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REVIEW

Trends and hot spots of coastal science in Moroccan Atlantic coast: a bibliometric analysis

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Abstract

Despite the growing focus in coastal conservation practice toward scientific evidence-based decision-making, there remains a need for enhancing knowledge management and its implication in coastal management planning. In this review manuscript, bibliometric analysis in conjunction with network analysis is used to describe qualitatively and quantitatively the progress, trends and hot spots of coastal science in Moroccan Atlantic coast. In total, 4891 publications from 1971 to May 2021 were collected. The performance of publication covering annual outputs, document types, language of publication, mainstream journals, the impact of the research by research area, coastal habitat type and study area were investigated.

Thereafter, co-word, co-authorship, co-country analysis and cluster analysis were conducted using VOSviewer software. The findings underscore a clear disparity in the research evolution. 52% of the total publications were produced between 2011 and 2021. 80% of them were published as journal articles. Journal of Materials and Environmental Science was the most active journal. Behind Morocco, France and Spain researchers have made the main contributions to this research area. 75% of publications have been limited to the coastlines and lagoons. In contrast, habitats such dayas and oasis have received little attention. Hydrobiology and ecology have being gradually deepened. The analysis also revealed a significant research bias against the south–central coastline, the regions of Moroccan Atlantic that have a high research need. This analysis suggests that future scientific effort on Moroccan Atlantic coastal ecosystems should relieve existing biases by increasing multidisciplinary integrated system research and encouraging inter-regional transfer of research resources to areas of low research effort, with a special emphasis on the critical research ecosystems in the southern coastline. Finally, some key recommendations were raised for strengthening the implementation of knowledge management within the concept of sustainable coastal management.

Keywords Coastal science · Moroccan Atlantic coast · Bibliometric analysis · Network analysis · Research trend

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1 Introduction

The keyword "policy relevance" is usually used when research results can assist to solve the issues faced by society in an appropriate way (Vydra & Kantorowicz, 2021). Research in an ideal world would provide a consistent direction for policy to address specific societal and environmental issues (Levine, 2020). In today's world, the situation is more complicated. It is difficult to draw specific guidelines from research that policy-makers and managers require for the implementation of a management plan (Cook et al., 2017). While challenging to address in the context of sustainable development concerns, there is still a pressing need for further consideration of the practical strengthening research findings to support policy decision-making (Nong et al., 2020). The challenges of conducting scientific research that crosses traditionally distinct disciplines and involves researchers, practitioners and intermediary actors are much more complex in coastal ecosystems that are marked by tipping points and ecological thresholds in their functioning (Hossain et al., 2016; Watson et al., 2018). The degradation of coastal ecosystems and their complexities suggest that the coastally oriented research community has a responsibility to periodically investigate its priorities and communicate efficiently data gaps and scientific information needed to address such issues (Anderies et al., 2019; Lewison et al., 2016a, 2016b). Their management spans a range of sectors including environment, health and education, fisheries and conservation, coastal aquaculture, water and energy, coastal tourism, coastal development, coastal biotechnology, pollution, climate change, impact of ocean acidification in coastal ecosystems, invasive species and coastal biodiversity, coastal economy, laws, regulations and politics and poverty (Wahl et al., 2016; Brandão et al., 2019; Burt et al., 2019; Chen et al., 2020). Consequently, policy-makers may acquire scientific evidence from across a wide variety of disciplines including ecology, social sciences, economics, etc. (Cochrane et al., 2019; Lewison et al., 2016a, 2016b). Strengthening, however, cross-disciplinary scientific collaboration for effective management of coastal areas (Rudd et al., 2013). As coastal pressures mount, there is an increasing need for research framework programs to conceptualize complex coastal issues, enhance research organization and lead scientist to support the regulation, management, adaptation and resilience of coastal ecosystems (Lewison et al., 2016a, 2016b; Oteke, 2018). These pressures are largely arising from the combined effects of climate change (e.g., Mooser et al., 2021; Ratter & Leyshon, 2021; Wang et al., 2021), anthropogenic factors (e.g., Cozzolino et al., 2017; Maneas et al., 2019; Jouffray et al., 2020; Velez et al., 2020), industry and tourism (e.g., Yuan et al., 2020; Wu et al., 2020), waste disposal and land-based pollution (e.g., Liu & Xing, 2019; Martuti et al., 2020), coastal cabling for communications (e.g., Mader et al., 2016; Vicen-Bueno & Eleftherakis, 2019), transport and energy production (e.g., Bonamano et al., 2016; Oskarsson et al., 2021), seaport/shipping development, coastal groundwater extraction, coastal mining and other human activities. It is the case of the Moroccan Atlantic coast that extends for about three thousand kilometers. The coast is a complex mosaic of different environments (coastal dunes, beaches, deltas, salty and fresh water marshes, rocky cliffs, mangroves, bays, lagoons and estuaries, etc.) with great ecological, social–cultural and economic values (Benmassaoud & Ibnkhaldoun, 2020; Chahid et al., 2016; Mhammdi et al., 2020). Scientific understanding of these ecosystems has proved crucial in the implementation of ecosystem-based management program (EBM) when effectively analyzed and communicated with all stakeholders involved in coastal science (Lima & Bonetti, 2020). Although considerable body of scientific knowledge has centered on the Moroccan Atlantic coast, its comprehensive management appears challenged. Difficulties such as deficiency

in scientifically sound planning, shortage of baseline information, lack of communication between researchers and users of science, poor funding for synthetic research in coastal science could hinder effective knowledge management. Nonetheless, most researchers focus on one/some specific researcher topic(s); to our knowledge, there is no review summarizes the research trends and revealed the emerging trend of coastal science in Moroccan Atlantic coast. Hence, a comprehensive review can be carried out using bibliometric tools, and a network analysis for clustering and mapping the relevant scientific information (Su et al., 2020). In this review manuscript, a holistic view of research on coastal science in Moroccan Atlantic coast is reviewed via bibliometric analysis in conjunction with network analysis. A total of 4891 publications are analyzed from 1971 to May 2021. (1) The variation in the characteristics of total publications, year of publication, document type, language of publication and journal coverage are summarized. (2) The distribution of publication outputs by research area, coastal habitat type and study area are analyzed. (3) The co-occurrence analysis of keywords, authors and countries are visualized. (4) The future directions and enabling actions that can be undertaken to facilitate the implementation of knowledge management within the concept of sustainable coastal management are discussed.

2 Methodology

2.1 Data collection

To ensure sufficient coverage, search databases include Scopus (Elsevier), Web of Science (Clarivate Analytics) and Google Scholar (Google Group) were used to compile a bibliography of all publications referring to the research on Moroccan Atlantic coastal ecosystems. The Scopus database (https://www.scopus.com/) holds the largest number of journals and provides outcomes of more consistent accuracy in comparison with other databases (Liu et al., 2019; Martín-Martín et al., 2018; Masi et al., 2020). As checked in May 2021, Scopus was indexing more than 81 million items and over 25,000 titles from 7000 publishers worldwide and get access to 1.7 billion of cited references (Elsevier, 2021). It has double the number of indexed journals than the Web of Science database (Sweileh et al., 2020). Maintained by Clarivate Analytics, Web of Science (https://clarivate.com/webofsciencegroup/solutions/web-of-science-core-collection/) covers all journals indexed in Emerging Sources Citation Index (ESCI), Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCIE) and Arts and Humanities Citation Index (AHCI) (Goh et al., 2020). It allows for acquiring long and complex search queries (Sweileh et al., 2020). The other robust source of references used in the review was the Google Scholar database (https://scholar.google.com/), used by its turn to track, sort, analyze and visualize publications (Martín-Martín et al., 2018). More sources as Hal (https://hal.archives-ouvertes.fr/), Theses.fr (http://www.theses.fr/) and Otrohati (https://otrohati.imist.ma/) were used search engine for PhD defended. A broad scope in terms of document types (journal articles, conference articles, books, book chapters, etc.) were used, in the belief that dependence on a large database would provide a more consistent result. Only keywords were selected for retrieval to improve the accuracy of the results and increase the degree of correspondence with the literature. "TITLE-ABS-KEY" operator was selected to limit our search to the keywords appeared in the publication title, abstract, author keywords and keywords plus. All possible combinations of keywords related to the topic were searched without language restriction between 1971 and 2021. The selected study period encompasses period of

enormous change in the ecology and economy of the Moroccan Atlantic coast. In order to allow a better understanding of the temporal evolution of the topic, documents were aggregated according to their year of publication, into six groups of nine-year intervals (except the last one) corresponding to the last five decades (1971–1980; 1981–1990; 1991–2000; 2001–2010; 2011–May 2021). This is a sufficiently extensive period yields useful insight and establishes the general research trends. The records were 3820, 2014 and 1213 documents in Web of Science, Scopus and Google Scholar, respectively. The records were 293 theses in Hal, Theses.fr and Otrohati. A total of 6340 documents were retrieved for further analysis.

2.2 Refinements of the results

The selected data including the following information: "document title," "author (s)," "affiliation(s)," "document type," "journal title," "language," "year of publication," "institution(s)," "abstract," "author keywords," "citation count" and "bibliographical information" were downloaded for further examination. Full records were downloaded into a reference manager (Mendeley) where duplicates were removed, saved to CVS format and then exported to VOSviewer for a subsequent analysis. Linlog/modularity approach of normalization and citations was selected as option for weights in the visualization scale. It is important to note that the download records were manually retrieved to solve issues such as missing data. Record was standardized with same formatting to extract the relevant information. After data cleaning, 4891 documents remained for analysis (Fig. 1).

2.3 Data analysis

As an indicator of scientific impact and production, the annual distribution of the published-document number and the contribution of documents for each of the authors, the number of total citations, average citations per article and impact factor (IF) of journals were investigated. The IF of a journal was obtained from the Journal Citation Reports (JCR) clarivate.com/products/web-of-science. In addition, the high-frequency keywords were extracted to reveal research hot spot. The impact of research by habitat type, research area and study area were analyzed in this study.

2.4 Data visualization

Microsoft Excel 2017, ArcGIS (version 10.5) and VOSviewer (version 1.6.9) visualization softwares were engaged to provide visual insights of coastal research. VOSviewer (Van Eck & Waltman, 2010) was used to read the data was standardized using fractionalization mode to perform a network analysis (Su et al., 2020). It was adopted in this study to visualize the relationships among the top productive authors, research institutions and the co-occurrences of keywords (Gao et al., 2019; Li et al., 2020). Network diagrams include nodes and links. Nodes reflect different components such as author, institution and keywords. The size of nodes in the network is proportional to the number of publications (or frequency); the larger the node, the greater the number of publications or the higher frequency (Van Eck & Waltman, 2011; Gao et al., 2019). The thickness and length of links between nodes reflect relationships of collaboration, or co-authorship/co-occurrence (Peng

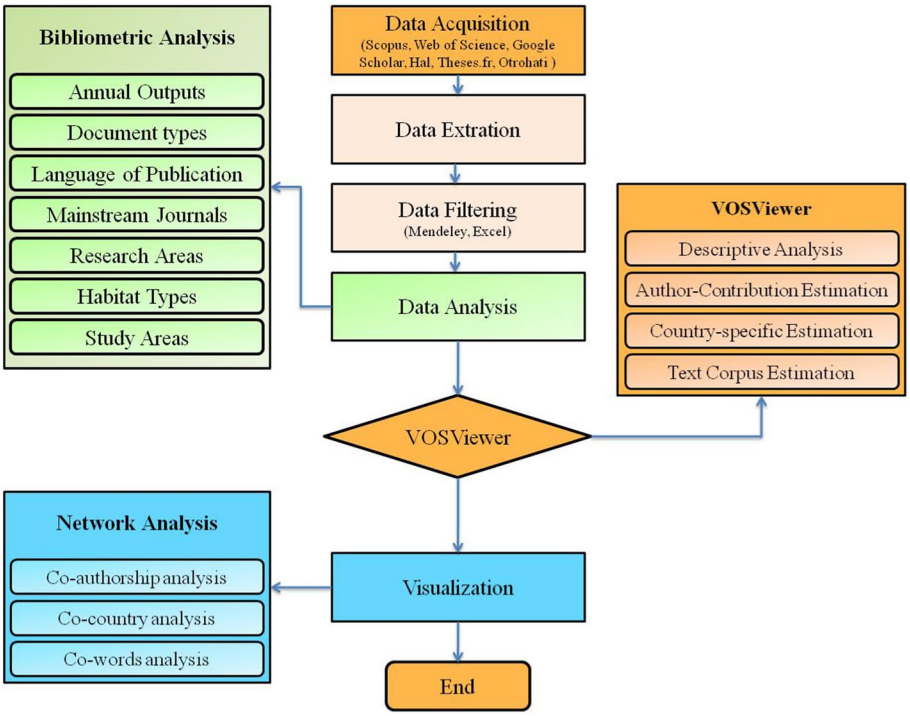

Fig. 1 Procedure for the bibliometric analysis used in this paper

et al., 2020). The color of the node/lines reflects different clusters or years (Liang et al., 2017).

3 Results

3.1 Bibliometric analysis

3.1.1 Publication years, document type and language of publication

The annual distribution of the published-document number expresses the overall situation and research patterns, while the latter highlights the overall trend features considering different development time periods. Thus, the combination of the published literature referring to the Moroccan Atlantic coastal ecosystems and fixed time window was achieved (Fig. 2). Due to the small number of early publications, the present study uses 1971–1980, 1981–1990, 1991–2000, 2001–2010 and 2011–2021, respectively, as first to fifth research periods. In the first decade (1971–1980), the increasing number of published documents per year was no more than 36 publications. In the second and the third decades, research grew slowly but steadily, and the annual average document number varies slightly between years. In last decade (2011–2020), the number of research documents increased rapidly, reaching a peak of 330 publications in 2020, signaling a surge in research

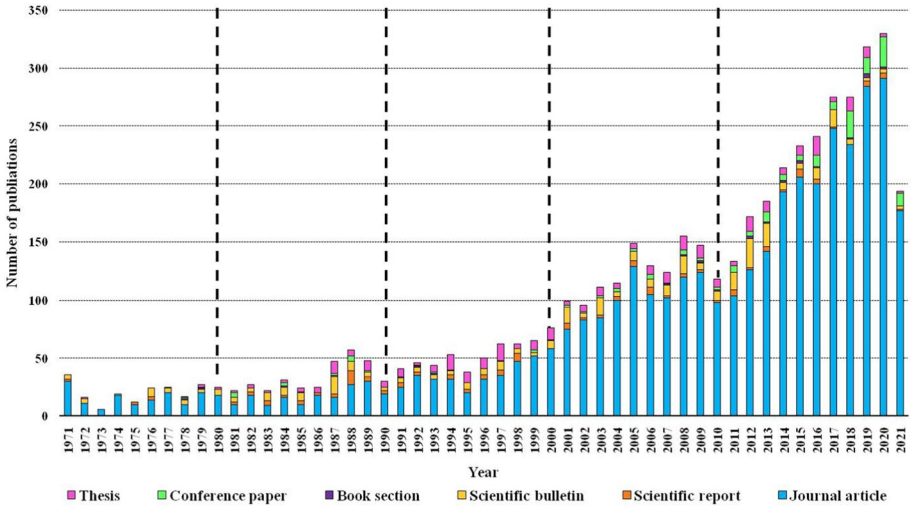

Fig. 2 Number of publications per document type by years

activity throughout the coast over the last decade. It is worth mentioning that the year 2021 was represented by 194 publications considering the months of January to May. Four-fifths of the total documents were published as journal articles (3924 publications; 80.22% of total documents) and more than three-twenty as scientific bulletins (6.9%) and theses (6%). Conference papers (3.43%), scientific reports (2.92%) and book Sects. (0.57%) comprised a small portion of the published documents. Almost one-twenty (4%) of documents were published as journal articles during the early phases of research (1971–1980) and more than one-half (51.68%) during the most recent period (2011–2021) (Fig. 2). The languages of all publications were grouped. The result shows that French (2457 publications; 50%) and English (48%) were by far the dominant academic language in the coastal research field. Several other languages including Spanish (0.65%), German (0.29%), Arabic (0.2%), Russian (0.12%) and Portuguese (0.04%) also appeared.

3.1.2 Journal publication

A total of 924 articles were published in a wide range of 1005 national and international journals. Table 1 summarizes the top journals (2.4%) in descending order with respect to the total number and percentage of published articles published (TP), impact factor (IF) and journal subject category. According to the category description in the SCImago Journal and Country Rank, coastal sciences covers resources concerning many aspects of the of the study of the coastal areas, among them environmental chemistry, environmental geology, water quality, oceanography, ecotoxicology, monitoring and coastal health. Journal of Materials and Environmental Science published the most articles with 126 articles (3.2%). Journal of African Earth Sciences ranked second with 70 articles (1.78%) while Deep-Sea Research Part I: Oceanographic research papers (1.07%) and AACL Bioflux (0.92%) ranked 3rd and 4th. The most commonly cited article was published in the 3rd position journal with 1188 citations. International Journal of Advanced Research ranked on top productive journal with the highest impact factor of 5.228, reporting that on average, the articles published in this journal has been cited five or more times per year. Progress

Table 1 Top most active journals during the period of 1971–2021 with the number of articles published, impact factor and journal subject category

Journal title	TP (%) ($n=3924$)	Citation	IF	Time period				Subject category*
				1981–1990	1991–2000	2001–2010	2011–2021	
Journal of Materials and Environmental Science	126 (3.2)	197	0.75	–	–	–	126	Pollution; waste management and disposal; environmental chemistry
Journal of African earth sciences	70 (1.78)	619	1.603	8	7	17	38	Earth surface processes; geology
Deep-Sea Research Part I: Oceanographic research papers	42 (1.07)	1188	2.6	16	7	6	13	Aquatic science; oceanography
AACL Bioflux	33 (0.92)	23	0.54	–	–	1	32	Aquatic science; ecology, evolution, behavior and systematics
Quaternaire	32 (0.81)	252	0.412	2	10	14	6	Earth surface processes; geology
Comptes rendus biologies	31 (0.8)	155	1.904	–	–	25	6	Biochemistry; genetics and molecular; biology; immunology and microbiology
Arabian journal of geosciences	26 (0.66)	76	1.327	–	–	–	26	Environmental Science
Acta horticulturae	26 (0.66)	38	0.26	–	1	8	17	Horticulture
Estuarine, coastal and shelf science	24 (0.61)	131	2.33	1	–	8	15	Aquatic science; oceanography
Cretaceous research	24 (0.61)	444	1.854	2	3	6	13	Paleontology
Comptes Rendus de l'Académie des Sciences	24 (0.61)	82	–	6	17	1	–	–
Progress in oceanography	23 (0.6)	944	4.06	–	1	14	8	Aquatic science; oceanography
European scientific journal	23 (0.6)	0.65	–	–	–	–	23	–
Afrique science	23 (0.6)	–	0.45	–	–	14	9	–
Revue des Sciences de l'Eau	22 (0.56)	45	0.33	1	–	9	12	Water science and technology
Regional studies in marine science	22 (0.56)	8	1.183	–	–	–	22	Animal science and zoology; Aquatic science; ecology, evolution, behavior and systematics
Eau, l'Industrie, les nuisances	22 (0.56)	19	0.02	–	1	3	18	Water science and technology
Physical and chemical news	21 (0.53)	11	0.876	–	–	8	13	Mathematical physics
Oceanologica acta	21 (0.53)	134	1.14	1	9	11	–	Aquatic science; oceanography

Table 1 (continued)

Journal title	TP (%) ($n=3924$)	Citation	IF	Time period				Subject category*
				1981–1990	1991–2000	2001–2010	2011–2021	
Marine biology	21 (0.53)	284	2.05	5	–	9	7	Aquatic science; ecology, evolution, behavior and systematics
International journal of advanced research	21 (0.53)	–	6.992	–	–	–	21	Environmental chemistry; pollution
Hydrobiologia	21 (0.53)	521	2.385	2	6	12	1	Aquatic science
Environmental toxicology	21 (0.53)	76	3.258	–	3	16	2	Health, toxicology and mutagenesis; management, monitoring, policy and law
Journal of Geophysical research: oceans	20 (0.5)	276	3.56	–	5	8	7	Aquatic science; oceanography

IF impact factor, *TP* total publications

*Data generated from SCImago Journal and Country Rank (SJR) (http://www.scimagojr.com/)

in Oceanography ranked 2nd with an impact factor of 4.06 and 944 citations. More than half (58.86%) of articles have published between 2011 and 2021. From 1981 to 1990, journal with most publications was Deep-Sea Research Part I: Oceanographic research papers. They have published almost two times as many articles than the second in the table, which is Journal of African Earth Sciences. Over the time, research priorities have changed, so too has the interested journal. Comptes Rendus de l'Académie des Sciences and Comptes Rendus Biologies were the most productive journal with during the period 1991–2000 and 2001–2010, respectively. Since the 2011, Journal of Materials and Environmental Science (126 articles) has become the preferred journal in which scientists have published their research on coastal science.

3.1.3 Research area

Priority research areas over time period is analyzed (Fig. 3a). Hydrobiology (33 publications; 15%) and ecology (in a broader sense) (14.7%) dominated research during the first decade (1971–1980), but with advancing time, the research began to emerge and studies were progressively used to answer a wider range of questions. Hydrology (19.7%) and marine geosciences (17%) maintained a steady growth while algology (1.47%) and energy (1.47%) dipped in the second decade (1981–1990). Microbiology/genetic (2%) was a new research points that appeared in this decade. In the third decade (1991–2000), hydrobiology (17%) and hydrology (15.44%) continued to be a concern. Ecotoxicology (14.8%) has a sudden increase from the third to the fourth decade and become a new research hot spot during this time period. In last decade (2011–2021), ecology (14.7%) and hydrology (13.6%) became crucial issues of coastal science. Other aspects, such as modeling and remote sensing monitoring methods including geographic information system (GIS), have received much more attention since then. Otherwise, climate change and oceanography have received minor attention.

3.1.4 Coastal habitat types

During the first decade, publications were analyzed a limited variety of coastal habitats. However, from the 207 published documents between 1971 and 1980. Almost half of them (130 publications; 48%) have been limited to the coastline studies, more than one-fifth to

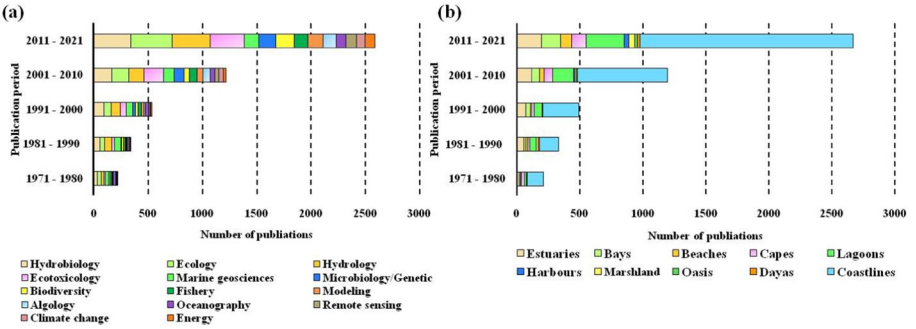

Fig. 3 Distribution of publications by **a** research area and **b** habitat type during the last five decades: 1971–1980, 1981–1990, 1991–2000, 2001–2010 and 2011-May 2021

the cape (12.5%) and estuaries (8%). The remaining habitats (lagoons, bays and beaches) were only the focus of 15% of the documents (Fig. 3b). In the second decade (1981–1990), the numbers of publications investigating the coastline has increased (155 publications; 47%). Estuaries (15%) and lagoons (15%) were the focus of over than one-third of the published documents. Recently (2011–2021), more than half (1691 publications; 63%) of the publications was devoted to investigate the coastline; 11.44% was conducted to analyze lagoons, 7% for estuaries, 5.6% for bays and 4.2% for capes. The remaining 8% were split between beaches (3.4%), marshlands (1.8%), harbors (1.2%), dayas (0.8%) and oasis (0.8%).

3.1.5 Geographic extent

Figure 4 shows the Moroccan Atlantic map with the most productive areas in terms of total number the published documents. Agadir coast including Agadir Bay, Agadir harbor and Taghazout Bay had the highest volume of scientific published studies and positioned at the top of the ranking with 538 (11%) publications; Casablanca coast ranked second with 481 (9.8%) publications. This is followed by Cape Blanc, which is ranked 3rd, with production increasingly closer 255 (5.21%) publications. Essaouira coast and Oualidia lagoon ranked 4th (236 publications; 4.8%) and 5th (220 publications; 4.5%), respectively. El Jadida Bay ranked 6th with 203 publications (4.15%), Rabat coast ranked 7th with 203 publications (4.15%) and Moulay Bouslham lagoon ranked 8th with 180 publications (3.7%). The geographic distribution of the published literature appears to be unevenly distributed across the Moroccan Atlantic coast (Fig. 4). Overall, the Northern Atlantic areas were clearly

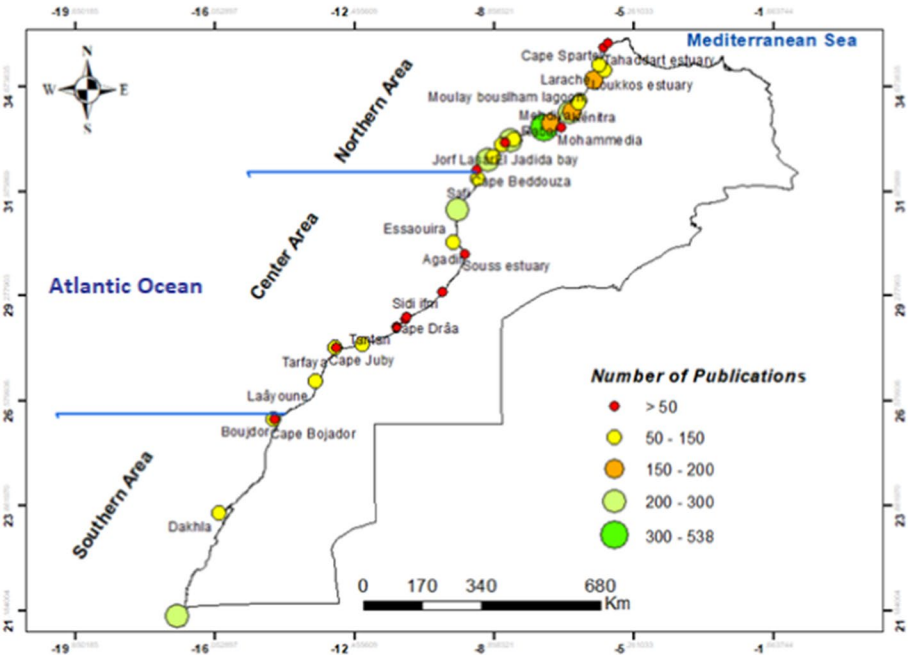

Fig. 4 Geographic distribution of the most productive areas by of number of publications. (1971–2021)

dominated the research throughout all analyzed period followed by the central Atlantic areas, while areas that receive relatively little attention were situated in the southern coast.

3.2 Network analysis

3.2.1 Co-word analysis

Co-word analysis is a key technology for content analysis (Mao et al., 2018). It permits researchers to visualize the problematic networks and discover scientific research hot spots. In this section, we base on the frequency of words appearing in titles, keywords and abstracts to capture co-occurrence relationships among different keywords. We set the minimum number of keyword occurrences to 10. Of all 14,409 keywords, 497 meet the threshold. The co-occurrence relationships among these 497 keywords was visualized and the total strength of the links between them was calculated. The co-occurrence map of keywords with the greatest total link strength is shown in Fig. 5. The size of the circle illustrates occurrences of keywords, and high occurrences typically have strong link strength. Keyword clustering divides the research contents into five clusters, where each one is distinguished by a different color. The red cluster involved the analysis of sedimentology, paleoecology, biostratigraphy and paleoceanography of the coast. The green cluster referred to the distribution of phytoplankton biodiversity in the coastal upwelling system (Moroccan Atlantic coast). The blue cluster focused on the evaluation of water quality pollution and environmental monitoring of heavy metal contamination in coastal waters. Indeed, heavy metals received focus on a high degree in coastal pollution research during the study period. Copper, cadmium and manganese addressed, respectively, more concern

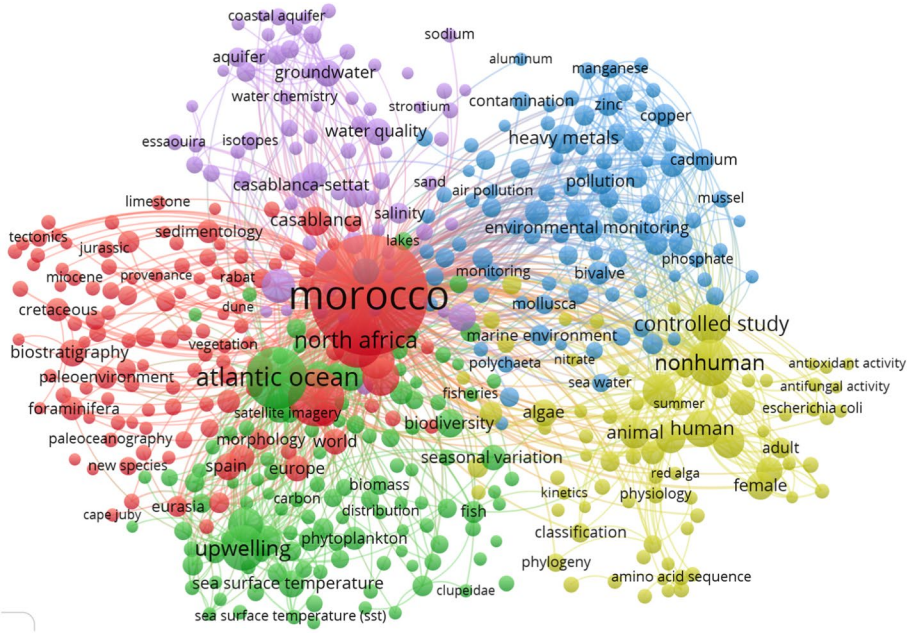

Fig. 5 Keywords co-occurrence and clusters

in coastal contamination. The purple cluster has connections with keywords mainly related to the Assessment of groundwater water quality and chemistry, especially in the region of Casablanca-Settat and Essaouira. Finally, the yellow cluster involved mainly the human behavior as an ecological driver of non-human evolution in coastal areas.

3.2.2 Co-authorship analysis

We set the minimum number of corporation document of an author as 8, of 7946 authors, 110 meet the threshold. For each of the 110 authors, the total strength of the co-authorship links between the authors was calculated. A collaboration network for the most productive authors was presented (Fig. 6). Using cluster analysis, authors were aggregated into 12 clusters; each one is marked with different color. It worth noting that Abdellatif Moukrim and Mohamed Maanan have highest publications and corporation number with other researchers.

3.2.3 Co-country analysis

As for co-country analysis, we set the minimum number of documents of a country as 10, of all 128 authors, 25 meet the threshold. For each of the 25 countries, the strength of the co-authorship links (LS) between the countries was calculated. The greatest relationship between countries of affiliation for each co-author was visualized (Fig. 7). The lines attach the countries whose authors have cooperated. Countries with the same color were commonly being cooperated more often than others. Morocco played a central position with the highest total collaboration intensity (LS = 823). The link strength between Morocco and France was maximum (LS = 571) with 537 collaborative publications; this could be an indicator of how wide international cooperation was carried out. Spain and Germany ranked second and third with LS = 267 and LS = 203, respectively. The cooperation between Morocco and European countries was much more active than African countries. With the continuous development of coastal science, African and Asian countries should strengthen their international cooperation with Morocco to improve their accomplishments.

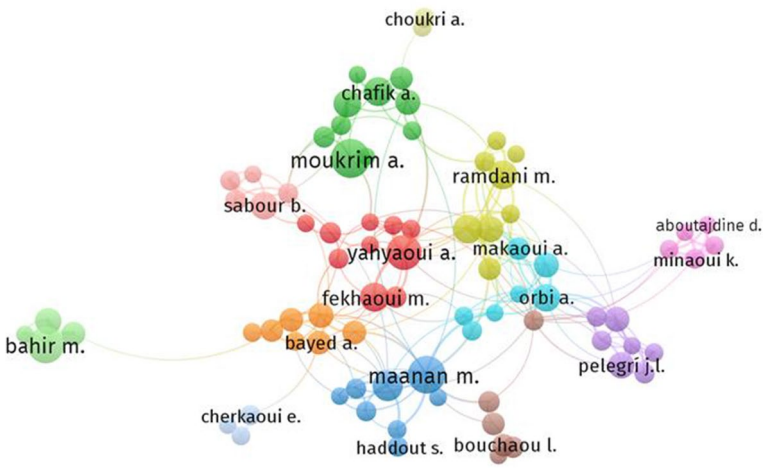

Fig. 6 Authors' co-authorship network analysis

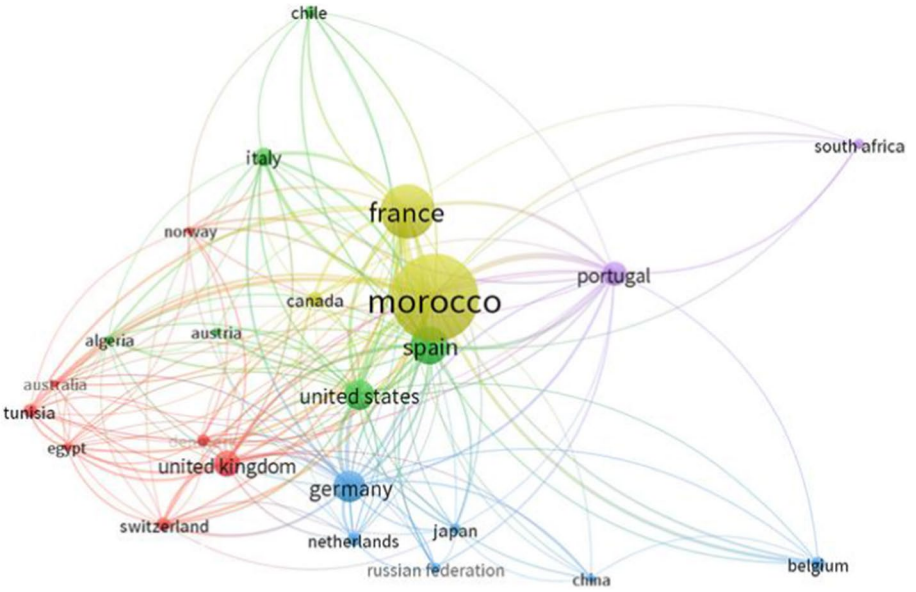

Fig. 7 Co-country network analysis

4 Discussion

4.1 Coastal research in flux

Although the growing pressures on coastal ecosystems are still apparent, the future of Moroccan Atlantic coast looks promising since the government understands that the use of the coast under the Coastal Blue Economy Growth (CBEG) concept with the Sustainable Development Goals (SDGs) and the United Nations Decade of Ocean Science for Sustainable Development (2021–2030) (IOC-UNESCO, 2020) requires concerted efforts on coastal science (Cochrane et al., 2019; Farcy et al., 2019). This bibliometric review encompasses the literature referring to coastal research in Moroccan Atlantic coast. The study contributes to the literature by providing a holistic view of the literature, covering the current state of research and identifying tendencies of coastal science in Moroccan Atlantic coast as well as the potential challenges and recommendations for future research agendas. Our results revealed that the recent advancements have considerably changed coastal research's overall character and functionality. Indeed, this sharp increase in the number of publications coincides with: (a) passage of a series of conventions (Integrated Coastal Zone Management (ICZM) protocol of the Barcelona Convention, Ramsar Convention) and legislation (law N°13–03; N° 31–06; N° 81–12) that favored field research, data collection and article publication; (b) implementation, in progress, of the National Coastal Plan and the regional plans provided for by the Coastal Law (Dahir No. 1-15-87 of July 16, 2015; Kingdom of Morocco, 2015) that shape their coastal monitoring requisites; (c) achievement of the Institutional Training Program that assisted research projects in coastal and oceanic ecosystems; accomplish the institutional purpose and strategic planning priorities in various areas of activity:

scientific research, scientific advancement, data collections, knowledge communication, contribution of science to technology. In the past decade, the scope of coastal policy gradually extended toward Integrated Coastal Management (Nachite & Sbaï, 2017; Snoussi, 2000). ICMZ appears explicitly in the government policy agenda. It has signed agreements with the African national development bank to advance the formulation of a coastal Policy of ICMZ (Akesbi, 2008). Such policy defines environmental management in an integrative way, by means of environmental descriptors, summarizing the local coastal functioning. In general terms, the efforts made recently to integrate ICMZ policy in coastal management point to a positive trend; however, there is still a long way to go. Strengthen the nexus between scientific research and a bottom-up policy is still required.

Additionally, governments have increasingly adopted various Morocco's coastal programs and instruments that highlight the importance of coastal governance research and enable a coordinated governance of the various activities associated with the Moroccan Atlantic coast. This is also demonstrated by the growth path of the number and quality of publications, the interdisciplinary topic, the quality of journals and authors involved in coastal research. Journal of Materials and Environmental Science, Journal of African Earth Sciences, International Journal of Advanced Research and Progress in Oceanography are the most productive journal. The most prolific authors include Prof. Abdellatif Moukrim and Prof. Mohamed Maanan. Geological analysis, oceanographic and hydrobiological characteristics of coastal upwelling system, coastal pollution and environmental monitoring of heavy metal contamination are the main research themes. Thought this, the roadmap for the evolution of coastal science has been outlined. The Moroccan Atlantic coast is dominated by three main forms of ecosystem: sandy beaches (2% of the coastal line), rocky coasts with cliffs (63%) and wetlands (35%), often classified as sites of biological and ecological interest (El Agbani et al., 1988). Among wetlands, coastline and lagoon valuations have appeared at consistently high levels of the published literature across the period. Oualidia lagoon is among the most investigated lagoons (220 publications). The population around the lagoon has increased from 7,741 to 18,616 inhabitants between 1971 and 2014 (El Mahrad et al., 2020) leading to pressures as seaweed harvesting, sand extraction, traditional fisheries and oyster aquaculture (Beryouni et al., 2012; Bocci et al., 2016; El Asri et al., 2015; Maanan et al., 2014). Such activities are responsible for nutrient enriched from the cultivated areas that cover 78% of the catchment (Damsiri et al., 2017); input of organic matter from aquaculture and phosphate enriched from the adjacent phosphate mine (Damsiri et al., 2015, 2017). These nutrients stimulate an increase in chlorophyll levels within the lagoon ecosystem (El Asri et al., 2018). In conrast, scientists draw little attention to ecosystems such Khenifiss lagoon (94 publications), where the anthropic impacts are not detected at present (El Mahrad et al., 2020). The lagoon is a protected area that has been designated by UNESCO as a world heritage site (El Mahrad et al., 2020). Besides, since the implementation of the Water Framework Directive (W.F.D, 2000), the hydrobiological status of the Moroccan Atlantic coastal ecosystems (14%) has been considerably investigated using a set of ecological tools that enhance biological assessments in highly dynamic aquatic ecosystems (Daief et al., 2014). We also recognize that the efforts for coastal conservation have been broader by improving the links between ecotoxicology (12%) and biological assessment tools (Wariaghli et al., 2013; Mansouri et al., 2018; Kouali et al., 2020). In spite of the optimistic attitudes of research tendency, it is worthwhile to note that further efforts are still required in energy (2.9%), climate change (2.9%), remote sensing (3.2%) and ecosystem modeling (4.7%). Indeed, for many monitoring situations the application of statistical analysis is sometimes suitable compared to the application of numerical simulations

(Karydis & Kitsiou, 2013). This is attributed to the simplicity of the statistical approach in comparison with modeling and their direct implementation through low-cost specialized software yielding consistent results (Karydis et al., 2013). In contrast, a direct observation in a system is insufficient, management strategies are more effective if designed to prevent unpleasant circumstances (Bergström et al., 2013). Environmental models are suitable for coastal and marine monitoring purposes (Borja et al., 2013). In addition to the unequal distribution of research effort between the research areas, our analysis also revealed tremendous geographic heterogeneity in the generation of scientific knowledge. In this sense, as mentioned earlier, research capacity is stronger in the northern coast with the highest number publications found in the northern coast. This disparity in research effort between the northern, central and southern coast could have different roots of climatic, economic, demographic, institutional and social character. After independence, the shift of population to the coast has continued at a steady pace. According to Mellas (2012), Moroccan Atlantic cities had 14.7 million inhabitants (46.68% of the total population) in 2010 while it represented only 6 million (39.21%) in 1971. Most of them living around the Rabat-Casablanca region (Mhammdi et al., 2020). Industrial activity has also sought out the coastal location with more than 75% of units and 77% of new investments (Mohammedia, Safi, Jorf Lasfar) (Laouina, 2019). In 2012, industrial areas concentrated 89% of production, emitted 95% of exports and received 89% of investments (DAT, 2017). Before 2015, Casablanca, Mohammedia and Jorf Lasfar harbors concentrated over 90% of the investments (Ministère de l'Equipement, 2016). Besides growing pressure from industrial activities, by 2030, more than 3% of natural coastal areas will be subject to anthropization and about 1.5% of agricultural land will be transformed for industry, tourism or urbanization (DAT, 2017). Furthermore, the Atlantic coast of Morocco receives most of the running water, particularly from the large northern watersheds of the Sebou, Oum Rbia and Tensift, which are heavily loaded with pollutants (Haddad et al., 2020). However, industrial and anthropogenic pollution, localization of the most productive research institutes/academic agencies in coastal science and a great number of persons using on the coast as a main source of income in the northern areas, placing more emphasis on local knowledge production. In addition, the rapid industrialization of northern region could have favored the establishment of new collaborations between local industry and scientists, engendering private financial support for academic research activities. In contrast, areas that are conspicuous for the research deficiency are situated in the southern coast, which may indicate more efforts should target on increasing research production in this region.

4.2 Impediments to the scientific knowledge management

Fundamental to improving the management relevance of scientific research on Moroccan Atlantic coastal ecosystems is the need for coastal managers and decision-makers to draw on the scientific advancements through the access to up-to-date scientific results (Cabral et al., 2015). Indeed, researches as producers of scientific information are held to be responsible for making such information available to managers and all stakeholders involved in the coastal research. Coastal decision-makers would have a clear-sightedness of the resources they should manage and managers would fully utilize available scientific to repair ecological damage and adopt ideas related to coastal restoration practices in an integrated management of improvement informed by sound monitoring. Nonetheless, a number of impediments prohibit the efficient management and exchange of scientific knowledge. The first is mainly associated with the limited accessibility to scientific information. Indeed, the

present synthetic research may not have exhausted the scientific literature in its entirety, and only those freely available online are collected. In other words, a significant number of articles available online (availability) do not meet accessibility criteria (accessibility) may undermine the real representation of the status of scientific knowledge in the Moroccan Atlantic coast. This is also the case in other countries, whereby governance frameworks are not clearly organized making the access to scientific information much more limited, thus showing that over half of the scientific information was not freely accessible to users, due to non-open-access journals. Even when scientific information was freely accessible to decision-makers, a previous study reported that only about one-fifth (19%) of research papers revealed clear propositions for management actions (Cvitanovic et al., 2015). Other impediments can be associated with: (a) an inadequate scientific information collection; (b) inadequate mobilization and exploitation of the scientific information collected in national planning of coastal monitoring; (c) lack of institutional capacity and infrastructure to adopt the necessary requirements for coastal knowledge management; (d) poor program planning and lack of organized national databases; and (e) timing mismatch between the need for research and implementation of a management plan (Cvitanovic et al., 2014). Following data collection and processing, scientific articles request an average of three years to be published (Cvitanovic et al., 2014). Scientific outcomes may thus be less useful to coastal decision-makers. These disparities in access to scientific knowledge prevent an effective collaboration between scientific researchers and coastal managers, especially where the transfer to scientists and institutions lacks the necessary skills (Durant et al., 2019). Nevertheless, without improving the necessary capacity for management of scientific knowledge, governments will continue to be short of the information they require for the sustained effective management of the Moroccan Atlantic coast.

4.3 Moving forward with priority coastal research

Knowledge management (KM) is key to scientific progress. It can be described as a cross-disciplinary activity that allows organizations to involve effectively the major processes of creating, storing, diffusing and using knowledge in order to accomplish their objectives faster and efficiently (Mchombu, 2007). Implementation of KM within the concept of sustainable development of coastal areas is required to achieve the objectives of the Integrated Coastal Zone Management (ICZM) that covers different aspects entailed in coastal evolution from information collection, exploitation and coastal planning to decision-making and monitoring coastal development (Lin et al., 2021). It has considerable implications for effective coastal research planning, admitting that serious disorganization and structural impediments to research disturbed the successful implementation of coastal adaptive governance, therefore causing coastal management feebleness.

Despite scientific efforts in understanding of Moroccan coastal ecosystems, the government still lacks an efficient research strategy to ensure that scientific knowledge feeds directly into the managers and policy-makers. This section proposes some tasks to be undertaken to improve the use of scientific knowledge in management planning of Moroccan Atlantic coast. First, to tackle the Moroccan Atlantic coast issues, multidisciplinary efforts at both national and international levels are essential. Although the necessary monitoring infrastructure is distributed across the country, research effort at the national level is to some extent uncoordinated, unevenly distributed and fragmented between the northern and southern coast, often being driven by the strategic interest of single actors and limited overarching coordination of scientific production. This is partially caused by limited

national collaboration, as well as funding opportunities that are highly competitive and favor small, standalone research projects. In this context, large-scale collaborative projects are needed to boost academic research and connect national and international expertise for effective management of Atlantic coast. Importantly, greater interdisciplinarity, particularly regarding connectivity with energy, climate change, remote sensing and ecosystem modeling as well as social and juridical sciences must also be addressed. Finally, to answer a next generation of coastal management questions, research community need to curate the strategies for prioritizing topics for their scientific research. This includes, for example, the setting of open funding calls and proposals for research projects or for standardized methods for coastal monitoring programs. Since the adoption of the United Nations (UN) Agenda 2030 which introduces the main Sustainable Development Goals (SDGs) (https://sustainabledevelopment.un.org/sdgs) at the UN Sustainable Development, Moroccan government has been declared to be resolute at putting in place an economic, constitutional and legislative framework to achieve the SDGs (Bounoua et al., 2020). In this context, research funders should insist through contractual engagement to make research findings freely accessible to users and provide additional funding to cover these activities charges. Intergovernmental organizations, academia, the scientific community have to build partnerships to bridge the data gaps between coastal researchers and the UN's Agenda 2030 SDGs. Additionally, international harmonization of data collection methodologies may evaluate in ways that are most suitable toward SDGs. Second, coastal accountability and transparency in regulatory evaluations could be improved through the generation of high-quality information (Ruiz-Frau et al., 2020), which should be made available on national coastal scientific platform to improve data sharing and progress collaboration across disciplines (Thessen et al., 2016). Next, the online platforms such as UNESCO International Coastal Atlas Network (ICAN), NOAA- or USGS-created datasets improving data sharing in coastal and marine science and establishing global-level data interoperability (Wright et al., 2011) may be essential to better coordinate and synthesize coastal research at the national level. Furthermore, the government could implement a national environmental database or clearing-house mechanism to maintain scientific knowledge visible and accessible to all stakeholders (Requier-Desjardins et al., 2011; Chasek et al., 2011). The challenge is to develop a national knowledge bank on the environmental framework of the Atlantic coastal regions. Users need to quickly find information about a particular coastal process of interest, as if collocated by their own particular set of time, location and topical criteria. The system disseminates data needs to be carefully maintained, updated, organized according to formal data use agreement and managed by trained database curators before sharing. Such system is supposed to ensure that managers can have access to the local information to support effective coastal management. It could have tools to foster online interaction between scientists and users, allowing them to constitute virtual communities, exchange and communicate knowledge on the trends and status of coastal ecosystems. However, closely interlinked communication between researchers, Moroccan stakeholders, civil society, industry representatives and governmental organizations is required to prioritize research questions and promote synergistic national collaboration rather than of inefficient competition (Hidalgo-Rus and Thiel, 2015; Omeyer et al., 2022). Clear communication between researchers and all coastal communities can help Moroccan authorities navigate toward the harmonization of strategic research and simplified scientific knowledge, allowing management of the Moroccan coastal areas in a sustainable way. At the same time, Moroccan experts, industry representatives and the Moroccan authorities have to share robust and simplified information faster and more openly than ever before to outline the way forward from a Moroccan perspective. In Morocco, cross-discipline dialogues

between the research communities should prioritize scientific quality and harmonization, addressing shortcomings, identifying priorities for future research and outlining ways forward to address coastal challenges. Particularly useful system is required to increase funding opportunities for cross-sector collaborations (Beier et al., 2017; Cook et al., 2013). Additionally, multiple platforms (e.g., workshops, seminars, conferences and social media) should also be utilized to define future research and provide an opportunity for moving toward evidence-based solutions (Stringer et al., 2013). A framework for enhancing the visibility of coastal knowledge can be nevertheless offered to local stakeholders through a combination of modern technologies (smartphone, laptops) and more traditional approaches (policy briefs/paper/technical reports/pen/oral). Modern technologies, particularly digital networks can be useful for ensuring the knowledge is provided on time (Stringer et al., 2013). On the other hand, focusing on co-production of knowledge whereby coastal policy-makers and managers contribute in scientific research should take place for sustainable research and policy (Underwood et al., 2013). Confirmed by other studies, permanent embedding scientists in managerial activities will bridge the divide between scientists and managers by understanding of scientific materials needs of managers (Cook et al., 2013; Jenkins et al., 2012; Young & Van Aarde, 2011). In addition, progress toward the sustainable management of Moroccan coastal area is widely attributed to institutional advancement. This should include institutional innovation by academic institutions, funding agencies, research funders and publishers to support scientist component for engagement activities, with both time allotments and dedicated funding (Cvitanovic et al., 2015). This will simulate coastal scientists with benefits extending to increase coastal research productivity and improve exchange of information. At the worldwide scale, Shanley & López, 2009 have investigated 268 scientists across 29 countries and noted that 93% of contributors agreed that funding bodies are effectively improve the dissemination of research findings. This method has been successfully adopted by funding agencies globally such as Australian Research Council (ARC), requiring that any ARC funding publications should be available as free electronic copies accessible repository within a 12 month (Cvitanovic et al., 2014). Besides, the driver–pressure–state–impact–response (DPSIR) framework can be adopted to inform coastal science. This approach has the capacity to bridge the gap between scientific discipline and involved science in coastal management. Indeed, DPSIR can serve as a template for organizing advanced research and providing viable options for managing and maintaining coastal systems (Lewison et al., 2016a, b).

5 Conclusions

Over the last years, the coastal research has received increasing attention in both developing and developed countries. Scientists have argued that coastal scientific research should play a crucial role in new information generation for more robust evidence-based coastal science, but is often hampered by a mismatch between the interests and academics' thematic areas (Ahmed & Thompson, 2019; Lee et al., 2020). This study has used bibliometric analysis in conjunction with network analysis to explore the emerging trend of coastal science in Moroccan Atlantic coast. The connected search for publications for the time period 1971–May 2021 led to a retrieval of 4891 documents from different research database. Numerous central visions have been provided by this review. First, a swift increase in the published literature referring to the Moroccan Atlantic coastal ecosystems has been witnessed over the last decade and it is expected that this rising tendency would continue in

the future. The high-quality journal-wise spread of the results promotes the advances in the topic. International Journal of Advanced Research leads the findings having maximum contribution of published articles followed by the Progress in Oceanography. Research groups including Prof. Abdellatif Moukrim and Prof. Mohamed Maanan collaborated and generated the most publications. Oceanographic and hydrobiological characteristics of coastal upwelling system, coastal pollution and environmental monitoring of heavy metal contamination were among the most preferred research academic topics across disciplines. Most of studies have addressed coastline and lagoon system. Among lagoons, Oualidia lagoon has been extensively investigated. The other systems received little attention. Geological analysis revealed a geographic imbalance is seen among study areas in publications with northern coast giving the maximum publications as these regions have advanced research infrastructures and institutional setup. Southern coast received little attention. Second, the review provides a synthesis of major impediments to the coastal scientific knowledge management along with positing areas in how we can do better. In brief, future development should focus on implementation of scientific infrastructure to: (1) provide unified access to robust and simplified data, software and services on the Moroccan coastal environments; (2) catalog all Moroccan Atlantic coastal data and facilitate data access (collection, extraction, discovery, visualization, normalization, archiving) through a web portal; (3) improve data availability, harmonization, interoperability, reusability and integrate data and knowledge; and (4) improve data sharing and progress collaboration across disciplines. Such suitable infrastructure can be a great opportunity for more robust evidence-based coastal science supporting decisions on state of science.

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