

OPINION ARTICLE

Review of the science and practice of restoration in Argentina: increasing awareness of the discipline

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The objective of this work was to obtain an overview of studies on ecological restoration carried out in Argentina to date. By means of the Scopus database, we performed two literature searches, one in Spanish (restau* and Argentina) and the other in English (restor* and Argentina). Between 1996 and 2013, 105 publications were registered, representing 2% of publications in Biology and Ecology. Most of these appeared in international journals (87%), in English (86%), and 28% were coauthored with researchers from other countries, favoring visibility at an international level. We observed an increase in the number of studies per year over time, with a significant increase beginning in 2008. Of the 18 ecological regions in Argentina, we found studies relating to 12 as well as four studies relating to restoration in urban areas. This review of the literature is intended to increase awareness of restoration in Argentina and help identify current gaps relating either to this subject or to specific ecological regions.

Key words: Latin America, networks, priority, South America

Implications for Practice

- In the ecological regions of Argentina that have not yet been dealt with in the scientific literature or that suffer high levels of transformation, the development and documentation of basic and applied research in restoration ecology is a priority.
- The support of both national and international networks as well as the exchange of information among those who carry out basic and applied research in restoration ecology in Argentina will make greater growth in this discipline possible in the country.

Introduction

Ecosystem restoration is recognized worldwide as a key component of conservation programs, and its development is essential for long-term sustainability (Aronson & Alexander 2013). Restoration is becoming a primary focus of natural resource management, for both terrestrial and aquatic environments (Millennium Ecosystem Assessment 2005). Over the last 30 years, ecological restoration has experienced remarkable growth on a global level (Clewell et al. 2009), along with an increase in research publications since the 1980s (Murcia & Guariguata 2014). This is the first document to analyze the diversity and focus of publications on ecological restoration in Argentina.

The Republic of Argentina, situated along with Chile in the extreme southern cone of the South American continent, stretches from subtropical to sub-Antarctic regions. Added to variations in altitude, this makes Argentina one of the countries with the highest diversity of biogeographic units in the world (Bertonatti & Corcuera 2000). There are 18 ecoregions (ecological regions) in the country, of which 15 correspond to the

continental area and the remaining three to the South Atlantic islands, the Argentine Antarctic and the Argentine Sea, that is the sea within the continental shelf off the Argentine mainland (Burkart et al. 1999). Of these, the regions with the highest level of habitat transformation are the Pampa (63%), Atlantic Forest (57%), Espinal (37%), Humid Chaco (29%), Yungas (12%), and 10% in Dry Chaco (Brown et al. 2006). The objective of this work was to obtain an overview of studies on ecological restoration carried out in Argentina to date. The specific aims were (1) to identify and quantify publications on the subject, (2) to classify the published studies by ecological region, type of ecosystem, type of investigation (basic research, assisted regeneration or active restoration), and principal threats.

Methods

Information Sources

The published works were identified by means of the Scopus database, which can be accessed free through universities and research centers in Argentina. Searches were performed in Spanish and English with the key words (restau* and Argentina; restor* and Argentina, respectively) included in the title,

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summary, or key words. The searches were carried out in all the subject areas, selecting the works published up to and including 2013. The number of publications in biology and/or ecology of Argentina were quantified within the subject area of Life Sciences.

Data Analysis and Presentation

The number of publications per year was quantified, and the type of journal (national or international), the language used, and the affiliation of the authors or coauthors, whether national or international, were recorded. Ecoregion and ecosystem types were identified and classified into basic research, assisted regeneration, and active restoration studies. Basic research refers to studies that contribute basic information, such as the biogeographical distribution or genetic variation of a species. Assisted regeneration, in this instance, referred to the removal or exclusion of the degrading agent without subsequent active manipulation to stimulate system recovery (McDonald 2000). Active restoration referred to intentional and physical manipulation of the system to kick-start recovery (Ntshotsho et al. 2011).

Results

The first publications came out in 1996. For the period 1996–2013, we identified 105 publications (approximately 2% of publications on Argentine Ecology and Biology), with an increase in the number of studies published per year as time passed (Fig. 1). Most of these appeared in international journals (87%), in English (86%), and 28% of the publications were coauthored with researchers from other countries (Table 1).

Of the 18 ecoregions, only 12 are represented with published work (Fig. 2), and the remaining six (The High Andes, Iberá Marshes, Monte of Sierras, Campos and Malezales, the South Atlantic Islands, and the Argentine Antarctic) do not figure in the publications. The ecoregions that were most represented with basic research and active restoration studies were Dry Chaco Forest, Pampa, and Patagonian Forests, and the least represented was the Humid Chaco. The invasion of exotic species, that is introduced plants and herbivores, as well as fires and changes in land use were the most frequently studied threats (Table 1). Four works related to urban restoration were registered.

Discussion

This work makes it possible to evaluate the development of this discipline at a national level by means of published research, increasing awareness of restoration in Argentina, and helps identify current gaps in the literature. Murcia and Guariguata (2014) recorded a similar level of growth in recent decades for Colombia. The first published studies on restoration in Argentina in the mid-1990s could be associated with international agreements, e.g. The Convention on Biological Diversity

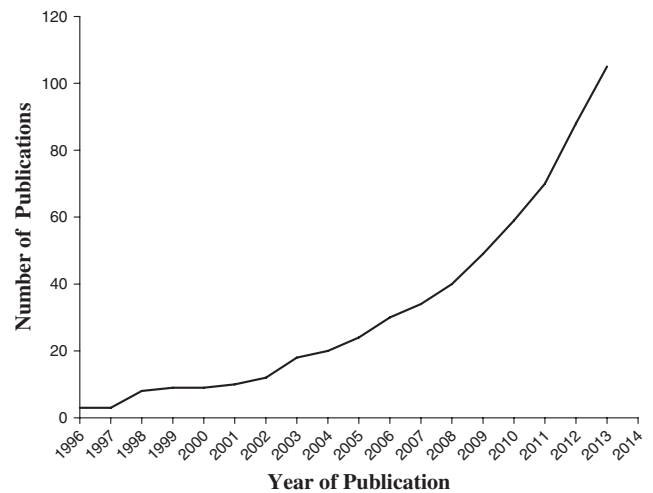


Figure 1. The number of publications on ecological restoration in Argentina, cumulative per year.

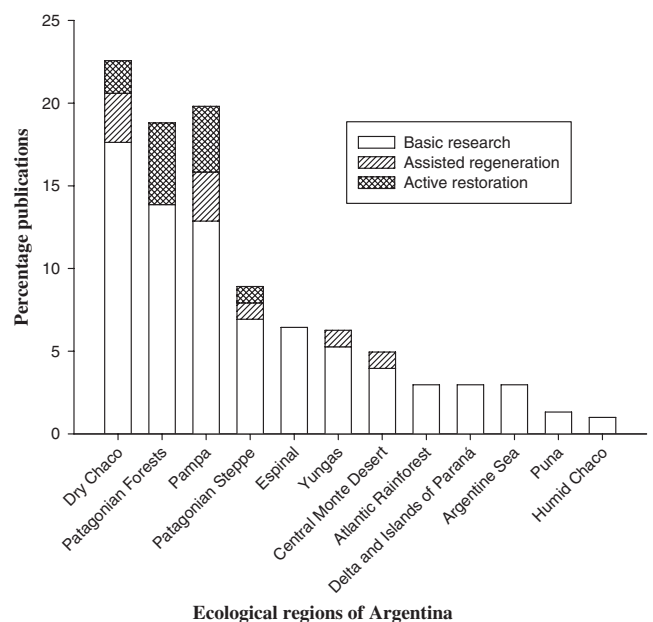


Figure 2. Scientific research published for each ecoregion in Argentina. The percentage of studies corresponding to basic research related to ecological restoration, assisted regeneration, and active restoration is indicated.

(1994) and The United Nations Convention to Combat Desertification (1996), which explicitly includes Ecological Restoration (Bertonatti & Corcuera 2000). The marked increase in interest in the subject after 2008 could be related to the influence of the first Society for Ecological Restoration World Conference in 2005.

The woody ecosystems (Dry Chaco Forest and Patagonian Forests) are among the most represented in the research published. This tendency to focus on the restoration of forest vegetation has also been observed in other Latin American countries

Table 1. Published studies according to ecoregion/ecosystem type. National journals are shown in bold (see Appendix S1, Supporting Information, for the bibliographic details).

Ecoregion/Ecosystem Type	Principal Threats	Type of Research			Authors
		BR	AG	AR	
Patagonian Forests/Forest	Fire, exotic species, livestock	X		X	Alnutt et al. (2003) ^{a,c} , Simberloff et al. (2003) ^{a,c} , Anderson et al. (2009) ^{a,c} , Peri et al. (2009) ^a , Garcia et al. (2010) ^{a,c} , Tercero-Bucardo and Rovere (2010) ^b , Wallem et al. (2010) ^{a,c} , Rovere and Calabrese (2011) ^b , Bassani et al. (2012) ^a , Pastorino (2012) ^a , Souto et al. (2012) ^{a,c} , Azpilicueta et al. (2013) ^{a,c} , Soler et al. (2013) ^{a,c} Varela et al. (2006)^b , 2011) ^a , Urretavizcaya et al. (2012) ^a , Svriz et al. (2013) ^{a,c} , Urretavizcaya and Defossé (2013) ^a Massaferro and Corley (1998) ^a
Patagonian Forests/Lake		X			
Dry Chaco/Forest	Fire, livestock, habitat fragmentation, exotic species	X			Abril (2003)^b , Abril and Bucher (1999) ^a , (2001) ^a , Marquez et al. (2002) ^b , Blanco et al. (2005) ^a , Menoyo et al. (2007) ^a , 2009) ^a , Giantomasi et al. (2008) ^a , Iglesias and Barchuk (2010)^b , Renison et al. (2010) ^a , 2011 ^{a,c} , 2013)^{b,c} , Julio et al. (2011) ^{a,c} , Flores et al. 2012) ^a , Kunst et al. (2012) ^a , Medina et al. (2012)^b , Cingolani et al. (2013) ^a , Pelegrin et al. (2013) ^a Leynaud and Bucher (2005) ^a , Albanesi et al. (2013) ^a , Torres et al. (2013) ^a Renison et al. (2005) ^a , Landi and Renison (2010)^b Merlo et al. 2011 ^a González et al. (1998) ^{a,c} , Ghersa et al. (2002) ^a , Peltzer et al. (2002) ^a , Tittonell et al. (2006) ^{a,c} , Ferreras et al. (2009)^b , de Villalobos and Zalba (2010) ^a , Burkart et al. (2011) ^a , Riestra et al. (2012) ^a , Spirito et al. (2012) ^a , Rodriguez and Jacobo (2013) ^a Tognetti et al. (2010) ^a , Loydi et al. (2012a ^{a,c} , 2012b) ^a Distel et al. (2008) ^a , Mazzolari et al. (2011) ^a , Cuevas and Zalba (2013)^b Herkovits et al. (1996) ^a , Gómez et al. (1998) ^a , Gómez et al. (2008) ^a , Mugni et al. (2013) ^a Mallo et al. (2010) ^a Coronato and Bertiller (1996) ^a , Bertiller and Bisigato (1998)^a , Laclau (2003) ^a , Peri et al. (2011) ^a , Zanon et al. (2012) ^a , Cordero et al. (2013) ^a Bertiller (1996) ^a Cuello et al. (2009) ^a
Dry Chaco/River Pampa/Grasslands	Pollution Habitat fragmentation, exotic species, livestock, agricultural crops, pollution	X X		X	
Pampa/River		X			
Pampa/Lake	Mine			X	
Patagonian Steppe/Grasslands	Exotic species, livestock	X			
Patagonian Steppe/Lake		X	X		
Patagonian Steppe/Grassland				X	
Espinal/Xeric Forest	Habitat fragmentation, agricultural crops	X			Abril (2003)^b , Zach et al. (2006) ^{a,c} , Aguilar et al. (2012) ^{a,c} , Noy-Meir et al. (2012) ^{a,c} , Contreras et al. (2013) ^{a,c}
Espinal/River	Pollution	X			Gagneten and Ceresoli (2004) ^b , Gualdoni et al. (2009) ^a
Delta and Islands of Paraná/Forest	Exotic species	X			Ribichich and Protomastro (1998) ^a , Kalesnik et al. (2013) ^a
Delta and Islands of Paraná/Wetlands		X			Carol et al. (2013) ^{a,c}
Atlantic Rainforest/Forest	Exotic species	X			Cabanne et al. (2007) ^{a,c} , Pietrek and Branch (2011) ^{a,c} , Lori and Salerno (2003) ^a
Central Monte desert/Shrublands	Livestock	X			Bisigato et al. (2002) ^a , Tadey and Farji-Brener (2007) ^a , Cerda et al. (2012) ^a , Llamas et al. (2013) ^b Sassi et al. (2009) ^a

Table 1. Continued.

<i>Ecoregion/Ecosystem Type</i>	<i>Principal Threats</i>	<i>Type of Research</i>	<i>Authors</i>
Yungas/Forest	Livestock, fire, logging, habitat fragmentation	X	Chacoff and Aizen (2006) ^a , Quiroga and Premoli (2007) ^a , Ianni et al. (2009) ^{a,c} , Ianni and Geneletti (2010) ^{a,c} , Sirombra and Mesa (2012) ^a , Renison et al. (2013) ^{b,c}
Argentine Sea/Sea	Pollution	X	Malizia et al. (2004) ^a , Dadon (2005) ^a , Machado-Schiaffino et al. (2009) ^{a,c} , Marcos et al. (2009) ^a
Puna/Shrublands	Livestock	X	Renison et al. (2013) ^{b,c}
Puna/River	Mine	X	Kirschbaum et al. (2012) ^{a,c}
Humid Chaco/Grasslands-Wetlands	Urban expansion	X	Schneider (2010) ^a
Urban areas/Lake		X	Ehrenhaus and Vigna (2006) ^{a,c} , 2008 ^{b,c}
Urban areas/Shrublands		X	Ares and Serra (2008) ^a
Urban areas/River		X	Almansi (2009) ^a

^aEnglish.^bSpanish.^cPublications with internationally affiliated authors.

(Overbeck et al. 2013), where governance issues related to forest restoration constitute an enormous challenge (Guariguata & Brancalion 2014). Similarly, the invasion of exotic species, one of the most frequently studied threats in the literature, constitutes one of the principal disturbances to conservation on a world scale (Vitousek 1990; Millennium Ecosystem Assessment 2005).

Through this review, it is possible to detect information gaps in ecological regions (The High Andes, Iberá Marshes, Monte of Sierras, Campos and Malezales, the South Atlantic Islands, and the Argentine Antarctic) and in subjects (e.g. social or economic aspects) not yet tackled. In the ecological regions lacking information, it should be a priority to evaluate the causes and level of degradation, the area of natural ecosystems remaining and the implementation of studies. The studies should begin with basic research in order to establish solid ecological foundations before proceeding with applied research in assisted regeneration or active restoration.

The importance of setting up a national restoration program cannot be emphasized enough. It should include training, research, implementation, monitoring, and political-legal aspects, as is being carried out in other Latin American countries: Brasil (Aronson et al. 2011), Colombia (Aguilar et al. 2015), and Chile (Echeverría et al. 2015). A national restoration program should also seek to strengthen restoration research in collaboration with colleagues belonging to national and international networks.

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Supporting Information

The following information may be found in the online version of this article:

Appendix S1. Studies on ecological restoration carried out in Argentina to date. (Source: Scopus database.)

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