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## Essays and Perspectives

# The use of nucleation techniques to restore the environment: a bibliometric analysis



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### ABSTRACT

The population awareness about environmental conservation is raising and this brought about an increase in the number of environmental restoration studies. Nucleation is a technique used for environmental restoration, where small nuclei of vegetation are established within degraded land. The aim of this paper was to evaluate, by doing a bibliometric analysis, the tendencies and gaps in the study of environmental restoration using the nucleation technique. Data were collected using The Web of Science® and Google Scholar® databases, from 1996 to 2012. Keywords used in the search of papers were nucleation, soil recovery, transposition of soil, bird perches, ecological succession, seed rain, restoration ecology, forest regeneration, degraded area and natural regeneration. Results showed that the number of published studies was low, although increasing in the last decade. The majority of the studies used more than one restoration technique or used natural perches as nuclei. Most of the studies were conducted in the Americas and by Brazilian researches. Many studies were not published as papers in scientific journals, but were available as master thesis or monographs. Natural and artificial perches, soil transposition and natural regeneration were the most successful techniques. The number of nucleation studies must increase and spread through the world, and their results need to be published to help other researches in the environmental restoration.

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## Introduction

Deforestation is a primordial human activity that is causing global changes in the climate and in land use that affects the biodiversity, carbon storage, environmental connectivity and

the nutrient dynamics in the soil (Foley et al., 2005). Revegetation is one of the existing alternatives to mitigate these problems (Pausas et al., 2006).

Revegetation is an ancient practice made by different folks in different times and regions (Rodrigues and Gandolfi, 2001). Most of the revegetation measures involve planting arboreal

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species (Rodrigues and Gandolfi, 1996, 2001). However, there are many problems highlighted by this practice due to the negligence of some ecological premises, like ecological succession (Araújo et al., 2005). This traditional model needs expensive technologies, which turn small projects impossible to be made, and have a strong dendrological view, using frequently exotic arboreal species, allowing local biological invasion and potentiating land degradation (Reis et al., 2003). This occurs because this model was developed for a quick and large vegetal biomass production (Bechara et al., 2007).

Environmental restoration techniques evolved after the appearance of the restoration ecology science (Cole et al., 2010). Today, restoration ecology is a goal to self-sustainability, participating in the restoration of the stability and biological integrity of the ecosystems (Rodrigues and Gandolfi, 2007).

One of the restoration techniques is nucleation (Martins et al., 2007). According to Reis et al. (2010), nucleation is a technique that uses small nuclei of vegetation within degraded land as starting points of vegetation regeneration. This technique tends to facilitate natural successional processes since it involves producers, consumers and decomposers, making it extremely effective (Reis et al., 2007). The vegetation nuclei have the function of attracting animals and plants, allowing other species to colonize the area (Yarranton and Morrison, 1974).

Six different nucleation techniques are normally used in restoration programmes: artificial perches, soil transposition, plantation in islands, Anderson groups, natural perches, and natural regeneration. The insertion of artificial perches in degraded areas helps in the increase of propagules in the substrate (dispersed mainly by birds from nearby forests) to accelerate the plant succession; the same is the goal for the natural perches, but in this case, small trees and bush are planted in degraded areas instead of the installation of artificial devices (Reis et al., 2003). Small portions of soils from non-degraded areas generally have great amounts of seeds and microorganisms within, and they can be transported to degraded areas aiming to accelerate the regeneration process (Espíndola et al., 2006). Anderson groups consist of the plantation of groups of key-tree species (those that naturally occur in the area), helping the increase of genetic variability (Tres & Reis, 2009). Dense groups of different plant species can be equidistant planted in degraded areas, and this technique is called plantation in islands (Corbin and Holl, 2012). In natural regeneration, no human interventions are made, being the area isolated and left to regenerate (Martins, 2001).

According to Martins (2007), the increase in the people's awareness about nature conservancy enabled an enhancement in the number of restoration studies that uses nucleation as a technique. Thus, the goal of this study was to conduct a literature revision about nucleation, pointing out tendencies and gaps, the most successful practices and methods, to help future restoration programmes and researchers.

## Methods

The bibliometric search was conducted using The Web of Science® and Google Scholar® databases. The Web of Science® database was chosen because it is considered the most

extensive and multidisciplinary database, being extensively used by academics (Azevedo et al., 2005). However, The Web of Science® does not index all scientific journals or other kinds of scientific publications, such as thesis and monographs. Google Scholar® was chosen as a searching database because this kind of scientific publications can be found, and because it provides free and easy access to academics worldwide.

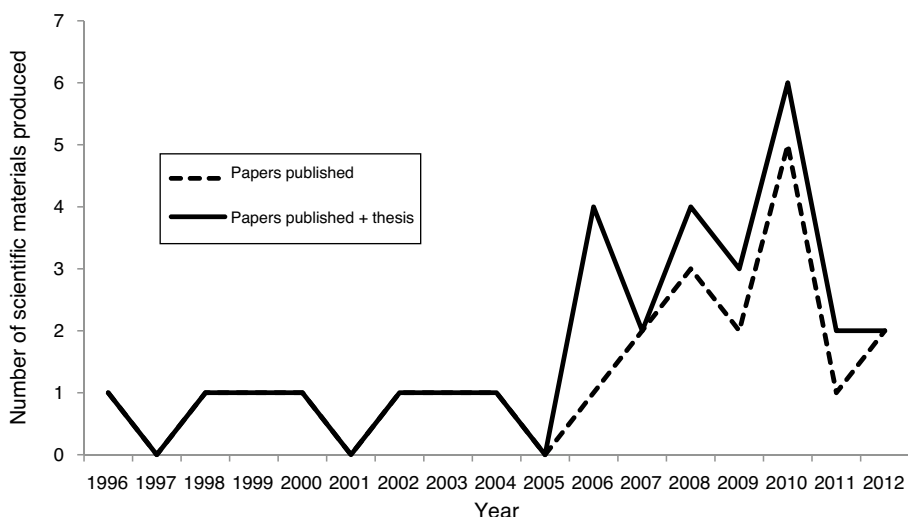
The keywords used in the bibliometric search were nucleation, soil recovery, transposition of soil, bird perches, ecological succession, seed rain, restoration ecology, forest regeneration, degraded area and natural regeneration (papers with these key-words in any part of its text were selected; a search using the Boolean operators "and" and "or" was also run). The search comprised the years 1996 to 2012 (almost all studies were published between these years). Initially, the search resulted in 112 papers in The Web of Science® database, which were all exported to the software Endnote 5®. Then, all abstracts were read and all papers out of the subject were deleted from the results, remaining only 14 papers. The search in Google Scholar® resulted in 17 papers, which were all used. All papers were integrally read and analyzed according to the following parameters: (1) Year of publication; (2) Authors; (3) Journal where it was published; (4) Journals' impact factor; (5) Database (The Web of Science® or Google Scholar®); (6) Technique of nucleation; (7) Study type (theoretical or experimental); (8) success of the technique of nucleation in the study, and (9) Country where the experiment was conducted (if theoretical, the country of the Institution of the first author). The impact factor of the journals was grouped as the follows: [(1) 0.1-0.9; (2) 1.0-1.9; (3) 2.0-2.9; (4) 3.0-3.9; (5) 4.0-4.9 and (6) 5.0-5.9]. Data were analyzed in percentages.

## Results

Twenty-three scientific papers and seven scientific materials (Dissertations, Thesis, Monographs, etc.) were published between 1996 and 2012. Papers found only in The Web of Science® database represented 26.09% (n=6); papers found exclusively in the Google Scholar® database represented 39.13% (n=9); papers found in both databases represented 34.78% (n=8) of the sample. When other scientific publications, such as thesis and monographs, were inserted in the Google Scholar® sample, there was an increase in their number, jumping from nine to 16 publications (39.13% to 53.33%; n=23 to n=30).

Considering only the results of the search in The Web of Science®, between 1996 and 2005, only seven papers were published, which represents less than one paper per year (0.7 papers per year). However, between 2006 and 2012, 16 papers were published (2.28 papers per year). The year of 2010 was the most representative, with five papers published (21.74%) (Fig. 1). Considering only the results of the search in Google Scholar® database, between 1996 and 2005, the same seven publications were found. However, from 2006 to 2012, 19 scientific materials were found, almost three publications per year (2.71 publications per year). The year of 2010 was again the most productive, with six publications (20%) (Fig. 1).

Thesis, congress/symposium abstracts, monographs and dissertations appeared in the results only therewith the year



**Fig. 1 – Number of papers about nucleation techniques of environmental restoration published between 1996 and 2012 found in The Web of Science (papers published) and Google Scholar (papers published + thesis) databases.**

2006, with three records, being two congress/symposium abstracts and one master dissertation; from 2008 to 2011, one record per year was observed, being one congress/symposium abstract in 2008, one master dissertation in 2009, and two monographs, one in 2010 and one in 2011.

Brazil was the country with more papers published, followed by United States and Spain, with four papers each (Table 1). The American Continent was represented by four countries that published during the period comprised by this study, being followed by the African Continent, with three countries. Europe and Asia were represented only by one country each, and Oceania did not publish any paper from 1996 to 2012 (Table 1).

Most of the published papers figured in the category 2 of the impact factor, followed by the category 6 and category 1. Three papers were published in journals with no impact factor (Table 2).

Papers about nucleation were published in 16 journals, being Ecological Applications the most chosen by the authors (Table 2). The journals Biotemas, Journal of Ecology,

Journal of Vegetation Science, Restoration Ecology and Revista Árvore published two papers each (Table 2). Seven publications were not published in scientific journals, being three congress/symposium abstracts, two master dissertations and two monographs.

Fifty-four researchers participated in the publications evaluated, but most of them figured in only one paper (1.43%). Ademir Reis was the researcher who published more papers about nucleation (5.71%; n = 5), followed by Rakan A. Zahawi, Dayse R. Tres, and Karen D. Holl, with three papers each (4.29%). Inserting the other scientific materials, the number of authors jumped to 64. The researcher with most of the publications turned to Dayse R. Tres (n = 6, 7.14%), followed by Ademir Reis, with five publications (5.95%).

Five different nucleation techniques were used by the researchers: natural perches, artificial perches, plantation in islands, soil transposition and natural regeneration; natural perches was the most used technique, appearing in 26.08% (n = 6) of the papers. Plantation in islands and natural regeneration followed natural perches, appearing in four papers each. Three papers cited more than one technique or cited artificial perches or cited soil transposition. When analyzing together the other scientific material from Google Scholar® search, an increase in the number of nucleation techniques was observed (from six to eight techniques); branches transposition and Anderson groups were cited only in non-published materials (Table 3). Papers citing more than one nucleation technique were the most representative, with 20.52% (n = 8) of the publications, followed by natural perches, natural regeneration and soil transposition (Table 3).

Twenty-two studies reported success in land regeneration, being natural perches the most successful nucleation technique used (n = 6; 27.27%), followed by soil transposition (n = 5; 22.72%), artificial perches (n = 4; 18.18%), natural regeneration (n = 3; 13.63%), plantation in islands (n = 2; 9.09%), branches transposition and Anderson groups (n = 1; 4.54% each). Natural regeneration, plantation in islands and artificial perches failed in land regeneration in three studies. Two studies tested

**Table 1 – Number of published papers and scientific material (thesis, monographs, congress abstracts, etc.) by countries from 1996 to 2012.**

Country	Papers published		Papers published + Thesis	
	n	%	n	%
Brazil	8	34.77	15	50
USA	4	17.39	4	13.34
Spain	4	17.39	4	13.34
Costa Rica	2	8.7	2	6.67
Uganda	1	4.35	1	3.33
Japan	1	4.35	1	3.33
Canada	1	4.35	1	3.33
Cameron	1	4.35	1	3.33
South Africa	1	4.35	1	3.33
Total	23	100	30	100

**Table 2 – Numbers and percentages of papers published in Journals indexed but The Web of Science®. The countries and impact factor of each Journal were also cited.**

Journal	n	%	Journal country	Impact factor
Ecological Applications	3	13.04	USA	5.102
Biotemas	2	8.7	Brazil	1.00
Journal of Ecology	2	8.7	United Kingdom	5.044
Journal of Vegetation Science	2	8.7	USA	2.77
Restoration Ecology	2	8.7	USA	1.681
Revista Árvore	2	8.7	Brazil	0.458
Scientia Agricola	1	4.35	Brazil	0.751
Revista Brasileira de Biociências	1	4.35	Brazil	–
Pesquisa Florestal Brasileira	1	4.35	Brazil	–
Natureza & Conservação	1	4.35	Brazil	–
Journal of Tropical Ecology	1	4.35	United Kingdom	1.401
Journal of Forest Research	1	4.35	Japan	0.767
Functional Ecology	1	4.35	United Kingdom	4.56
Forest Ecology and Management	1	4.35		2.487
Ecology	1	4.35	USA	4.849
Acta Oecologica	1	4.35	USA	1.570
Total	23	100		

more than one nucleation technique at the same time; one of these studies tested soil transposition, branches transposition, natural regeneration, artificial perches, and Anderson groups, being the last technique the only one that failed in the regeneration of the environment. The other study tested natural regeneration, Anderson group, and soil transposition; only soil transposition failed in the regeneration of the environment.

Most of the published scientific papers and non-published scientific material were based on nucleation experiments ( $n=18$ , 78.24%;  $n=21$ , 70%, respectively). Revision papers are present, but in less numbers for both publication categories ( $n=5$ , 21.74%;  $n=9$ , 30%, respectively).

## Discussion

The number of environmental restoration papers that use nucleation as the main technique is increasing over the years, but the number of researchers/countries did not follow this pattern. The number of restoration papers is still incipient;

this could be reflecting the lack of interest of the scientific community in the amelioration and/or in the testing of the techniques of environmental restoration, or that the researchers that restore the environment are not interest in publishing their results (maybe due to the use of non-scientific methodologies). However, when we observe that the majority of published papers were based on nucleation experiments instead of being theoretical, the hypotheses of the lack of interest of the researchers in testing nucleation techniques may be discarded.

The number of nucleation researchers is low (54 if the non-published scientific material is counted), and most of them published only one paper about this theme. Brazilian researchers Ademir Reis and Deisy R. Tres figure between the most productive researchers, having published more than three papers. Ademir Reis introduced the theme in Brazil in the 90s, putting the country in a special place among the few countries that had published in this research line. American and African countries studied the most of the nucleation techniques, while Asian and Oceania countries studied the less this theme. These results showed how unequal are the distribution of environmental restoration action using nucleation techniques across the world.

There was a special interest in the use of natural perches, plantation in islands and natural regeneration techniques; papers with more than one nucleation technique were also common. Natural perches, soil transposition and artificial perches were the most successful techniques and their use should be stimulated. Each technique has its particularities and should be used according to the degradation level of the area (Espíndola et al., 2005). The use of natural perches, for example, is associated with the plantation of berry trees; these species are capable of attracting diverse fauna, promoting interspecific encounters inside the degraded lands, and acting as nucleators (Reis et al., 2009). Winterhalder (1996) suggested that the nucleation capability of certain plants is important to promote revegetation in degraded areas, i.e., not all plant species are useful as nucleators.

**Table 3 – Nucleation techniques cited in the published papers and unpublished scientific literature (thesis, monographs, congress abstracts, etc.).**

	Published papers		Published papers + Thesis	
	n	%	n	%
Natural perches	6	26.08	6	15.38
Natural regeneration	4	17.39	6	15.38
Plantation in islands	4	17.39	4	10.26
Many techniques	3	13.04	8	20.52
Artificial perches	3	13.04	4	10.26
Soil transposition	3	13.04	6	15.38
Anderson groups	0	–	3	7.69
Branches transposition	0	–	2	5.13
Total	23	100	39	100

The plantation in islands technique is characterized by the formation of small nuclei (islands) where different plant species are planted (grass, weed, shrubs, lianas and trees), generally with rapid flowering and fructification, in a way to facilitate the attraction of pollinators, disperses, predators and decomposers. This generates an environment suitable for colonization, regeneration and reproduction of other species (Bechara, 2006). The effectiveness of the nuclei will be maximum if planned with species that flowers and fructifies during the entire year, offering food items continuously (Oliveira et al., 2003), and if planned with plants that have a great genetic heterozygosity, since the succession in the degraded area will depend upon the initial available genetic material (Kageyama, 2003).

In areas with small levels of perturbation, where seed banks, plantlets, sprouting and seed rain are present, natural regeneration is the suggested technique, since there is a possibility of self-restoration; actions may be concentrated in isolation of the areas from disturbing factors by the construction of fences and firebreaks (Rodrigues, 2002; Tomazi et al., 2010).

The use of many nucleation techniques at the same time is suggested by Reis et al. (2003). According to the authors, each technique promotes many functional effects that, when carried out in conjunction, generate a variety of natural flows over the degraded area, sustaining key processes and collaborating with the rescue of the complex conditions of a natural environment. The use of many different techniques will allow rapid community stability, enhancing its successional rhythm (Reis et al., 2003; Schlawn and Zahawi, 2008; Tres, 2006b).

However, it is important to remember that to determine the better strategy to restore an area, it is necessary to understand a series of processes that occur in the community (Tres et al., 2005; Corbin and Holl, 2012). It is essential to conduct a preliminary diagnosis of the resilience potential of the areas, aiming to provide crucial indicatives about the better restoration techniques to be used (Bechara, 2006; Guinle, 2006; Tres, 2006a).

The results found in the present study showed the importance of making a bibliometric search in different databases, especially if the number of publications about the theme of interest is low, since many papers, mainly those published in journals of low impact factors, may not be available in The Web of Science® database. The Web of Science® database cites journals evaluated by the Journal of Citation Reports (JCR) and the rank produced by JCR is based on the number of times the papers are cited (JCR, 2005); journals with local circulation are normally not ranked by JCR, what limits their appearance in specific databases. These papers could be important to evaluate less well-known restoration techniques or by bringing historical information of low-visibility local regeneration programmes, or even by reporting restoration programmes that fail (frequently journals publish studies with positive results; Fanelli, 2010).

In conclusion, nucleation is an environmental restoration technique poorly used in the world; researchers, especially of Asia and Oceania, should use and test this technique, with scientific methodologies and rigour, and publish their results in high quality journals. This would help in the disclosure of the nucleation technique, helping other researches in the

implementation of restoration programmes, diminishing land degradation.

## Conclusions

Nucleation techniques are rarely used by researches around the world, but the few results found in the literature showed that these techniques are very efficient in the regeneration of the environment, thus, nucleation techniques should be used more often.

Compared with other countries, Brazil is the most productive of studies using nucleation techniques. More countries could use this technique for the environmental regeneration.

Most of the studies about nucleation techniques are being published in journals with low impact factor. More scientific criteria should be implemented in the studies, as well as the technique should be more spread to the scientific community, in a manner such that the studies could be more easily accessed by scientists and be published in journals with higher impact factors.

Among the nucleation techniques, natural perches, plantation in islands, and natural regeneration were the most used. More studies using the other techniques should be conducted.

## Conflict of interest

The authors declare no conflicts of interest.

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