



Review

Assessing ecological restoration as a research topic using bibliometric indicators



João Paulo Romanelli^{a,*}, Jaqueline Tomiê Fujimoto^b, Marcilene Dantas Ferreira^a, Douglas Henrique Milanez^c

^a Environmental Sciences Dept. – PPGAm, Federal University of São Carlos, São Paulo, Brazil

^b Civil Engineering Dept. – PPGEU, Federal University of São Carlos, São Paulo, Brazil

^c Materials Engineering Dept., Centre for Technological Information in Materials, Federal University of São Carlos, São Paulo, Brazil

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ABSTRACT

A bibliometric analysis was performed to evaluate the global scientific production on ecological restoration from the period of 1997 to 2017. This analysis was based on online database of Science Citation Index Expanded – Web of Science© and a total of 3297 publications was retrieved. The analysis comprised seven main aspects: (1) publication activity, (2) Web of Science categories, (3) journals, (4) countries, (5) authors, (6) organizations and (7) keywords. The results indicated that the annual publications on ecological restoration study have recently increased. The USA play an important role as they have published highly in this field and have been the most frequent partner in international collaborations. American researchers have accumulated most of the publications. The Chinese Academy of Science is the emblematic organization, with 363 published papers. The Restoration Ecology and Ecological Engineering are the two most used journals to disseminate results. The major related research areas are “Environmental Science Ecology”, “Forestry” and “Biodiversity Conservation”. Studies about “restoration”, “*pinus ponderosa*”, “climate change”, “biodiversity” and “ecosystem services” have become the main subject of research along the years. Analyses of keywords suggested that there is a relatively lack of information about “soil” and “tropical ecosystems” among the analyzed studies. Overall, this framework proved to be effective to evaluate the recent research trends and to contribute with researchers and governments on management and decision-making on science.

1. Introduction

Environmental restoration techniques have evolved significantly in recent years, especially after the emergence of the science of restoration ecology (Cole et al., 2010), which contributes to substantially enhance the body of related literature (Li and Nan, 2017). Many environmental actions, however, have not yet reached the practice aims of ecological restoration (Araújo et al., 2005; Rodrigues and Gandolfi, 2007) and this fact suggests that the real effects of biodiversity recovery and ecosystem services remain uncertain and not tested (Ren et al., 2016).

Ecological restoration appears to be one of the most promising practices to restore the integrity and functionality of ecosystems in degraded areas (Devoto et al., 2012; Balaguer et al., 2014) and it aims, among other aspects, at ensuring the sustainability of ecosystem services (Robinson et al., 2013; Hu et al., 2017) in areas affected by the negative effects of recent ecological changes (Covington et al., 2001; SER, 2002). According to initiatives such as the Convention on

Biological Diversity (CBD, 2012), the Intergovernmental Science and Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2013) and massive action policies (IUCN, 2014), ecological restoration practices are a global priority (Calmon et al., 2011; Ren et al., 2016; Aronson et al., 2016), and have been recognized as one of the United Nations Sustainability Development Goals (UN, 2015).

Therefore, to better understand part of the breadth from a particular area of science, such as ecological restoration, it is useful to conduct integrated and systematic analyses of global scientific production (Borgman and Furner, 2002; Song and Zhao, 2013), investigating the recent status and emerging trends. Some researchers have used this strategy to target their research focus (Neff and Corley, 2009; Li and Nan, 2017). In this sense, bibliometric analysis plays an increasingly important role in managing and supporting decisions in the scientific scope, technological policies and research management (Ravichandran, 2012; Song and Zhao, 2013).

Bibliometrics is a statistical technique which includes registered

* Corresponding author.

E-mail addresses: joapromanelli@hotmail.com, joapromanelli@gmail.com (J.P. Romanelli).

information about scientific publications, citations, patent documents and reports (Okubo, 1997; Van Raan, 2014). Recently, this technique has received special attention from the scientific community (Merigó and Yang, 2017) because it allows the integration of information on the development of specific research fields (Zhang et al., 2016) or whole disciplines (Li et al., 2011; Liao and Huang, 2014). It is a tool that benefits researchers and governments, reducing scientific boundaries between countries or regions (Yu et al., 2017).

In this field, bibliometric mapping is a striking research topic (Borner et al., 2003), since it allows the visualization of indicators presented as networks (Van Eck and Waltman, 2009). Currently, there is a lack of work applying this systematic evaluation model to assess the status and issues surrounding the theme of ecological restoration. In this study, we sought to fill this gap by developing a bibliometric analysis over the last 21 years (1997–2017), presenting a global overview and highlighting its hot spots and future trends. Specifically, this study aimed at: (1) examining trends in the “ecological restoration” research activity over the past two decades through the online subscription-based scientific citation indexing service; (2) presenting an overview about “ecological restoration” according to the distribution of papers by: publication activity, Web of Science categories, journals, countries, authors, organizations and keywords; and (3) evaluating the international collaboration networks by bibliometric mapping method.

2. Material and methods

2.1. Data collection

Bibliometric indicators have been developed considering the bibliographic data of publications indexed in the online database of Science Citation Index Expanded (SCI-E) – Clarivate Analytics' ISI – Web of Science® (<https://webofknowledge.com/>), which has an extensive and multidisciplinary coverage of bibliographic data of cutting edge scientific publications. The database is usually used as a source for academic studies (Azevedo et al., 2005; Boaneres and Azevedo, 2014) and for bibliometric studies (Okubo, 1997; Milanez et al., 2013; Van Raan, 2014). The term “ecological restoration” was designated to describe the scientific knowledge about restoration associated to ecological theories.

The search expression consisted in applying “ecological restoration” to the “Topic” field, which seeks for publications through their title, abstract, author's keywords, and WoS-assigned keywords called Keywords Plus (Boudry et al., 2018). These records necessarily brought the words “ecological restoration” in an associated way and in that exact order, due the use of quotation marks (Știrbu et al., 2015). Only articles and reviews have been considered in this analysis, because they represent the majority of documents with complete research results and outcomes (Fu et al., 2013; Boudry et al., 2018). The research comprised the timespan from 1997 to 2017 and dataset were downloaded on January 22, 2018. After searching, a total of 3297 bibliographic data of scientific publications were retrieved and collected (94.26% articles and 5.74% reviews). The assessment involved the following information obtained from the collected sample: (1) publication activity, (2) Web of Science categories, (3) journals, (4) countries, (5) authors, (6) organizations and (7) keywords. The synthesis of the methodology employed is presented in Fig. 1.

2.2. Data analyses

All analyses were performed using the “Analyzing Results” tool provided by the database with support of the MS Excel (v. 2016) to perform calculations and develop charts (indicator visualization). Maps of collaboration based on co-authorship and co-occurrence analysis were developed using VOSviewer software (version 1.6.6; www.vosviewer.com) to understand how countries, research institutions, and authors have been organizing themselves in this theme. VOSviewer

is a robust tool that uses clustering algorithms and functionalities based on the strengths of the connections among items to help the analyses of the network. The evaluation of the authors' affiliation was performed based on the “Author Information”, contained in the publications and it may not to represent all of their academic links.

To investigate the most popular research topics, their overall trends and knowledge gaps, an assessment comparing the Keywords Plus and Author's keywords has been carried out. Keywords Plus supplies additional search terms extracted from titles on cited papers and footnotes (Garfield, 1990), and include important terms for research (Boudry et al., 2018). Web of Science uses these keywords in order to improve information retrieving routines (Milanez et al., 2013). In this sense, non-repeated words or terms obtained by comparison between Keywords Plus and Author's Keywords with few occurrences were considered non-focused themes on studies about ecological restoration. The meaningless words (also called stopwords) were not taken into account, and the final listed words were separated into two groups: generic words (representing general terms) and directive words (representing specific terms). The set of directive words was used to validate the keywords analysis through a second search on Web of Science.

3. Results and discussion

3.1. Evolution of scientific activity: prior analysis

Restoration of ecosystems is an ancient practice. However, the scientific field of restoration ecology is relatively recent (Anderson, 2005). The 1980s are considered a historical landmark that characterizes the two phases of the restoration domain (Rodrigues et al., 2009; Oliveira and Engel, 2011), which is defined: by scientific knowledge associated to techniques; and by the association of these techniques with ecological theories (Young et al., 2005; Durigan and Mello, 2011).

The domain of ecological restoration has developed a broad and diversified body of literature in recent decades, which addresses several aspects of ecological interaction (Weiner, 1995; McPherson and DeStefano, 2003). This fact is relevant both to the science of restoration ecology and to the practice of ecological restoration (Young et al., 2005). The evolution of publications between the years 1997 to 2017 associated with the five main WoS Categories can be found in Fig. 2.

It is clear that ecological restoration can be considered an emerging theme of research as consequence of the general trends shown by the chart column (Fig. 2). Moreover, concerns about the environmental preservation in favor of sustainable development have been promoting the increase of the global scientific production on ecological restoration (Bloomfield et al., 2017).

In general, this topic has shown to be relevant all over the world, covering 107 different countries. Among them, the USA and China have accumulated the largest number of publications. Of course, the analysis should take into account the fact that most ISI-listed journals are published in English, which favors countries that speak this language (Okubo, 1997; Tao et al., 2015).

3.2. Main journals and most impacting papers

Overall, all retrieved papers were published in a wide range of 596 different journals. However, most journals (about 96%) have published fewer than 20 papers in the last two decades. Consequently, it is understood that these journals are peripheral in relation to scientific studies concerning ecological restoration. The top 20 most active journals, which represent about 40% of all publications, are listed in Table 1. The journal that publishes on behalf of the Society for Ecological Restoration (SER) – Restoration Ecology – is responsible for 9.7% from the total number of publications retrieved, heads the journals ranking and shows the importance of the Society.

The second most influent journal in the ranking, the Ecological Engineering, published over half of the first ranked journal (5.3%),

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