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Review

Ecosystem Services in Southern Africa: Current and Emerging Trends—A Bibliometric Review

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Abstract: The assessment of ecosystem services (ESs) is important for Africa's sustainability and progress. Healthy ecosystems benefit humans in various forms; however, continuous anthropogenic activities have led to rapid alterations in their compositions, structures and functions worldwide. Due to the lack of understanding on the role of ES assessment in southern Africa, many ES assessment practices and methodologies have been widely debated Thus, a bibliometric analysis of ESs in southern Africa was conducted for the period of 1996–2021, to present the key features of ES assessment practices and methodologies and reveal evolutionary trends in this field. The results showed that in southern Africa, not many ES assessment studies have been published; however, South Africa was the most productive country in terms of author collaboration and publication output. Other leading countries in this field include the UK, USA, Germany and Australia. The most productive institutions in southern Africa are located in South Africa, and are the University of Cape Town, the Council for Scientific and Industrial Research (CSIR), Rhodes University, the University of KwaZulu Natal, and the University of Stellenbosch. The five funding institutions that are most active in supporting ES assessment in southern Africa are European. The main publishers of the research are either American or European and include the highly influential publishers Elsevier, Wiley, MDPI, Springer Nature and Resilience Alliance. VOS Viewer was employed as a visual analysis tool and CiteSpace as a graphic analysis tool to conduct the bibliometric analysis. A key conclusion is that most authors use qualitative methods to assess people's livelihoods and wellbeing as they relate to provisional and cultural services, while remotely sensed imagery is used as a key tool to assess the spatial extent of provisional and regulating services. Research recommendations include promoting a transdisciplinary approach in ES assessment in southern Africa.

Keywords: ecosystem services; southern Africa; bibliometric analysis; transdisciplinary

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1. Introduction

The ecosystem services (ESs) concept has gained traction due to the importance of nature's contribution to people's development [1]. This ESs concept can be traced back to the 1960s and beginning of the 1970s [2–4], when it first emerged as a framework to manage ecosystem damage caused by vast anthropogenic threats [5,6]. However, the idea has since transformed and been applied to advise political agendas through, for example, the Millennium Ecosystem Assessment (MEA), The Economics of Ecosystems and Biodiversity (TEEB) in 2010, and more recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) [7]. Hassan and Nawcho [8] adopted the definition of ESs from the MEA [9], which states that ESs are the benefits that humans acquire from ecosystems, either directly, or indirectly.

Ecosystem services are now defined as the benefits that people receive from the sustained management of biodiversity and ecosystem functions [10]. Although some authors emphasize either an ecological or economic perspective when defining ecosystem services [11], other definitions focus on different ES assessment methods such as ESs and human well-being (HWB) [12], ecosystem services to humans [13], ES value derivation [14] as well as quantifying and mapping ESs [15–17], and the utility of ecosystems for biodiversity [18–20]. ESs benefit people in various forms, such as through provisioning [21], supporting [22], regulating [23], and cultural services [24]. However, their utilization has led to rapid alterations in ecosystem composition, structure, and function [10,25]. For example, it has been shown that more than 58% of terrestrial Earth has been modified due to anthropogenic activities [21]. These include political instability [26], degradation [7], droughts [27], diseases [27], urbanization [28], industrialization [29], and inadequate knowledge of human wellbeing and livelihoods [30].

ESs studies in African countries, in particular in southern Africa, are confronted with challenges of ESs identification [31] and data acquisition and quantification [32]. For example, Beyers et al. [33] assessed supporting ESs in the Karoo and found a quantitative decline in ecosystem services, leading to an increase in unemployment and ecosystem vulnerability. Furthermore, knowledge on the spatial extent of ESs is limited and inconsistent [34], such that it is difficult to realize the scale of these ESs and predict their outputs in southern African countries [35]. Results from Wissely et al. [36] reflect inadequate assessments of the benefits of the non-use value of ESs to meet the needs of the people while sustaining the environment. Thus, the lack of clear approaches for quantifying and mapping ESs [30,37] using transdisciplinary research methods [38] is a major research gap in ESs studies in southern Africa.

Globally, ES research has been relatively well documented in previous studies [33,36]. However, to the best of our knowledge, few bibliometric studies [7,8,22,35,39,40] have sought to emphasize the importance of a transdisciplinary perspective on ecosystem service research. Bibliometrics that qualitatively and quantitatively analyzes the published literature has gained increasing importance, because such an analysis provides new perspectives on the knowledge structure and development of a scientific field such as ES mitigation strategies [40]. For example, Pauna et al. [4] conducted a bibliometric analysis of global scientific literature on ES impacts on the human economy and human wellbeing. Their results show that the MEA had a major influence on scientific literature on ESs and HWB published from 2005 to 2016. Zhang et al. [22] performed a bibliometric assessment of highly cited articles on ESs and found that most of the studies were conducted in North America and Europe. Chen et al. [41] also conducted a bibliometric assessment of ES studies and found that the most highly cited journals are American but the authors are not prominent.

These studies, however, did not address the issue of transdisciplinary methods in ES assessment in southern Africa. Consequently, it is imperative to review existing studies on ESs in southern Africa to track the current trends on the subject, as well as to identify emerging trends for directing future research. Thus, we conducted a bibliometric analysis of the scientific literature on ecosystem services and human well-being in southern Africa for the period 1996–2021. This paper aims to answer the following questions:

(1) What are the major methodologies used in ES assessment in southern Africa?
(2) What trends are there in journal outputs on the subject, including the number of articles, which are the highly cited authors and journals, and how are ESs and human wellbeing categorized?
(3) What are the overall current and emerging trends in ES assessment in southern Africa?

The paper is organized as follows: following a brief introduction, "Data Acquisition and Methods" and "Bibliometric Analysis Methods" detail the research methods used in the study. The "Results and Discussion" section provides and discusses the findings. "Current and Emerging Trends" describes the trends found, and their implications for future ecosystem assessment in southern Africa. This section also provides recommendations

towards promoting transdisciplinary research. The "Conclusions" section provides the major conclusions from the study.

1.1. Data Acquisition and Methods

We used the Institute for Scientific Information (ISI) Web of Science Core Collection (WoSCC) database due to its high reliability and inclusivity of data, to select publications over the study time range from 1991 to 2021. The timespan 1991–2021 was selected because of the interest in southern Africa for pursuing sustainable development goals (SDGs). Relevant articles within southern Africa were therefore selected from 1996 to 2021. Data were retrieved on 22 March 2022. The first main search terms included: TS (Topic) = ("Ecosystem Services" AND "Africa"). This yielded a result of 2348 documents. To contextualize the results, TS (Topic) = ("Ecosystem Services" AND "Southern Africa") was then extracted from the above result, and this yielded 467 documents. Moreover, within the latter results, more searches were conducted with terms such as: TS = ("Ecosystem Services" AND "Quantifying" OR "Mapping") AND TS = ("ecosystem service" AND "Human Wellbeing" OR "Livelihoods") AND TS = ("Ecosystem Services" AND "People's perceptions") (Figure 1). These subtopics were chosen as themes and emerging ESs themes for future methodological research. This data search did not discriminate on document types.

1.2. Bibliometric Analysis Methods

Bibliometrics uses quantitative analysis methods to examine knowledge structures and the development of research fields [4]. This paper combines both bibliometric analysis and network analysis maps for the construction of various networks based on the relationships between countries, journals, organizations, authors, grants and keywords dealing with the same topic [41]. For comparability, the bibliometric analysis in this paper was performed using the software VOSviewer (version 1.6.17) and CiteSpace (version 5.8. R3) (Figure 1).

Previous ES-related bibliometric studies identified several research directions. For example, Wang et al. [31] used CiteSpace to study scientific research articles on ecosystem services and human wellbeing between 1991 and 2018. Their results showed that the Chinese Academy of Science was the most productive institution worldwide for this field of enquiry. Amberber et al. [7] also published an article on the status, approaches and challenges of the exploration of ecosystem services in Ethiopia. The authors investigated spatially explicit models used by previous authors for ES assessment. The review indicated that only 73 articles had ever been published on ES assessment in Africa as a whole, and this included those for Ethiopia. A bibliometric review of articles published on ecosystem services in Africa by Wangai et al. [2] showed that most of the studies were conducted in South Africa, Kenya and Tanzania, and they mainly focused on watershed analysis and catchment ecosystems.

Another relevant study by Pauna et al. [4] used the bibliometric tool VOSviewer to investigate scientific literature on ecosystem service research in general. Their results showed that the MEA had a major impact of the publication trend since its meeting in 2005. Although these bibliometric analysis studies were innovative and set trends for further research, not all the aspects of ES assessment were addressed, particularly for the southern Africa region. VOS viewer was primarily used in this study as it is a powerful tool to visually represent temporal trends in academic research. Furthermore, the analysis method employed the total link strength and links (see Table 1), which added more value to the results obtained in this bibliometric analysis. CiteSpace was used as a supplementary tool to analyze academic and emerging trends and present them graphically. This is a valuable input as it strengthened and validated the results. Such a combination can identify not only key research gaps, major funders, major journals and academic collaborations but also provides insight into possible future research directions in southern Africa.

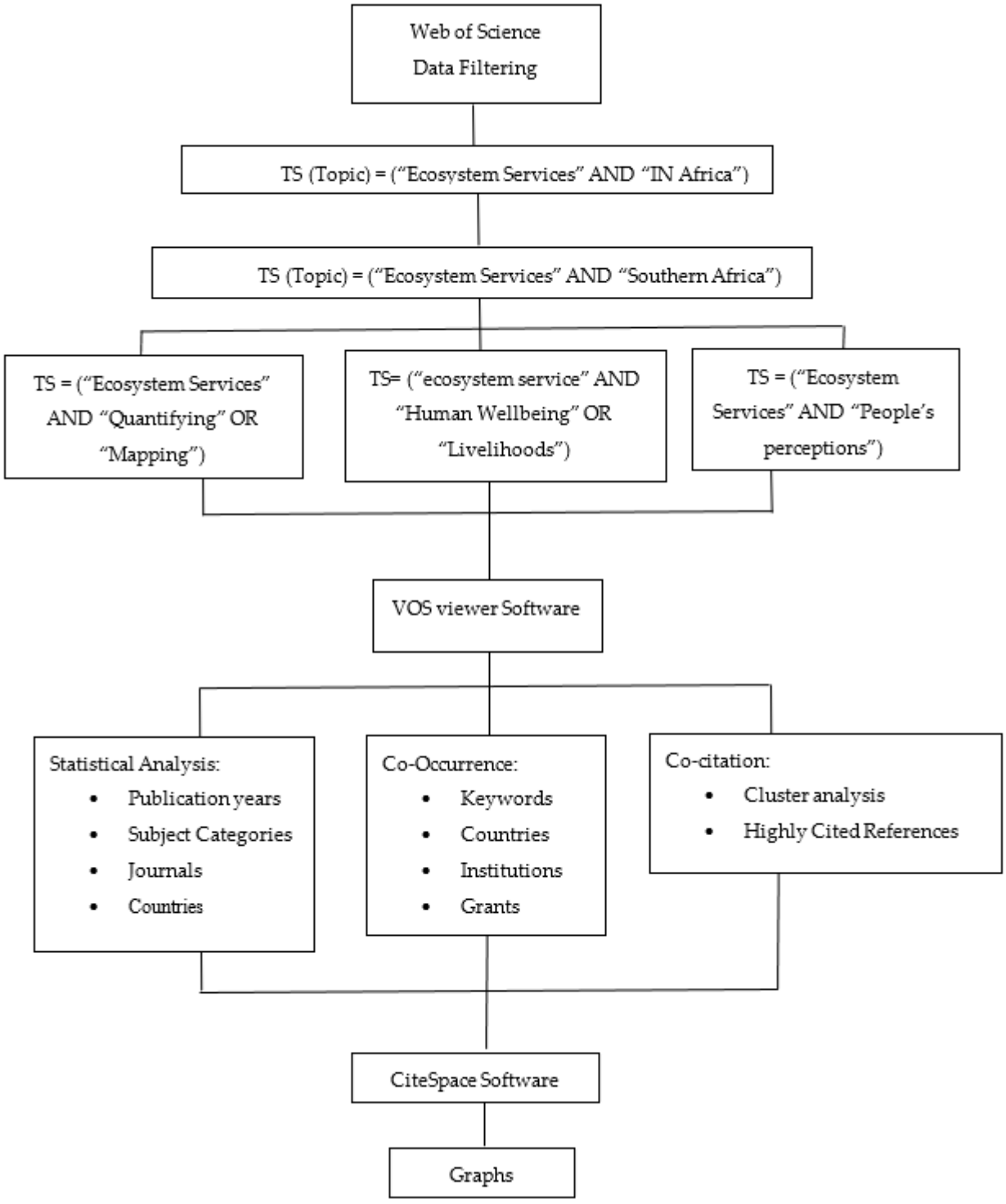


Figure 1. Schematic of bibliometric analysis employed for this study.

Table 1. Analysis terms used by VOS viewer and CiteSpace.

Term	Description
Items	Objects of interest (e.g., publications, researchers, keywords and authors)
Link	Connection or relation between two items (e.g., co-occurrence of keywords)
Link strength	Attribute of each link, expressed by a positive numerical value. In the case of co-authorship links, the higher the value, the higher the number of publications the two researchers have co-authored
Network	Set of items connected by their links
Cluster	Sets of items included in a map, that is, one item with other items
Weight attribute: number of links	The number of links of an item with other items
Weight attribute: total link strength	The cumulative strength of the links of an item with other items

The use of the ISI Web of Science was relevant for this study for several reasons. Although other databases such as SCOPUS could have been used in the bibliometric assessment, SCOPUS yielded fewer results when searching for "ecosystem services" as a term or topic. For example, when "ecosystem services" was searched for all fields on SCOPUS, it returned 53,465 articles; when "Africa" was then added as a filter, 1848 documents appeared. After the filter "1972 to 2021" was added, 1673 documents were returned. Scopus returned only four articles on ESs for the period 1981–1990. Of these, only one by Wilkin DC [42] was relevant as it was the first of its kind in this search that introduced a form of spatial analysis in the field of ESs. A SCOPUS search thus did not yield a good representation of publications for the study. Thus, Web of Science was used instead.

Table 1 shows the terminology used by VOSviewer and CiteSpace to analyze the results.

2. Results and Discussion

2.1. Distribution of ES Research in Africa

Figure 2 illustrates the results obtained for Africa and southern Africa. For context, the overall ES research in Africa was analyzed, and the results showed that the first publication on the topic was by Fjeldsa in 1994 [43], which described geographical patterns for young relict species of birds in Africa and South America, and their implications for conservation priorities. Over the period 2005–2021, the number of relevant publications increased annually, with 2021 having the highest number of 346 (15%) (Figure 2). The steady increase after 2005 followed the publication of the Millennium Ecosystem Services Assessment in that same year. The majority of publications were produced between 2013 and 2021 because of the realization of nature's contribution to livelihoods as well as the need to protect nature so that ecosystem services can be maintained [44]. The top 10 publishers were Elsevier (814 items), Springer Nature (327), Wiley (284), MDPI (166), Taylor and Francis (108), Resilience Alliance (60), Frontiers Media Sa (52), Public Library Science (41), Cambridge University Press (37) and Oxford Univ Press (32). Of the top 10 countries that published the most articles related to ESs in Africa, South Africa was the foremost, with 1213 publications (51%); and Canada was last, with 168 publications (7%).

For southern Africa, the annual number of publications on ES research steadily increased over the period 1991–2021. A total of 467 articles were published during this period, with the first publication by Bridges in 1996 [45] discussing the possibility of an improved holistic approach in soil science research in southern Africa. The highest number of publications (59, representing 15%) was recorded for the year 2021. A notable increase in the number of annual publications was observed from 2011 to 2021, with 80% of the publications recorded for environmental sciences and ecology research.

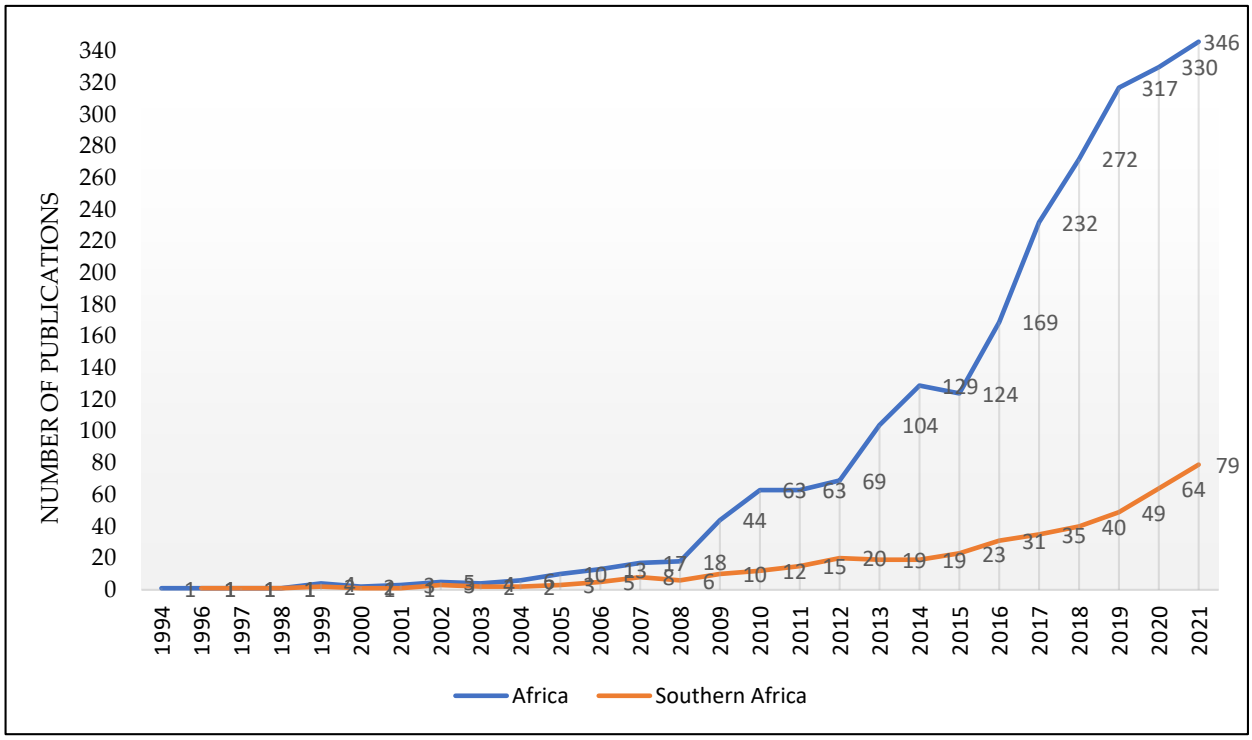


Figure 2. Annual number of ESs publications in Africa and southern Africa from 1994 to 2021.

2.2. Cooperation amongst Countries with Southern Africa

Figure 3 is a visualization of a co-authorship countries' network that visualizes the correlation of articles that were published with the countries where the authors come from. To reduce redundancy, a minimum threshold was applied of 6 articles published per country, resulting in the identification of 42 countries. The analysis produced 7 different clusters, 287 links and 1146 total links strength. South Africa was ranked the highest in all parameters of total link strength, links, articles, and citations. The most productive countries after South Africa were the UK, USA, Germany, and Australia (Table 2). It is notable that only one African country features in the top 5 most productive countries publishing on southern African ES research. South Africa is the only country that has the most publications across all methodologies and topics in ES research both in Africa and southern Africa. This may be explained by the influence of Johannesburg as the economic hub [46] and by the environmental pull factors that are found in South Africa. South Africa, for example, is bordered by two oceans—the Atlantic and Indian [28]—which provides good breeding grounds for various ecosystems supporting both biodiversity and livelihoods. This also makes the country popular for tourism in Africa [46] and for academic research. It is also worth noting that Malawi, Botswana, Zimbabwe and Namibia are among the southern African countries that are emerging in ES research.

Table 2. Most co-operative publishing countries according to total link strength.

Country	Occurrences	Links	Total Link Strength
South Africa	195	42	373
UK	72	30	263
USA	101	31	169
Australia	41	22	106
Germany	58	24	56

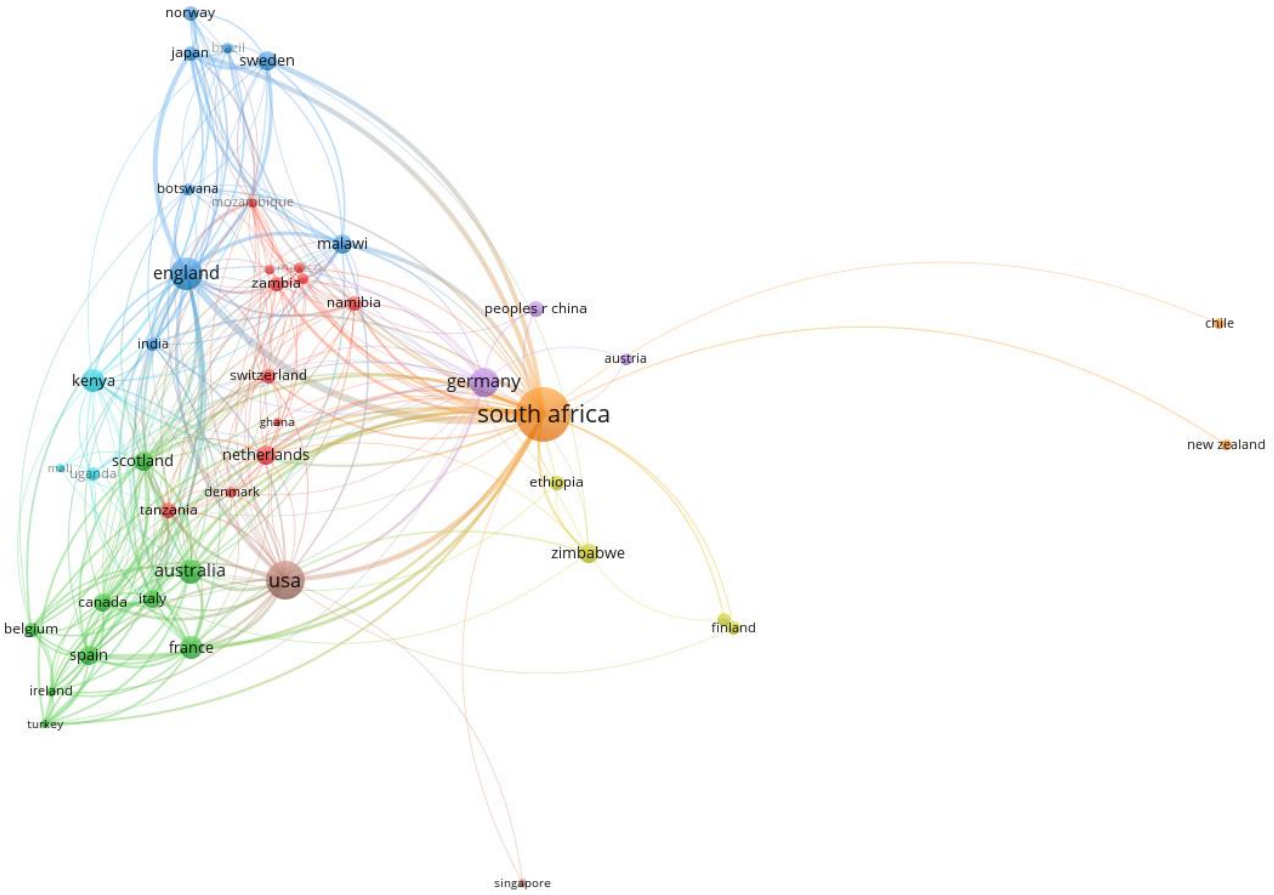


Figure 3. Co-authorship network of countries publishing on ESs from 1996 to 2021.

The notable increase in annual publications showed that the European countries publishing on ESs in southern Africa focus on environmental conservation and environmental justice topics. This may have been motivated by the publication of the MEA report in 2005 that encouraged ecosystem sustainability for complex environments. Although South Africa is the most productive publishing country on ES assessment in southern Africa, it is a cause for concern that it is the only African country in the top 5 most productive countries.

2.3. Performance of Quantitative and Qualitative ESs Studies

A co-occurrence analysis of author keywords amongst quantitative ES assessments in southern Africa was performed for 1996–2021. For the analysis, a minimum threshold of 4 keyword occurrences was set. Of the 343 keywords found, only 61 meet the threshold. This resulted in a total of 6 clusters, 231 links, and 262 total link strengths (Figure 4). Table 3 shows the top 5 keywords co-occurring in articles on ESs using quantitative methods. These keywords are "biodiversity" with 10 occurrences, 30 links and a total link strength of 50; "ecosystem services" with 10 occurrences, 25 links and 49 total link strength; "conservation" with 7 occurrences, 19 links and 29 link strength; "vulnerability" with 5 occurrences, 19 links and 28 total link strengths, and "participatory GIS" with 4 occurrences, 16 links and 24 total link strengths. This implies that work on ecosystem services in Africa has focused on biodivesity and conservation. Although the top 5 key words in the literature are mainly outcomes the articles are concerned with, it is important to note that the clusters are also converged according to the methodology used. For example, cluster 1 mainly comprises studies using imagery analysis, cluster 2 engages with land-use change perceptions, cluster 3 employs participatory mapping, cluster 4 quantifies livelihoods, cluster 5 utilizes land-use policies and frameworks, and articles in cluster 6 use classification schemes and remote sensing accuracies.

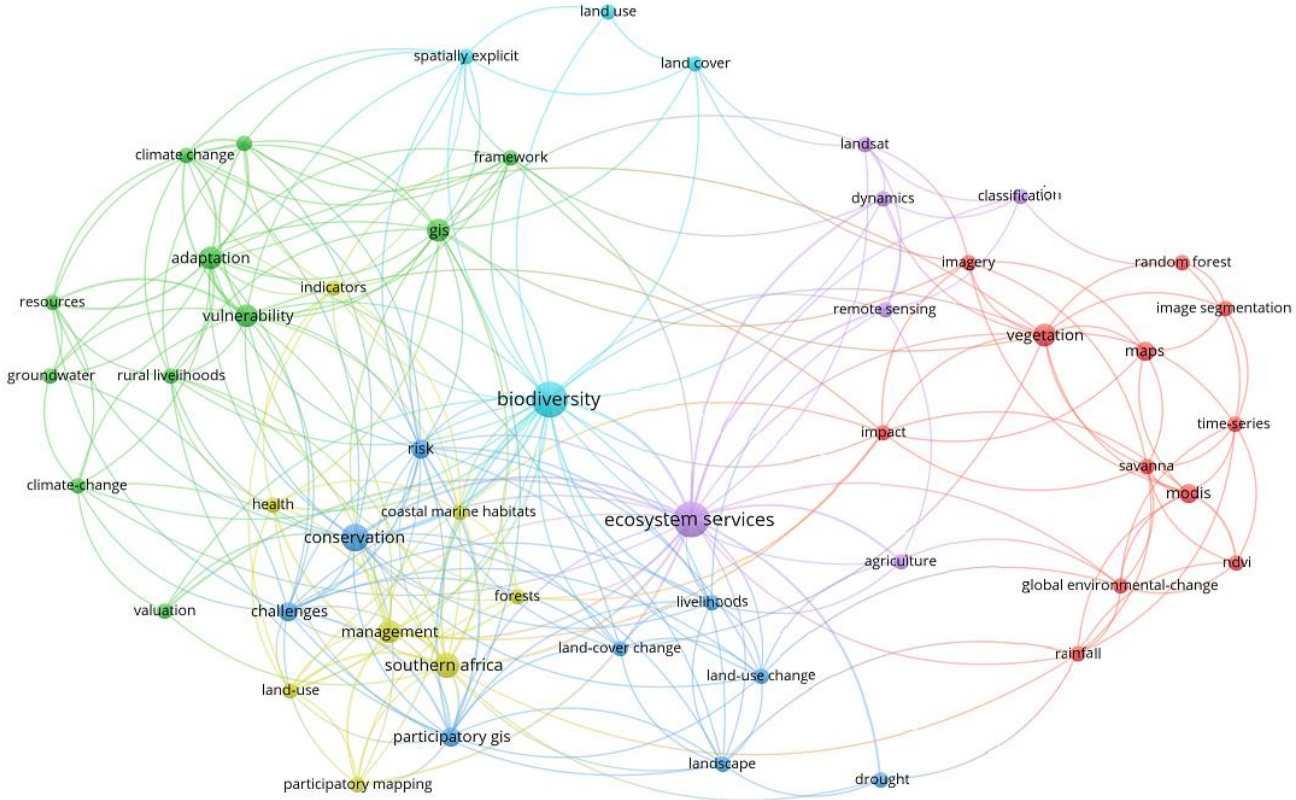


Figure 4. Co-occurrence network map of keywords from quantitative ES assessments for southern Africa published from 1991 to 2021.

Table 3. Top 5 keywords on the co-occurrence network map of ESs based on total link strength.

Keyword	Occurrences	Links	Total Link Strength
Biodiversity	10	30	50
Ecosystem Services	10	25	49
Conservation	7	19	29
Vulnerability	5	19	28
Participatory GIS	4	16	24

A co-occurrence analysis of author keywords amongst qualitative ES assessment in southern Africa was also performed for the period 1996–2021. For the analysis, a minimum threshold of 4 keyword occurrences was set. Of the 532 keywords found, only 107 met the threshold. This resulted in a total of 8 clusters, 984 links and a total link strength of 1227 (Figure 5). Table 4 shows the top 5 keywords co-occurring in articles on ESs using qualitative methods. The keywords found are "ecosystem services" with 26 occurrences, 81 links and 152 total link strength; "biodiversity" with 14 occurrences, 51 links and 86 total link strength; "livelihoods" with 12 occurrences, 52 links and 82 link strength; "conservation" with 15 occurrences, 48 links and 77 total link strengths, as well as "climate change" with 12 occurrences, 46 links and 70 total link strengths. It is worth noting that although "livelihoods" has a higher ranking in terms of the total link strength, "conservation" has more occurrences than either "livelihoods" and "biodiversity". Although "livelihoods" has the same number of occurrences as "climate change", it is ranked third because of the greater number of links and total link strength than both conservation and climate change. The clusters formed according to qualitative methods used in the ES research. For example, cluster 1 is concerned with indigenous knowledge systems, cluster 2 relates to people's perceptions, cluster 3 adopts valuation systems, cluster 4 engages policy and frameworks,

cluster 5 utilizes mitigation and adaptation strategies, cluster 6 employs modelling, cluster 7 is associated with sustainable agriculture, and cluster 8 applies management practices.

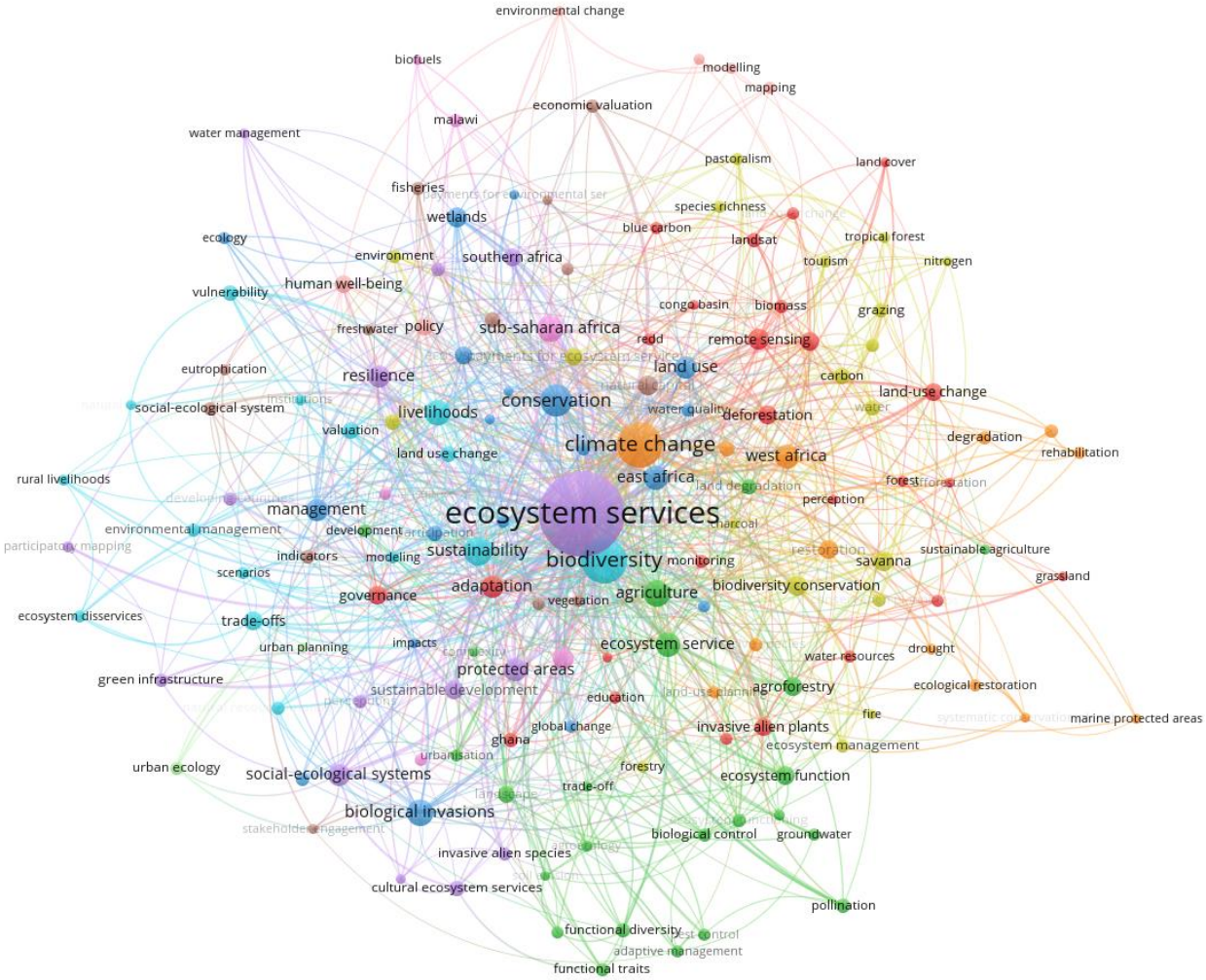


Figure 5. Co-occurrence network map of keywords from qualitative ES assessments for southern Africa published in 1996–2021.

Table 4. Top 5 most occurring keywords in qualitative studies according to total link strength.

Keyword	Occurrences	Links	Total Link Strength
Ecosystem Services	26	81	152
Biodiversity	14	51	86
Livelihoods	12	52	82
Conservation	15	48	77
Climate Change	12	46	70

Figures 4 and 5 provide a visual representation of all the publications in the period 1996–2021 using either qualitative or quantitative methods of inquiry for ES assessment in southern Africa. The overall results show that more than 50% of all the publications mostly use qualitative rather than quantitative methods. Based on keyword bursts, "ecosystem services" had the highest total link strength (Table 4) in qualitative methods, specifically in clusters relating to people's perception (Figure 5). Although "livelihoods" has the same number of occurrences as "climate change" (Table 4), it is ranked third because of the stronger link and total link strength it has compared to both conservation and climate change. This is important because it highlights the significance of livelihoods in current ES

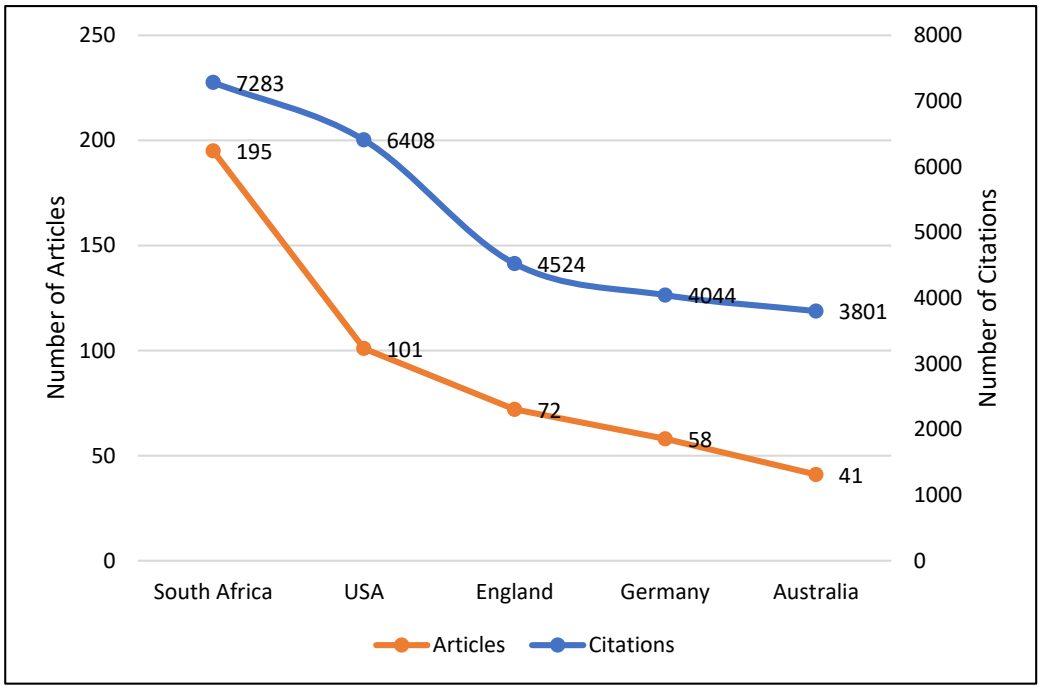
research and for possible future multidisciplinary research. Figure 5 shows the keyword bursts from articles that have used quantitative methods in assessing ESs in southern Africa. The results show that biodiversity has the highest total link strength, and it is located in the image analysis cluster. A significant number of studies have not used empirical methods to assess ESs in southern Africa. This may be due to the limited availability of datasets for this region, as well as the expenses incurred for accessing remotely sensed data for the regions as most of southern Africa is underdeveloped and includes large protected areas with endemic plant and animal species.

2.4. Academic Cooperation and Institutions Performances

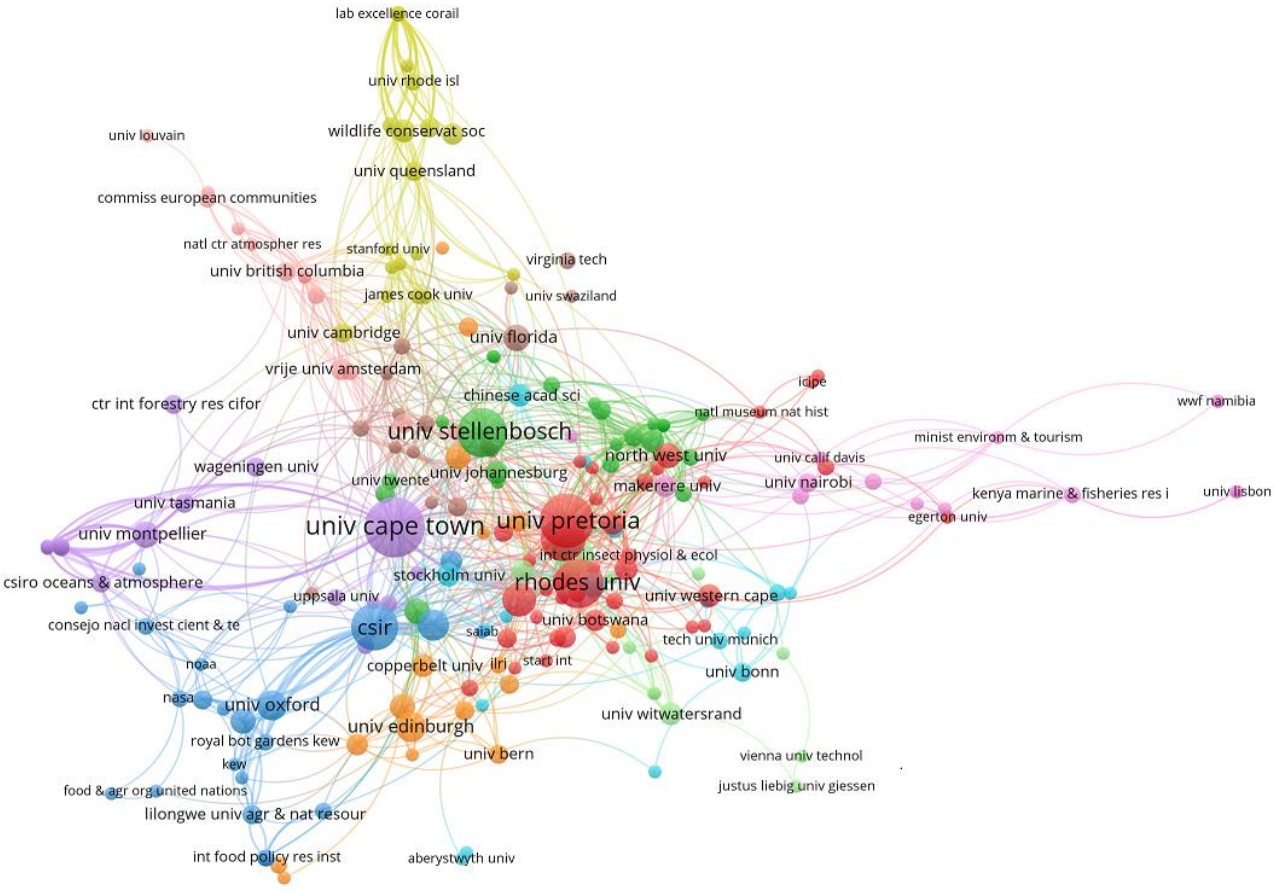
Academic cooperation among different institutions is important. International collaborations on ES research in southern Africa were mapped, using a minimum threshold of 3 articles per country. Of the 107 countries who collaborated, 58 met the threshold. South Africa is the foremost, with 195 documents, 7283 citations and a total link strength of 425; followed by USA with 101 documents, 6408 citations and 399 total link strength; then the UK with 72 documents 4524 citations and 379 total link strength. Germany is placed fourth, with 58 documents, 4044 citations and 258 total link strength, and Australia takes fifth place with 41 documents, 3801 citations and 244 total link strength. Figure 6a shows the correlations between the academic cooperation and citation scores according to articles published and number of citations.

Figure 6b illustrates the most productive institutions in ES assessment in southern Africa from 1996 to 2021. The minimum number of documents produced was set at 3 per organization, and of the total of 842 organizations, only 107 met the threshold. Among all of them, the top 5 institutions are South African. The University of Cape Town holds first place, with a total of 39 documents and 1547 citations; the Council for Scientific and Industrial Research (CSIR) produced 24 documents with 843 citations; Rhodes University presented with 26 documents and 446 citations; the University of KwaZulu Natal displayed 21 documents and 533 citations; and 26 documents and 1846 citations were found for the University of Stellenbosch. It is worth noting that despite the high number of documents and citation scores, Stellenbosch University has a low ranking mainly because its total strength link of 40 is the lowest among the top 5 institutions.

Figure 6a,b illustrate the most productive institutions in ES research in southern Africa for the period of 1996–2021. Among all of them, the top 5 institutions are South African, demonstrating that the country is the most active in this field. All five institutions have access to private and public research funding, and their productivity levels demonstrate that South Africa is the leading developing country in this field of research. The second and third most productive institutions are both from South Africa, namely the CSIR and Rhodes University, which also have access to private and public research funding. Other productive institutions from the country include the University of Cape Town, University of Pretoria, University of KwaZulu Natal and University of Johannesburg.



(**a**)



(**b**)

Figure 6. (**a**) Correlation between total number of citations and article publication, per country. (**b**) Most productive institutions publishing on ES research in southern Africa.

2.5. Author and Journal Performances

Table 5 lists the 9 most productive journals in the study field in 2021, accompanied by the total number of relevant publications in each journal, as well as the impact factor of each journal, as retrieved from CiteSpace. Elsevier is the most productive journal, with 25 relevant papers and accounting for 36.7% of the total number of relevant publications. The second most productive publisher is Springer Nature (9 papers, representing 13%), followed by Wiley (8 papers, or 11.7%), MDPI (7 papers, or 10.2%), Taylor and Francis (5 papers, or 7.3%), Frontiers Media Sa (4 papers, or 5.8%), Nature Portfolio (2 papers, or 2.9%), Pensoft Publishers (2 papers or 2.9%) and Resilience Alliance (2 papers, or 2.9%). The majority of the top 9 most productive journals are published by Elsevier, one of the most prominent academic publishing companies in the world.

Table 5. Top 9 most productive journals in the field of ESs in southern Africa for the period 2021.

Publishers	Record Count	%	IF (2021)
Elsevier	25	36.7	8.5
Springer Nature	9	13.2	4.5
Wiley	8	11.7	6.6
MDPI	7	10.2	3.2
Taylor and Francis	5	7.3	4.8
Frontiers Media Sa	4	5.8	2.4
Nature Portfolio	2	2.9	3.4
Pensoft Publishers	2	2.9	2.7
Resilience Alliance	2	2.9	4.1

% is percentage of the total record count. IF is the journal's impact factor as of 2021.

Table 6 shows the top 10 most cited authors ES assessment in southern Africa during the last two decades (2000–2021), as analyzed with CiteSpace. Among them, the most cited article is "The broad footprint of climate change from genes to biomes to people" by Scheffers et al. [47] which was published in SCIENCE in 2016 and had been cited 465 times as of 2021. The second most cited article, with 432 citations, is "An operational model for mainstreaming ecosystem services for implementation" by Crowling et al. [48]. This is followed by an article by Van Jaarsveld et al. [49] titled "Measuring conditions and trends in ecosystem services at multiple scales: The Southern African Millennium Ecosystem Assessment (SAfMA) experience", with 139 citations. Most of highly cited articles were written by authors from English-speaking European countries, indicating that authors from these countries may have a much better command of the English language, and their writing is thus more influential [46].

Table 6. Top 10 most cited articles from 1996 to 2021.

PY*	NTC*	Article Title	AN*	Publisher City	Publisher
2016	465	The broad footprint of climate change from genes to biomes to people	Scheffers, Brett R. et al.	Washington	Amer Assoc Advancement Science SCIENCE
2008	432	An operational model for mainstreaming ecosystem services for implementation	Cowling, Richard M. et al.	Washington	Natl Acad Sciences

Table 6. *Cont.*

PY*	NTC*	Article Title	AN*	Publisher City	Publisher
2005	139	Measuring conditions and trends in ecosystem services at multiple scales: the Southern African Millennium Ecosystem Assessment (SAfMA) experience	van Jaarsveld, A.S. et al.	London	Royal Soc
2002	139	Rainwater management for increased productivity among small-holder farmers in drought prone environments	Rockstrom, J. et al.	Oxford	Pergamon-Elsevier Science Ltd.
2005	119	Changes in nature's balance sheet: Model-based estimates of future worldwide ecosystem services	Alcamo, J. et al.	Wolfville	Resilience Alliance
2011	108	Scientific concepts for an integrated analysis of desertification	Reynolds, J.F. et al.	Hoboken	WILEY
2016	98	Green Revolution in Sub-Saharan Africa: Implications of Imposed Innovation for the Wellbeing of Rural Smallholders	Dawson, Neil et al.	Oxford	Pergamon-Elsevier Science Ltd.
2006	75	Future ecosystem services in a Southern African river basin: a scenario planning approach to uncertainty	Bohensky, Erin L et al.	Hoboken	WILEY
2007	71	Coping strategies in livestock-dependent households in east and southern Africa: A synthesis of four case studies	Thornton, Philip K. et al.	New York	Springer/Plenum Publishers
2015	69	Biofuels in sub-Saharan Africa: Drivers, impacts and priority policy areas	Gasparatos, A. et al.	Oxford	Pergamon-Elsevier Science Ltd.

PY* = Publication Year, NTC* = Number of Times Cited, AN* = Author Names.

2.6. Perfomance of Funding Agencies

The availability of funding has an impact on the number of articles published annually. Figure 7 shows the top 25 funding agencies actively supporting ES research in southern Africa in the last decade, as referred to in CiteSpace. The United Kingdom Research Innovation (UKRI) has funded most of the research papers—a total of 39 papers. The National Environment Research Council (NERC) is second, providing funding for a total of 36 publications. This is followed by the National Science Foundation (NSF) (28 publications), the European Commission (EC) (27 publications), and the Economic Social Research Council (ESRC) (23 publications funded). It is worth noting that the top 5 funding agencies are not African; the African institutions, the National Research Foundation and South African National Parks (SanPARKS) appear at numbers 17 and 19, respectively, having funded 6 and 5 publications, respectively.

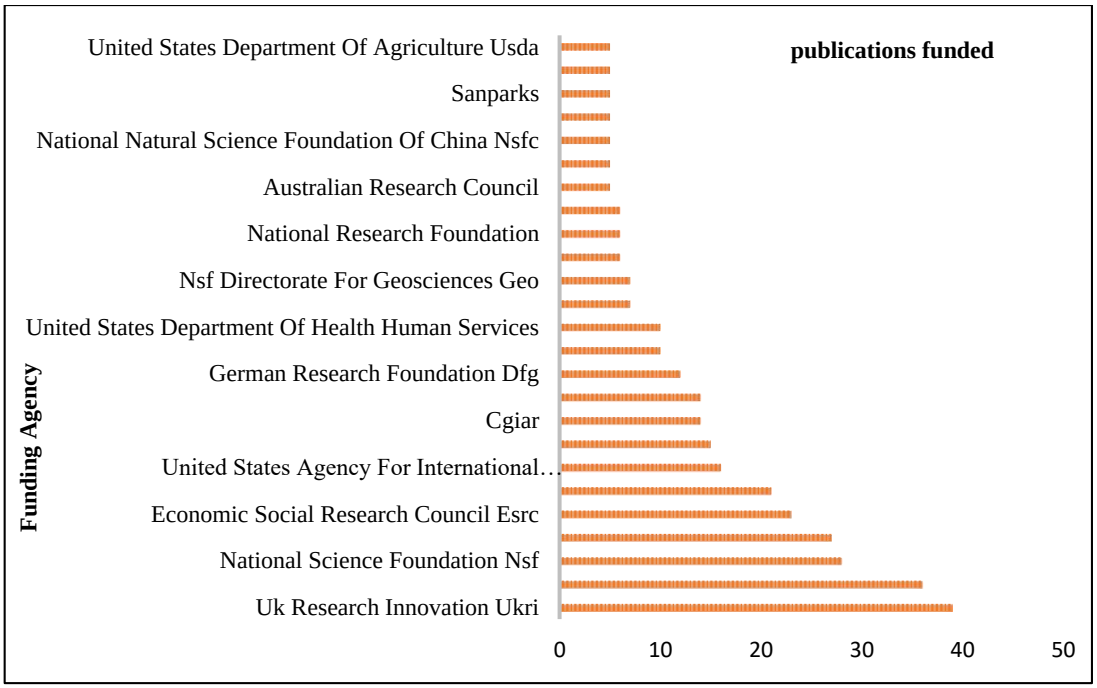


Figure 7. Funding agencies and their funded publications in southern African ES research from 2010 to 2021.

It should also be noted that most European countries publish extensively on southern African ecosystems (Figure 7). Possible reasons for this may be the greater availability of funding and institutional support from these affluent countries. The correlation between funding institutions and journals that charge a high processing fee is also worth noting. This means that having access to publishing in these journals requires financial stability and expensive equipment—something most southern African institutions do not have. Methodologically, European-funded research that has used remotely sensed datasets has also employed additional socioeconomic datasets to validate their results. For example, Weinzier et al. [20] conducted a spatial assessment of the risk of land degradation in the Okavango River Catchment, southern Africa. The study was funded by the Federal Ministry of Education and Research Germany and used remote sensing and GIS-based techniques. The authors concluded that remote sensing and GIS-based approaches were an important benchmark to standardize the degradation risk assessment, but socioeconomic datasets must be added to improve the accuracy of the model [50]. A common problem in developing countries is the lack of access to funds for supplementing the results from an existing analysis or methodology. This may lead to publication delays or non-publication.

It is also worth noting that the period 2010–2021 was used to analyse funding support for ESs following the economic depression during that time in southern Africa [51].

2.7. Major Research Methods in ESs Field

ES research encompasses the scope of ecosystems that draws upon natural, human-made, and cultural environments [28]. Due to different research interests in ESs, qualitative, quantitative and transdisciplinary methods are applied. Table 7 lists the three mainstream methods in ES research, which are further classified into different sub-methodologies, including qualitative (case study, interview, focus group, questionnaires and stakeholder engagements), quantitative (mapping, remote sensing and GIS, land-use based and participatory GIS), and transdisciplinary types (mixed methods and multi-criteria decisioning analysis) [52]. Qualitative research has been the dominant research method since it investigates real-life contexts to address a wide range of research questions [53] and has been applied across a number of disciplines, including business, education, health, law, and

other social sciences [51]. Focus groups and stakeholder engagement methods are also well-known qualitative research methods used for studying behavioral systems across people or units of power [54,55]. However, qualitative methods such as case studies, interviews and questionnaires lack scientific objectivity [50]. Further disadvantages of employing focus groups as a qualitative methods include limited flexibility, superficial coverage of complex topics, and a limited range of answers due to fear when some groups believe that the interviewer is from a government agency [53]. For example, Musakwa et al. [30] examined the relationship amongst Gonarezhou National Park management and national park stakeholders and communities to understand the impact of the relationships on biodiversity and ecosystems. Their study used qualitative methods such as structured interviews, government and public stakeholder engagements as well as key informant focus groups. Although they concluded that a partnership arrangement between communities and the park management is a desirable model that can be applied in national parks in Zimbabwe and Africa as a whole, for better ecosystem management and tourism, they also identified a need for quantitative analysis for this model [30]. Furthermore, they discouraged the use of focus groups, as they found it difficult to obtain in-depth information from the respondents using this research method.

Quantitative methods, such as remote sensing and GIS analysis, mapping techniques, participatory GIS, and land-use-based analysis of ES research are some of the most widely used methodologies for ES assessment on a large scale [34]. A big advantage of this approach is that the results are authoritative, reliable, and generalizable on a larger spatial level [56]. Quantitative research is also advantageous for studies that require calculations, such as when measuring ESs tradeoffs across different contexts [57]. However, it is difficult to evaluate specific ESs systems if there is insufficient data due to the lack of accurate and updated information in certain areas [18]. Furthermore, survey or quantitative analysis instruments are vulnerable to errors such as from flawed measurement and sampling techniques [58]. Another disadvantage is that while quantitative research involves measurements, some matters are difficult to quantify, and researchers may be unable to obtain datasets timeously for the analysis [59]. For example, Elbasit et al. [57] quantified ESs in South Africa using remote-sensing techniques. Their results showed a significant change in land use, with corresponding spatial alterations, thus impacting local communities' potential access to resources. The authors, however, admitted that remote sensing techniques alone may not provide the only solution to the problem. Due to their accessibility, remote sensing tools have been widely used to assess provisioning services [28]. In hindsight, this leads to the neglect of other ESs such as regulating services, which are the basis of all life [60]. Furthermore, ESs are interconnected and complex; therefore, it is impossible to quantify one ES without considering the others [22].

Table 7. Comparison of major methods used for ES research, adopted from Ignatieva et al. [54].

Method	Definition	Advantage	Disadvantage	Methods	Used by
Qualitative	Qualitative research is considered to be particularly suitable for exploratory research (e.g., during the pilot stage of a research project, for example). It is primarily used to discover and gain an in-depth understanding of individual experiences, thoughts, opinions, and trends, and to dig deeper into the problem at hand	A big advantage of qualitative research is the ability to deeply probe and obtain rich descriptive data about social phenomena through structured interviews, cultural immersion, case studies, and observation, for instance.	Qualitative studies often take more time to complete due to the pain staking nature of gathering and analyzing field notes, transcribing interviews, identifying themes and studying photographs, for example. Studies are not easily replicable or generalizable to the wider population. Conscious or unconscious bias can influence the researcher's conclusions. Since it lacks rigorous scientific controls and numerical data, qualitative findings may be dismissed by some researchers as anecdotal information.	1. Case Study Method 2. Questionnaires 3. Focus Groups 4. Interviews 5. Stakeholder Engagement	1. (Choruma and Odume [59]; Romeu-Dalmau et al. [60]) 2. (Musakwa et al. [61]; Arbieu et al. [62]) 3. (Zabala and Sullivan [51]; Shrestha et al. [52]; Masunungure and Shackleton [63]) 4. (Gandiwa et al. [64]) 5. (Musakwa et al. [30]; (Musesengwa et al. [65])
Quantitative	Quantitative research is concerned with numbers. It is used to quantify opinions, attitudes, behaviors, and other defined variables, with the goal to support or refute hypotheses about a specific phenomenon, and potentially contextualize the results from the study sample in a wider population (or specific groups).	A big advantage of this approach is that the results are authoritative, reliable and generalizable to a larger population. Quantitative research is advantageous for studies that involve numbers, such as measuring achievement gaps between different groups of students, or assessing the effectiveness of a new blood pressure medication.	Survey instruments are vulnerable to errors such as mistakes in measurement and flawed sampling techniques. Another disadvantage is that quantitative research involves numbers, but some topics are too difficult to quantify in numbers. Datasets may be difficult to obtain timeously for analysis.	1. Mapping 2. Remote Sensing and GIS 3. Participatory GIS 4. Land-Use based	1. (Mugo et al. [56]; Landman et al. [66] and Aldous et al. [67]) 2. (Cho et al. [55]; Mugo et al. [56] and Weinzierl et al. [20]; Hossain & Hassim, [68]) 3. (Zhu et al. [69]; Mayr et al. [70] and Urban et al. [27]) 4. (Abutaleb et al. [71]; and Palmer et al. [72])

Table 7. *Cont.*

Method	Definition	Advantage	Disadvantage	Methods	Used by
Transdisciplinary	Transdisciplinary is "integrative research concepts" which engages academic researchers from different disciplines and stakeholders (non-academic participants).	The pros of the transdisciplinary approach are its ability to incorporate results of natural and social studies into landscape design, the ability to involve stakeholders in different project activities and to disseminate the research results in practice.	The complexity and diversity of research methods require time to adjust to and understand the problem, to learn the essentials of other disciplines, to digest the data, to try different types of analyses, to discuss results and to arrive at conclusions.	1. Multi-Criteria Decision Analysis 2. Mixed Methods	1. (Favretto et al. [73]; Arbieu et al. [62]; Musakwa and Wang [74]) 2. (Linol et al. [75]; Sitas et al. [76]; Ndebele-Murisa et al. [77])

3. Current and Emerging Trends

The results from the bibliometric analysis on ES publications indicate that significant research progress has been made by researchers from both developed and developing countries. Current trends of ES assessment include remote-sensing quantifiable assessments and empirical methods using survey datasets. Emerging trends in methodologies for analyzing ESs (Figure 4) include the use of vegetation indices, valuation, and image segmentation. This means that more articles mention the possibility of using these methods for ES assessments in southern Africa. Emerging qualitative research trends (Figure 5) include the consideration of mitigation strategies, livelihoods and indigenous knowledge systems. Thus, more research is being published that evaluates the use of these approaches in ES assessment, as well as identifying the need for transdisciplinary methods.

With increasing attention on preserving natural ecosystems, it is expected that future research studies will focus on ES mechanisms, regulations, and legislation, and thus lead to the need for transdisciplinary studies on ESs (Table 7). Mixed-methods studies and transdisciplinary research on ESs in southern Africa can facilitate collaboration amongst policymakers, ES promoters, participants, organizations and other stakeholders to minimize the impacts of climate related changes on both the environment and people. In addition, it is crucial to ensure that both local communities and scientific tools are engaged in ES assessment in southern Africa, so that stable and equitable development can be realized. This means that future studies should continue to provide empirical evidence from the results of implementing various policies developed at both local and national levels, with the aim of enhancing resource efficiency and sustainable consumption of various resources in the region.

Furthermore, transdisciplinary studies can help assess the impacts of various ESs and conservation policies so that appropriate evidence-based policies can be implemented. For example, Delzeit et al. [38] conducted research using stakeholder engagement to define trends, policies, trade-offs and technologies that globally affect the transition towards a sustainable bioeconomy. Their findings suggest that including multiple stakeholder engagement in the formulation of research questions and scenarios avoided unbalanced problems of ownership and produced an evidence-based co-design process of enquiry for establishing a sustainable bio economy [38]. Therefore, this demonstrates the need for transdisciplinary studies in ES assessment.

In addition to stakeholder involvement, we suggest the application of spatial tools such as remote sensing, geographical information systems, machine learning and artificial intelligence in ES research, within the context of southern Africa. These can support online and real-time analysis for mitigating policy implementation and the allocation of appropriate resources for human well-being. Such applications will help relevant

stakeholders identify the key problems accurately so that prompt actions can be taken timeously. Furthermore, ESs should not be quantified independently. In instances where data are available, regulatory services should be quantified along with other ecosystem services as they form the basis of all life—for example, in quantifying woody vegetation species and sediment retention for ecosystem management as they may be crucial for human wellbeing in rural protected areas.

Ultimately, more international comparative studies and collaborations as well as greater journal inclusivity (Table 6) will enable scholars from different countries and institutions to learn and communicate their methods [46]. These initiatives, while allowing ES practitioners to share their expertise and experience, will ideally contribute to both economic development and the conservation of protected areas, as well as create employment for local communities. However, an increase in global human population and the accompanying anthropogenic activities have led to rapid alterations in the composition, structure and functions of ecosystems as well as their degradation [7]. Appropriate implementation of recommendations from ES assessments can direct various efforts from government agencies, local communities, tourists, suppliers, researchers and stakeholders to better protect local ecosystems for current and future generations. Therefore, a transdisciplinary approach to ES assessment and management is a valuable emerging trend for progressing ecosystem sustainability.

4. Conclusions

In order to present the key features and uncover the evolutionary trends in ecosystem service assessment in southern Africa, a bibliometric analysis was conducted in this study, for the period 1991–2021. It should be noted that VOSviewer and CiteSpace were both used to analyze the literature presented in this paper. We recommend that other systematic tools be used for further research and a chance at obtaining clearer results. Although the use of both CiteSpace and VOSviewer were beneficial for this paper, we recommend that CiteSpace be incorporated more in future bibliometric research as the platform provides more tools of enquiry than other systematic review platforms.

The bibliometric results in this paper show that, overall, the number of publications on ES assessment in Africa have been gradually increasing, except for a slight decrease in the year 2021. Not many ESs studies have been published for southern Africa; however, South Africa is the most productive country for publications and author collaborations. There is a greater number of qualitative ES assessment studies in southern Africa, when compared with empirical studies published in the period 1991 to 2021. This is noteworthy considering that ESs studies only began to be conducted in 1991 with relevant studies only being published from 1996. A key finding is that most authors use qualitative methods to assess people's livelihoods and wellbeing in collaboration with provisional and cultural services, while remotely sensed imagery is used as a key tool to assess the spatial extent of provisional and regulating services. The key publishers include Elsevier, Wiley, MDPI, Springer Nature and Resilience Alliance, and they are all not African publishers. The leading countries in this field include South Africa, UK, USA, Germany and Australia. These countries have close academic collaboration with institutions and highly cited authors. The University of Cape Town, CSIR, University of Rhodes, University of KwaZulu Natal and University of Stellenbosch are the top 5 most productive institutions in southern Africa, and although these are South African institutions, the top 10 most highly cited articles are not from these institutions.

The funding institutions that are the most productive in ES assessment in southern Africa are mostly European. The only African institutions amongst the top 20 funders are the NRF and SANPARKS, both of which are South African. In this regard, we recommend that foreign funding institutions be open to work with southern African scholars. This will present opportunities to explore ecosystems, as well as expose African authors to international journals. According to the keyword analysis, "ecosystem services", "biodiversity" and "livelihoods" are the most used keywords in qualitative ES methodologies, and

peoples' perceptions and are the most frequently used measure. "Biodiversity", "conservation", and "management" are the most frequently used keywords in empirical studies conducted with remotely sensed imagery and GIS. The findings conclude by presenting the major methodologies used in ES assessment in southern Africa and describing the need for transdisciplinary studies in a complex environment.

Finally, the key findings of this study provide valuable insights into topics related to contextual ES research. It provides valuable suggestions that can help researchers to identify feasible research topics and select appropriate methods so that they can contribute to the knowledge development of this emerging field. Publications not found in the Web of Science database were omitted in this study. This may exclude some influential articles and important contributions. Thus, further research should include other databases, such as ResearchGate, Google Scholar, and Scopus, so that additional relevant papers can be sourced and included for further analysis and evidence-based research. Finally, this study recognizes transdisciplinary research as a vital emerging trend for ecosystem services assessment. It recognizes the need for developing transdisciplinary research methods to support sustainable ecosystem services assessment and policymaking.

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