)	472	80	17 %	52
	(Bagstad et al., 2013b)	428	63	15 %	48
	(Bagstad et al., 2013a)	316	49	16 %	35
2014	(Harrison et al., 2014)	337	48	14 %	42
	(Fisher et al., 2014)	149	31	21 %	19
	(Krasny et al., 2014)	109	10	9 %	14
2015	(Sandifer et al., 2015)	525	31	6 %	75
	(Brown and Fagerholm 2015)	286	34	12 %	41
	(Luederitz et al., 2015)	231	26	11 %	33
2016	(Maes et al., 2016)	341	43	13 %	57
	(Fish et al., 2016)	306	60	20 %	51
	(Jacobs et al., 2016)	216	51	24 %	36
2017	(Costanza et al., 2017)	946	125	13 %	189
	(Tolessa et al., 2017)	232	14	6 %	46
	(Xie et al., 2017)	204	12	6 %	41
2018	(Wood et al., 2018)	167	16	10 %	42
	(Turkelboom et al., 2018)	141	23	16 %	35
	(Bouwma et al., 2018)	125	26	21 %	31
2019	(Rimal et al., 2019)	92	2	2 %	31
	(Cheng et al., 2019)	72	15	21 %	24
	(Wang et al., 2019)	56	0	0 %	19
2020	(Costanza 2020)	58	8	14 %	29
	(Lajoie-O`Malley et al., 2020)	52	0	0 %	26
	(Jiang et al., 2020)	40	1	3 %	20
2021	(Zhang et al., 2021)	16	0	0 %	16
	(Valencia Torres et al., 2021)	13	1	8 %	13
	(Quatrini 2021)	11	0	0 %	11

Table 5
Top 30 articles most cited by articles in Ecosystem Services. Arranged in order of descending Ecosystem Services citations.

Publication	Ecosystem Services cites	Total cites	Ecosystem Services/ total cites
(Costanza et al., 1997)	295	12,554	2.4 %
(de Groot et al., 2010)	205	2,062	9.2 %
(Fisher et al., 2009)	163	1,840	7.9 %
(Costanza et al., 2014)	143	2,675	4.9 %
(Chan et al., 2012)	135	881	11.8 %
(de Groot et al., 2012)	128	1,283	8.3 %
(Costanza et al., 2017)	125	946	12.3 %
(de Groot et al., 2002)	119	2,765	3.7 %
(Burkhard et al., 2012)	118	1,197	9.6 %
(Raudsepp-Hearne et al., 2010)	110	1,216	8.9 %
(Daniel et al., 2012)	106	850	11.9 %
(Daily et al., 2009)	105	1,285	7.2 %
(Díaz et al., 2015)	98	1,121	7.6 %
(Nelson et al., 2009)	93	1,637	5.4 %
(Engel et al., 2008)	93	1,417	6.3 %
(Gómez-Baggethun et al., 2010)	93	885	9.7 %
(Bennett et al., 2009)	92	1,399	6.1 %
(Boyd and Banzhaf 2007)	90	1,295	6.6 %
(Hein et al., 2006)	90	874	9.0 %
(Carpenter et al., 2009)	77	1,435	5.2 %
(Rodríguez et al., 2006)	71	895	8.0 %
(Díaz et al., 2018)	69	963	6.1 %
(Norgaard 2010)	66	687	9.3 %
(Pascual et al., 2017)	66	687	7.0 %
(Gómez-Baggethun and Barton 2013)	64	870	7.0 %
(Mace et al., 2012)	62	980	5.9 %
(Naidoo et al., 2008)	61	733	7.6 %
(Foley et al., 2005)	56	7,660	0.7 %
(Power 2010)	53	1,240	4.2 %
(Wunder et al., 2008)	53	751	6.3 %

received more research attention.

One of the largest publishers of ES articles is the journal *Ecosystem Services* itself, publishing 1,304 articles by the end of 2021. Out of all these articles, 76 did not include the term ‘ecosystem services’ in the title, abstract, or keywords and were left out of our analysis of the author network. These articles do, however, use similar or equivalent terms including: ‘nature’s contributions to people’, ‘valuing nature’, ‘environmental payments’, ‘natural capital’, etc.

The fact that about half of the 30 most influential articles in *Ecosystem Services* (Table 3) were published behind a pay wall, not open source, shows that paying for open-source articles may not be a prerequisite to becoming well cited. With today’s ability to distribute publications through email and various websites, restricting access to articles is less of a barrier to dissemination.

In Table 6, we found that articles in *Ecosystem Services* were cited by other articles in *Ecosystem Services* as much as they were by *Sustainability (Switzerland)* (1087 citing articles in each case). When looking at the two lists in Table 6, approximately half the journals are on both the citing and cited lists, showing that these journals influence each other and publish on similar topics forming a cluster of 9 ES journals.

Table 6
The top 20 journals that cite articles in Ecosystem Services (citing journals) and the top 20 journals that are cited by articles in Ecosystem Services (cited journals). The journals that are on both lists are in bold.

Top citing journals	Number of citing articles	Top cited journals	Number of citations
Ecosystem Services	1087	***Ecosystem Services***	6133
Sustainability (Switzerland)	1087	***Ecological Economics***	5060
Ecological Indicators	602	***Ecological Indicators***	1873
Science of the Total Environment	602	*PNAS*	1569
Land Use Policy	394	*Science*	1314
Journal of Environmental Management	373	***Ecology and Society***	1298
Ecological Economics	332	*Landscape and Urban Planning*	1097
Land	327	***Land Use Policy***	1094
Journal Of Cleaner Production	275	***Journal of Environmental Management***	1067
Forests	253	***PloS ONE***	967
Urban Forestry and Urban Greening	229	*Nature*	943
International Journal of Environmental Research and Public Health	210	*Biological Conservation*	858
PloS ONE	204	*Global Environmental Change*	806
Shengtai Xuebao	196	*Conservation Biology*	753
Landscape And Urban Planning	189	***Science of The Total Environment***	657
Ecology and Society	188	*Frontiers in Environmental Science*	652
Water (Switzerland)	187	*BioScience*	651
Remote Sensing	181	***Environmental Science & Policy***	612
Ocean And Coastal Management	176	*Current Opinion in Environmental Sustainability*	596
Environmental Science & Policy	163	*Ambio*	576

The majority of the remaining 11 journals in the ‘citing journals’ list are focused on more specific topics like forests, health, remote sensing, or oceans. These topics strongly relate to specific ecosystem services and so papers on them cite articles in *Ecosystem Services*. By contrast, in the list of ‘cited journals’, the remaining 11 journals are mostly very broad journals publishing on a multitude of topics. These journals include *Nature*, *Science*, *PNAS*, and *Ambio*, for example.

Unsurprisingly, the 9 journals found in both lists in Table 6, are also found in Fig. 5, which shows the 10 journals in each year that published the most papers in the field of ecosystem services. Most of the journals shown in Fig. 5 published an increasing number of ES articles over time. This is to be expected as the number of ES articles is growing overall. There are a few journals that either have one strong year or a small number of strong years of publishing ES articles. This may be due to a special issue on ES in that journal or groups of ES articles coming out every few years.

It is important to remember that we only include citing and cited journals in this study. There are several highly cited reports including the *Millennium Ecosystem Assessment, TEEB,* and IPBES, as well as several edited books that are not included in this analysis. Given the many different and often unclear ways that citations to these reports and their individual chapters are recorded in *Scopus*, we could not accurately count the number of citations they received.

5. Conclusions

It is clear that ecosystem services has become a major area of scientific research and policy application. Since our assessment of the field in 2012, the numbers of publications, authors, topics, and journals publishing papers in this field have grown substantially. In 2012, we concluded that “…the topic area of ecosystem services is highly collaborative, prolific, and well cited” (Costanza and Kubiszewski, 2012). That is still the case but even more so. The global networks of researchers have expanded and diversified, and the policy uptake of the research has increased dramatically. The *Ecosystem Services* journal has played a central role in this expansion and policy influence.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We dedicate this article to the late Leon Braat, first editor in chief of *Ecosystem Services*. He was a driving forces in the rapid growth, quality, and policy relevance of the journal as documented in this article. We also thank the editor and two anonymous reviewers for their helpful comments on earlier drafts.

References

Bagstad, K.J., Johnson, G.W., Voigt, B., Villa, F., 2013a. Spatial dynamics of ecosystem service flows: A comprehensive approach to quantifying actual services. Ecosyst. Serv. 4, 117–125.
Bagstad, K.J., Semmens, D.J., Waage, S., Winthrop, R., 2013b. A comparative assessment of decision-support tools for ecosystem services quantification and valuation. Ecosyst. Serv. 5, 27–39.
Bennett, E.M., Peterson, G.D., Gordon, L.J., 2009. Understanding relationships among multiple ecosystem services. Ecol. Lett. 12 (12), 1394–1404.
Bouwma, I., Schleyer, C., Primmer, E., Winkler, K.J., Berry, P., Young, J., Carmen, E., Špulerová, J., Bezák, P., Preda, E., Vadineanu, A., 2018. Adoption of the ecosystem services concept in EU policies. Ecosyst. Serv. 29, 213–222.
Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecol. Econ. 63 (2), 616–626.
Braat, L.C., de Groot, R., 2012. The ecosystem services agenda:bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosyst. Serv. 1 (1), 4–15.
Brown, G., Fagerholm, N., 2015. Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. Ecosyst. Serv. 13, 119–133.
Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping ecosystem service supply, demand and budgets. Ecol. Ind. 21, 17–29.
Carpenter, S.R., Mooney, H.A., Agard, J., Capistrano, D., DeFries, R.S., Díaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W.V., Sarukhan, J., Scholes, R.J., Whyte, A., 2009. Science for managing ecosystem services: beyond the millennium ecosystem assessment. Proc. Natl. Acad. Sci. 106 (5), 1305–1312.
Chan, K.M.A., Satterfield, T., Goldstein, J., 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecol. Econ. 74, 8–18.
Chaudhary, S., McGregor, A., Houston, D., Chettri, N., 2015. The evolution of ecosystem services: A time series and discourse-centered analysis. Environ Sci Policy 54, 25–34.
Cheng, X., Van Damme, S., Li, L., Uyttenhove, P., 2019. Evaluation of cultural ecosystem services: A review of methods. Ecosyst. Serv. 37, 100925.
Costanza, R., 2020. Valuing natural capital and ecosystem services toward the goals of efficiency, fairness, and sustainability. Ecosyst. Serv. 43, 101096.
Costanza, R., de Groot, R., Sutton, P.C., van der Ploeg, S., Anderson, S., Kubiszewski, I., Farber, S., Turner, R.K., 2014. Changes in the global value of ecosystem services. Glob. Environ. Chang. 26, 152–158.
Costanza, R., Howarth, R.B., Kubiszewski, I., Liu, S., Ma, C., Plumecocq, G., Stern, D.I., 2016. Influential publications in ecological economics revisited. Ecol. Econ. 123, 68–76.
Costanza, R., Kubiszewski, I., 2012. The authorship structure of “ecosystem services” as a transdisciplinary field of scholarship. Ecosyst. Serv. 1 (1), 16–25.
Costanza, R., d’Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O’Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world’s ecosystem services and natural capital. Nature 387 (6630), 253–260.
Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S., Grasso, M., 2017. Twenty years of ecosystem services: How far have we come and how far do we still need to go? Ecosyst. Serv. 28, 1–16.

Crossman, N.D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., Drakou, E. G., Martín-Lopez, B., McPhearson, T., Boyanova, K., Alkemade, R., Egoh, B., Dunbar, M.B., Maes, J., 2013. A blueprint for mapping and modelling ecosystem services. Ecosyst. Serv. 4, 4–14.

Daily, G.C., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J., Shallenberger, R., 2009. Ecosystem services in decision making: time to deliver. Front. Ecol. Environ. 7 (1), 21–28.

Daniel, T.C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J.W., Chan, K.M.A., Costanza, R., Elmqvist, T., Flint, C.G., Gobster, P.H., Gret-Regamey, A., Lave, R., Muhar, S., Penker, M., Ribe, R.G., Schauppenlehner, T., Sikor, T., Soloviy, I., Spierenburg, M., Taczanowska, K., Tam, J., von der Dunk, A., 2012. Contributions of cultural services to the ecosystem services agenda. PNAS 109 (23), 8812–8819.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complex. 7 (3), 260–272.

de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L.C., ten Brink, P., van Beukering, P., 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecosyst. Serv. 1 (1), 50–61.

de Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol. Econ. 41 (3), 393–408.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Brondizio, E., Chan, K.M.A., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y., Zlatanova, D., 2015. The IPBES Conceptual Framework — connecting nature and people. Curr. Opin. Environ. Sustain. 14, 1–16.

Díaz, S., U. Pascual, M. Stenseke, B. Martín-López, R. T. Watson, Z. Molnár, R. Hill, K. M. A. Chan, I. A. Baste, K. A. Brauman, S. Polasky, A. Church, M. Lonsdale, A. Larigauderie, P. W. Leadley, A. P. E. v. Oudenhoven, F. v. d. Plaat, M. Schröter, S. Lavorel, Y. Aumeeruddy-Thomas, E. Bukvareva, K. Davies, S. Demissew, G. Erpul, P. Failler, C. A. Guerra, C. L. Hewitt, H. Keune, S. Lindley and Y. Shirayama. (2018). Assessing nature's contributions to people. *Science* 359(6373): 270-272.

Engel, S., Pagiola, S., Wunder, S., 2008. Designing payments for environmental services in theory and practice: An overview of the issues. Ecol. Econ. 65 (4), 663–674.

Fish, R., Church, A., Winter, M., 2016. Conceptualising cultural ecosystem services: A novel framework for research and critical engagement. Ecosyst. Serv. 21, 208–217.

Fisher, J.A., Patenaude, G., Giri, K., Lewis, K., Meir, P., Pinho, P., Rounsevell, M.D.A., Williams, M., 2014. Understanding the relationships between ecosystem services and poverty alleviation: A conceptual framework. Ecosyst. Serv. 7, 34–45.

Fisher, B., Turner, K., Zylstra, M., Brouwer, R., de Groot, R., Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirkby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu, D., Balmford, A., 2008. Ecosystem services and economic theory: Integration for policy-relevant research. Ecol. Appl. 18 (8), 2050–2067.

Fisher, B., Turner, R.K., Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecol. Econ. 68 (3), 643–653.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global Consequences of Land Use. Science 309 (5734), 570–574.

Gómez-Baggethun, E., Barton, D.N., 2013. Classifying and valuing ecosystem services for urban planning. Ecol. Econ. 86, 235–245.

Gómez-Baggethun, E., de Groot, R., Lomas, P.L., Montes, C., 2010. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. Ecol. Econ. 69 (6), 1209–1218.

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N., Geertsema, W., Lommelen, E., Meiresonne, L., Turkelboom, F., 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosyst. Serv. 9, 191–203.

Hein, L., van Koppen, K., de Groot, R.S., van Ierland, E.C., 2006. Spatial scales, stakeholders and the valuation of ecosystem services. Ecol. Econ. 57 (2), 209–228.

Jacobs, S., Dendoncker, N., Martín-López, B., Barton, D.N., Gomez-Baggethun, E., Boeraeve, F., McGrath, F.L., Vierikko, K., Geneletti, D., Sevecke, K.J., Pipart, N., Primmer, E., Mederly, P., Schmidt, S., Aragão, A., Baral, H., Bark, R.H., Briceno, T., Brogna, D., Cabral, P., De Vreese, R., Liquete, C., Mueller, H., Peh, K.S.H., Phelan, A., Rincón, A.R., Rogers, S.H., Turkelboom, F., Van Reeth, W., van Zanten, B.T., Wam, H.K., Washbourne, C.-L., 2016. A new valuation school: Integrating diverse values of nature in resource and land use decisions. Ecosyst. Serv. 22 (Part B), 213–220.

Jiang, W., Lü, Y., Liu, Y., Gao, W., 2020. Ecosystem service value of the Qinghai-Tibet Plateau significantly increased during 25 years. Ecosyst. Serv. 44, 101146.

Krasny, M.E., Russ, A., Tidball, K.G., Elmqvist, T., 2014. Civic ecology practices: Participatory approaches to generating and measuring ecosystem services in cities. Ecosyst. Serv. 7, 177–186.

Kubiszewski, I., Mulder, K., Jarvis, D., Costanza, R., 2021. Toward better measurement of sustainable development and wellbeing: A small number of SDG indicators reliably predict life satisfaction. Sustain. Dev. 30 (1), 139–148.

Kubiszewski, I., Muthee, K., Rifaee Rasheed, A., Costanza, R., Suzuki, M., Noel, S., Schauer, M., 2022. The costs of increasing precision for ecosystem services valuation studies. Ecol. Ind. 135, 108551.

Lajoie-O'Malley, A., Bronson, K., van der Burg, S., Klerkx, L., 2020. The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. Ecosyst. Serv. 45, 101183.

Lakerveld, R., 2012. Applying political ecology to ecosystem services: Operationalizing an alternative approach to ecosystem services research using an empirical case study in Odisha. M.Sc, India.

Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., Panzer, L., Partelow, S., Rau, A.-L., Sasaki, R., Abson, D.J., Lang, D.J., Wamsler, C., von Wehrden, H., 2015. A review of urban ecosystem services: six key challenges for future research. Ecosyst. Serv. 14, 98–112.

Mace, G.M., Norris, K., Fitter, A.H., 2012. Biodiversity and ecosystem services: a multilayered relationship. Trends Ecol. Evol. 27 (1), 19–26.

Maes, J., Egoh, B., Willemen, L., Liquete, C., Vihervaara, P., Schägner, J.P., Grizzetti, B., Drakou, E.G., Notte, A.L., Zulian, G., Bouraoui, F., Luisa Paracchini, M., Braat, L., Bidoglio, G., 2012. Mapping ecosystem services for policy support and decision making in the European Union. Ecosyst. Serv. 1 (1), 31–39.

Maes, J., Liquete, C., Teller, A., Erhard, M., Paracchini, M.L., Barredo, J.I., Grizzetti, B., Cardoso, A., Somma, F., Petersen, J.-E., Meiner, A., Gelabert, E.R., Zal, N., Kristensen, P., Bastrup-Birk, A., Biala, K., Piroddi, C., Egoh, B., Degeorges, P., Fiorina, C., Santos-Martín, F., Naruševičius, V., Verboven, J., Pereira, H.M., Bengtsson, J., Gocheva, K., Marta-Pedroso, C., Snäll, T., Estreguil, C., San-Miguel-Ayanz, J., Pérez-Soba, M., Grêt-Regamey, A., Lillebø, A.I., Malak, D.A., Condé, S., Moen, J., Czúcz, B., Drakou, E.G., Zulian, G., Lavalle, C., 2016. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosyst. Serv. 17, 14–23.

Millennium Ecosystem Assessment (MEA), 2005. Ecosystems and Human Well-Being: Synthesis. Island Press.

Musa, Z., 2021. How Many Academic Journals are There in the World? PublishingState. com, PublishingState.

Naidoo, R., A. Balmford, R. Costanza, B. Fisher, R. E. Green, B. Lehner, T. R. Malcolm and T. H. Ricketts. (2008). Global mapping of ecosystem services and conservation priorities. *Proceedings of the National Academy of Sciences of the United States of America* 105(28): 9495-9500.

Nelson, E., Mendoza, G., Regetz, J., Ploasky, S., Tallis, H., Cameron, D.R., Chan, K.M.A., Dailey, G.C., Goldstein, J., Dareiva, P.M., Lansdorf, E., Naidoo, R., Ricketts, T.H., Shaw, M.R., 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Front. Ecol. Environ. 7, 4–11.

Norgaard, R.B., 2010. Ecosystem services: From eye-opening metaphor to complexity blinder. Ecol. Econ. 69 (6), 1219–1227.

Pagiola, S., 2008. Payments for Environmental Services: From Theory to Practice. World Bank, Washington DC.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R.T., Başak Dessane, E., Islar, M., Kelemen, E., Maris, V., Quaas, M., Subramanian, S.M., Wittmer, H., Adlan, A., Ahn, S., Al-Hafedh, Y.S., Amankwah, E., Asah, S.T., Berry, P., Bilgin, A., Breslow, S.J., Bullock, C., Cáceres, D., Daly-Hassen, H., Figueroa, E., Golden, C.D., Gómez-Baggethun, E., González-Jiménez, D., Houdet, J., Keune, H., Kumar, R., Ma, K., May, P.H., Mead, A., O'Farrell, P., Pandit, R., Pengue, W., Pichis-Madruga, R., Popa, F., Preston, S., Pacheco-Balanza, D., Saarikoski, H., Strassburg, B. B., van den Belt, M., Verma, M., Wickson, F., Yagi, N., 2017. Valuing nature's contributions to people: the IPBES approach. Curr. Opin. Environ. Sustain. 26–27, 7–16.

Pearsall, S.H., 1984. In Absentia Benefits of Nature Preserves: A Review. Environ. Conserv. 11 (1), 3–10.

Power, A.G., 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philos. Trans. R. Soc., B 365 (1554), 2959–2971.

Quatrini, S., 2021. Challenges and opportunities to scale up sustainable finance after the COVID-19 crisis: Lessons and promising innovations from science and practice. Ecosyst. Serv. 48, 101240.

Raudsepp-Hearne, C., G. D. Peterson and E. M. Bennett. (2010). Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proceedings of the National Academy of Sciences* 107(11): 5242-5247.

Rimal, B., Sharma, R., Kunwar, R., Keshtkar, H., Stork, N.E., Rijal, S., Rahman, S.A., Baral, H., 2019. Effects of land use and land cover change on ecosystem services in the Koshi River Basin. Eastern Nepal. *Ecosystem Services* 38, 100963.

Rodríguez, J.P., Beard, T.D., Bennett, E.M., Cumming, G.S., Cork, S.J., Agard, J., Dobson, A.P., Peterson, G.D., 2006. Trade-offs across Space, Time, and Ecosystem Services. Ecol. Soc. 11 (1).

Ruckelshaus, M.H., Jackson, S.T., Mooney, H.A., Jacobs, K.L., Kassam, K.-A.-S., Arroyo, M.T.K., Báldi, A., Bartuska, A.M., Boyd, J., Joppa, L.N., Kovács-Hostyánszki, A., Parsons, J.P., Scholes, R.J., Shogren, J.F., Ouyang, Z., 2020. The IPBES Global Assessment: Pathways to Action. Trends Ecol. Evol. 35 (5), 407–414.

Sandifer, P.A., Sutton-Grier, A.E., Ward, B.P., 2015. Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. Ecosyst. Serv. 12, 1–15.

Sarkki, S., Niemelä, J., Tinch, R., van den Hove, S., Watt, A., Young, J., 2013. Balancing credibility, relevance and legitimacy: A critical assessment of trade-offs in science–policy interfaces. Sci. Public Policy 41 (2), 194–206.

Steger, C., Hirsch, S., Evers, C., Branoff, B., Petrova, M., Nielsen-Pincus, M., Wardropper, C., van Riper, C.J., 2018. Ecosystem Services as Boundary Objects for Transdisciplinary Collaboration. Ecol. Econ. 143, 153–160.
Stern, D.I., 2014. High-ranked social science journal articles can be identified from early citation information. PLoS One 9 (11), e112520.
Sutton, P.C., Anderson, S.J., Costanza, R., Kubiszewski, I., 2016. The ecological economics of land degradation: impacts on ecosystem service values. Ecol. Econ. 129, 182–192.
Tolessa, T., Senbeta, F., Kidane, M., 2017. The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia. Ecosyst. Serv. 23, 47–54.
Turkelboom, F., Leone, M., Jacobs, S., Kelemen, E., García-Llorente, M., Baró, F., Termansen, M., Barton, D.N., Berry, P., Stange, E., Thoonen, M., Kalóczkai, Á., Vadineanu, A., Castro, A.J., Czúcz, B., Röckmann, C., Wurbs, D., Odee, D., Preda, E., Gómez-Baggethun, E., Rusch, G.M., Pastur, G.M., Palomo, I., Dick, J., Casaer, J., van Dijk, J., Priess, J.A., Langemeyer, J., Mustajoki, J., Kopperoinen, L., Baptist, M.J., Peri, P.L., Mukhopadhyay, R., Aszalós, R., Roy, S.B., Luque, S., Rusch, V., 2018. When we cannot have it all: Ecosystem services trade-offs in the context of spatial planning. Ecosyst. Serv. 29, 566–578.
Valencia Torres, A., Tiwari, C., Atkinson, S.F., 2021. Progress in ecosystem services research: A guide for scholars and practitioners. Ecosyst. Serv. 49, 101267.
Wang, L., Zheng, H., Wen, Z., Liu, L., Robinson, B.E., Li, R., Li, C., Kong, L., 2019. Ecosystem service synergies/trade-offs informing the supply-demand match of ecosystem services: Framework and application. Ecosyst. Serv. 37, 100939.
Wood, S.L.R., Jones, S.K., Johnson, J.A., Brauman, K.A., Chaplin-Kramer, R., Fremier, A., Girvetz, E., Gordon, L.J., Kappel, C.V., Mandle, L., Mulligan, M., O'Farrell, P., Smith, W.K., Willemen, L., Zhang, W., DeClerck, F.A., 2018. Distilling the role of ecosystem services in the Sustainable Development Goals. Ecosyst. Serv. 29, 70–82.
Wunder, S., Engel, S., Pagiola, S., 2008. Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. Ecol. Econ. 65 (4), 834–852.
Xie, G., Zhang, C., Zhen, L., Zhang, L., 2017. Dynamic changes in the value of China's ecosystem services. Ecosyst. Serv. 26, 146–154.
Zhang, Z., Peng, J., Xu, Z., Wang, X., Meersmans, J., 2021. Ecosystem services supply and demand response to urbanization: A case study of the Pearl River Delta, China. *Ecosyst. Serv.* 49, 101274.