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# Trends in global research in deforestation. A bibliometric analysis

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ABSTRACT

The main aim of this study was to analyse topics of research, scientific production, collaboration among countries, and most cited papers on deforestation through a bibliometric and social network study of articles found in the Web of Science database. The most productive subject areas corresponded to Environmental Sciences, Ecology and Environmental Studies. The articles were published in 458 different journals. A total of 2051 research articles were obtained. The main challenges identified for deforestation include "land use change", "conservation", "climate change", "rain forest" and "reducing emissions from deforestation and degradation". Social and economic topics are understudied. An important level of international collaboration has been identified, including the triangle of the United States, Brazil and the European Union, as well as others.

## 1. Introduction

The loss of forest leads to increased insolation due to decreased cloudiness, which also causes additional increased land surface reflectance (Bala et al., 2007). Other major effects include changes in aerosol emissions from contaminated continental atmosphere to the oceans with a subsequent modification of rainfall patterns (Andreae et al., 2004; Butt et al., 2011; Saad et al., 2010), alteration of wind behaviour due to changes in surface roughness and a major impact on atmospheric moisture and thus precipitation (Betts et al., 2004).

The Amazonia forest is one of the planet's most important biological resources and a key player in the Earth's ecosystem. The terrestrial photosynthesis that occurs in Amazonia corresponds to 15% of that overall on the planet (Field et al., 1998), and it is estimated that a quarter of the planet's terrestrial species can be found in this vast territory (Dirzo and Raven, 2003). However, it is today facing increasing stress due to apparently unstoppable deforestation and climatic change conditions (Malhi et al., 2008). Evaporation and condensation of water that occurs in the Amazonia forest are major elements of global atmospheric circulation, and thus negative impacts on precipitation patterns not only affects the surrounding countries of South America but also the entire Northern Hemisphere (Gedney and Valdes, 2000; Werth and Avissar, 2002).

The last available data indicates that a surface corresponding to 13% of the Amazonia forest has been deforested by human activities (INPE, 2012)). Amazonia's deforestation is mainly concentrated along the southern and eastern margins, currently known as the "arc of deforestation", and along the Andean piedmont. A large proportion of the deforested land (62%) is used as cattle pasture, with a serious impact on the region's climatic equilibrium (Lenton et al., 2008; Nobre and Borma, 2009; Malhado et al., 2010). Cattle farming is thought to be the main driver of environmental change (Leite et al., 2012). An additional 6% is used as cropland, mainly dedicated to soybean production, and the remaining 32% is used with the aim of re-growing the lost vegetation (Soares-Filho et al., 2006; Ramankutty et al., 2007). The modification caused by deforestation activities depends to a large extent on the type of activity replacing the forest. As reported by different authors, land use for soybean production reduces precipitation to a greater extent than land converted to cattle farming (Costa et al., 2007; d'Almeida et al., 2007)

Some of the ecosystem services attributed to the Amazonian forest include a high biodiversity reservoir, climate change regulator, source of carbon storage (Soares-Filho, 2010; Nepstad et al., 2008), and living territory for several million people (Pan, 2011) as well as an increasing environment for the production of agricultural resources. Current research based on global and regional climate models has placed a limit of 40–50% deforested surface as critical (Sampaio et al., 2007; Nobre and Borma, 2009; Davidson, 2012, Costa and Yanagi, 2006). The possibility of reaching this "point of no return" has received increasing attention from scientists and policy makers over the past 30 years (FAO, ITTO,

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2011; Malhi et al., 2008; Davidson, 2012).

The expansion and development of protected areas is one, but not the only, strategy adopted by national and international entities when aiming at the conservation of the Amazonian forests and their ecosystem activities (Áreas Protegidas da Amazônia programme: http://www.mma.gov.br/port/sca/arpa/). The creation of new protected areas in combination with governmental laws to prevent deforestation and degradation processes on private lands has resulted in increased conservation of large areas of the Amazonian forests (Assunção et al., 2012; Davidson, 2012; Laurance, 2012)

New evidence has shown a 70% decline in deforestation of the Brazilian Amazonian forests, indicating that it is possible to minimize the loss of forest surface areas. This was achieved through law enforcement, limitations on access to credit, intervention activities in both the soy and beef industries and the aforementioned incremental addition of protected areas. These strategies, in combination with a decrease in the demand for new deforestation, have contributed to the decline. Slowing deforestation is thus possible by using effective territorial approaches, which also contribute to the task of achieving sustainable development of areas subject to deforestation risk (Nepstad, 2014).

The analysis of research trends through bibliometric studies is receiving considerable attention, as they provide valuable information on scientific research and its progression in a specific field of study (Vain, 2007). Despite the increasing public importance of research on deforestation, there are currently no available scientometric studies on the effect of deforestation on agricultural activities. The main aim of this research was to achieve a better understanding of the available scientific knowledge with regards to the effects of deforestation on climate change as well as on the evolution of this phenomenon through published articles included in the Web of Science database

## 2. Methods

The Web of Science Core Collection from Thomson Reuters was the source from which the articles analysed in this study were obtained. The search was not performed using the Topic field option, which includes the fields Title, Abstract and Keywords in order to avoid the occurrence of a large number of non-relevant results. The search was thus conducted using the Title option as: Title = ("deforest* OR disforest*). The asterisk truncation provides all the possible files that contain the same root (e.g., the terms "deforesting", "deforested" and "deforestation" are extracted from "deforest*"). The amount of records obtained using these terms was 2306. The records were revised to confirm their pertinence to the field, so that a set of 255 records containing book reviews and book chapters (n = 180), news items (n = 43), meeting abstracts (n = 29), and biographical items (n = 3) were excluded, resulting in 2051 papers under study. The keyword standardization was carried out to group synonyms and variations in the spelling of the same concept (mainly, singular and plural, acronyms and derivations).

To identify trends in scientific research on the topic of study, a bibliometric analysis of journals of publication, subject categories in which the journal is classified, most frequently author key words used in each subject category, articles reviewed that had the highest number of citations and the impact factor of journals were combined. The most prolific countries and the most commonly used keywords were identified using social network analysis (SNA). This was achieved by reporting the number of co-occurrences in the articles extracted from the bibliometric search. Keyword density maps were represented using the VOSViewer software. Pajec software (Batagelj and Mrvar, 2002) was used to investigate the network of co-words as well as the collaboration between countries. Journal impact factor data was extracted from the 2014 edition of the Journal Citation Reports.

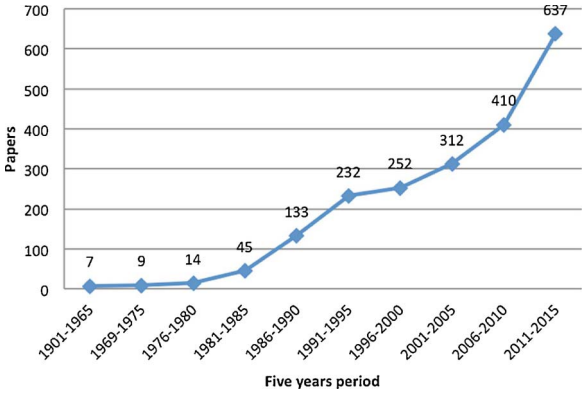


**Fig. 1.** Evolution of published papers.

## 3. Results

A set of 2051 published papers were obtained. The first article recorded in WOS dates from 1954 (Fig. 1). The number of publications has shown a steady increase, from 30 in the period before the 1980s (1.46%) to 637 from 2011–2015 (31.06%).

### 3.1. Annual evolution and journals of publication

The articles were published in 458 different journals. Table 1 shows the 19 journals with more than 20 published papers with the country of publication, citations, impact factor, WOS subject categories and quartile. The journals publishing the most papers are *Forest Ecology and Management* (n = 52), *Science (n = 43), Environment Conservation* (n = 41) and *Ambio* (n = 31). The most-cited journals were *Science* (n = 5.211*), Proceedings of The National Academy of Sciences of the United States of America* (n = 2.418), *Nature* (n = 1.724), *Conservation Biology* (n = 1.720) *and Journal of Climate* (n = 1.709). The ranking of journals according to the ratio of citations per paper is similar, but placing *Conservation Biology* before *Nature*. Additionally, following *Nature* (IF = 41.456) and *Science* (IF = 33.611), journals with a higher impact factor were *Proceedings of the National Academy of Sciences of the United States of America (IF = 9.674), Global Change Biology (IF = 8.044)* and *Global Environmental Change-Human and Policy Dimensions* (IF = 5.089). Most of the journals are included in the first quartile of the Journal Citation Reports.

### 3.2. Key word analyses and subject categories

The number of published articles during the five-year period and the most frequent keywords are shown in Table 2. In general, all words have increased in frequency. The word "Amazonia", which was present in 9.1% of the articles in the five-year period from 1991–1995, appears in 28.3% of the articles in the five-year period 2011–2105. "Land use change" increased from 2.6% to 29% in the same five-year period. "Conservation" and "climate change" increased from 0.9% to 18.2% and 12.4%, respectively. Some words have declined over the last five years, such as "biodiversity", "tropical forests", "rain forest" and "dynamics". Among the words that have had little variation over the last five years are "land cover change", "vegetation", "climate", "population", "biomass" and "remote sensing".

Web of Science categories with the highest number of published articles, journals with the most articles in each area and the most frequent key words are described in Table 3. The list is topped by Environmental Sciences (n = 496), with the most frequent key words being "Amazonia", "land use change" and "forests", and by the following most productive journals: *Environmental Conservation*, *Ambio* and *Climatic Change*. Two other areas with more than 200 published articles were Ecology (n = 283) and Environmental Studies (n = 233). In