DESERTIFICATION RESEARCH IN ARGENTINA

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ABSTRACT

In Latin America, Argentina is second – behind Brazil – in extent of drylands: 55% of its territory. Research on desertification and dryland degradation has a lengthy tradition, being undertaken even prior to the establishment of the United Nations Convention to Combat Desertification. The paper aims to analyse desertification research in Argentina, the disciplines from which its knowledge arises and the topics receiving greater attention. The work focuses on the results from descriptive, bibliometric and social network analyses of a sample of articles on desertification in scientific journals indexed in Web of Science. A visual representation of citation relationships was created considering keywords such as 'desertification', 'dry*land*', '*arid' and 'development', 'policy' or 'economy' among others, in 'Argentina'. According to this search, the number of papers per year dealing with desertification in Argentina is only 4·3. National knowledge, usually categorized as traditional knowledge, is barely captured by international databases. The challenge for the scientific community is to make traditional knowledge visible and disseminate the findings. Results demonstrate that desertification research in Argentina is in a great proportion related to studies of soil erosion and soil degradation, and only in a minor proportion to socioeconomic issues. However, desertification problems are the outcome of interactions among physical–biological, socioeconomic and political dimensions, and therefore, the science summoned to analyse them must not only be a science centred on isolated themes but also one resulting from interdisciplinary studies and integrated approaches. Copyright © 2015 John Wiley & Sons, Ltd.

KEY WORDS: bibliometrics; desertification research; Argentina; UNCCD; social network analysis

INTRODUCTION

Dryland areas around the world are affected by land degradation (Qadir *et al.*, 2013; Cerdà *et al.*, 2014; Omuto *et al.*, 2014), and Argentina is affected by land degradation processes because of social, economic and biophysical changes (Abraham *et al.*, 2011; Kröpfl *et al.*, 2013; Palacio *et al.*, 2014).

In Latin America, drylands extend from the north of Mexico to the south of Argentina and represent 25% of the land surface area. Seventy-five percent of them have desertification problems (Morales, 2005). In Argentina, drylands represent 55% of the country's land area, and, to varying degrees, all of them have desertification problems (Abraham *et al.*, 2014). The magnitude of the economic losses caused by these processes becomes evident if one considers that Argentina's drylands produce 50% of the agricultural production and 47% of the livestock production and that almost one-third of the country's total population lives in them (SAyDS, 2002).

According to the internationally agreed meaning, desertification is 'land degradation in arid, semiarid and dry sub-humid areas, and is primarily due to human activities and to climate variations' (UNCCD/PNUMA, 1995). This notion alludes to degradation processes, understood as processes of productivity loss, anchored in drylands, and resulting from the action of climatic and human factors. Formally, the definition encompasses all lands where climate is classified as dry, ranging from hyper-arid, arid and semiarid to dry sub-humid. This classification is based on values of the aridity index (*AI*), that is, the mean annual relationship between an area's rainfall and its potential evapotranspiration. Thus, hyper-arid regions present an $AI < 0.05$, arid regions one between 0·05 and 0·20, semiarid regions one between 0·20 and 0·45, and dry sub-humid regions show an index between 0·45 and 0·70 (UNCCD/PNUMA, 1995).

At global scale, the first concerns related to desertification processes date back to 1977, in particular at the United Nations Conference in Nairobi, where the importance of this scourge is acknowledged, mostly in relation to the drought that affected extensive regions of the Sahel in Africa. It is in 1994, and after verifying that the phenomenon reached global scale, that the International Convention to Combat Desertification [United Nations Convention to Combat Desertification (UNCCD)] is created, a United Nations agency that will concentrate the main discussions around the issue, set the lines of action that should guide the different national states in their combat actions and provide devices for the search for funding sources to help the most affected countries. At present, over 195 countries have ratified the Convention, and in this way, they have become party countries, assuming the commitment to advance in combating desertification processes.

As part of the discussions held within the Convention, now it is recognized that desertification processes are complex environmental problems that combine a natural and social

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cause–effect cycle (Abraham, 2003, 2009; Reynolds *et al.*, 2005, 2007; Stringer, 2008). Moreover, it is postulated that desertification and poverty are deeply linked phenomena that cannot be addressed detached from other environmental scourges that have an impact at global level, among which climate change stands out (Stern, 2006). Being a complex problem and one of social/natural linkage, it is imperative that actions to combat desertification should promote dialogue among the scientific community, decision makers, funding agencies and local populations, and, finally, it is necessary that the scientific community accompanies and gets involved in decision-making processes, contributing interdisciplinary and integral studies that value the biophysical, socioeconomic (Reynolds *et al.*, 2007) and political dimensions (Torres Guevara, 2000; Stringer *et al.*, 2011; Abraham *et al.*, 2014) of this process.

The creation of the UNCCD considerably increased the world's interest in drylands, and ever since its origins, the Convention has promoted the adoption of integrated approaches – interdisciplinary and capable of considering the biophysical, socioeconomic, political and institutional dimensions. Despite these recommendations and even minimizing the greater weight assigned in Latin America to the socioeconomic and political dimensions, desertification-related studies coming from the scientific field have taken little notice of the contributions of social sciences and have, over time, given greater predominance to those of the physical–biological sciences (Vogt *et al.*, 2011). Along these lines and in particular relation to existing scientific knowledge, it is pointed out that the little available knowledge of drylands is still worrisome, that even scarcer is the knowledge regarding the economic dimensions of desertification and that major difficulties to attain an integrated understanding of the problem still persist. As a result, a recent work carried out at request of the UNCCD indicates that sustainable dryland management remains a pending task (Low, 2013; Poulsen, 2013).

Moreover, several Latin American authors highlight that, under strong economic dependence, the socioeconomic causes of desertification bear more importance than the physical ones, and therefore, both scientific efforts and combat actions should start from acknowledging the primacy of the human, socioeconomic and political dimensions of this process (Torres Guevara, 2000; Ruíz & Febles, 2004; Abraham *et al.*, 2014). This is also a trend in the international research community (Izzo *et al.*, 2013; Salvati *et al.*, 2013; Yan & Cai, 2013; Bisaro *et al.*, 2014; Fleskens & Stringer, 2014; Jones *et al.*, 2014; Stringer & Harris, 2014).

In Argentina, research on desertification, dryland degradation and drought (DDLD) has a strong development, undertaken before the establishment of the UNCCD. However, until the onset of the 21st century, it was pointed out that existing knowledge failed to capture the characteristics of desertification processes in their whole complexity and that knowledge, overall, was limited to describing degraded natural resources taken isolatedly – resourcist view (Abraham, 2003). This has posed obstacles to the integration of the political, social, economic and natural

dimensions into the processes to combat desertification (Matallo, 2005; Pulido & Bocco, 2011).

Given the previous discussion, it is desirable to analyse desertification research in Argentina to detect the light and shadow areas in existing knowledge with a view to planning future endeavours. To proceed in this kind of analytical directions, bibliometric and social network analyses are applied. In last decades, these tools have been increasingly used to support policy decision making (Cross *et al.*, 2005; Smith & Marinova, 2005). Bibliometric studies are defined as 'the discipline that measures and analyses the production of science under the form of articles, publications, citations, patents or other more complex derived indicators' (Okubo, 1997 in MINCyT, 2009: 10) and provide knowledge of the characteristics and evolution of research – including that related to desertification – in the country. It is understood that scientific publications are an essential result of the country's scientific activity. Social network analysis also allows identifying relationships and relevance of themes and study regions (Crona & Hubacek, 2010). In this context, research topics are considered nodes, their importance being defined by the number of corresponding keywords mentioned in scientific publications.

Faced with the challenge that scientific knowledge should cooperate in sustainably managing drylands, the goal of this work is to analyse desertification research in Argentina, considering its structure and evolution over time and taking into account the disciplines from which knowledge arises as well as the topics receiving greater attention. Associated to this, it is sought to clarify whether there have been variations over time in the research on desertification and dryland degradation in the country that have brought research close to the comprehensive contents that are internationally required.

MATERIAL AND METHODS

The methodology used has consisted of retrieving articles from Web of Science (WoS) by combining different search commands (Table I). Only seven articles were found when the research commands in WoS were 'dry*land* AND desertification AND Argentina'. Therefore, they were expanded to 'dry*land* OR arid OR semi*arid OR subhumid' in order to capture all the possible denominations around desertification-affected areas. Other keywords related to socioeconomic and policy dimensions such as 'development', 'economy', 'policy', 'gender', 'food' or 'poverty' were included as search commands. This search process yielded papers combining all the concepts pointed out in Table I. The next task consisted of removing unsound references from the database, that is, duplicated articles, papers without author's keywords (our analysis is based on the authors' keywords; herein keywords), articles not corresponding to Argentina or those not related to soil or land degradation. The outcome of this process was a final database containing 72 papers to be analysed referring to 296 different keywords. A number of publications and diversity of themes were analysed along four equivalent 5-year periods – 1993–1997,

Table I. Web of Science search equations and number of articles per search

Search commands using the field topic	No. of ref.
dry*land* AND desertification AND Argentina	7
dry*land* OR arid OR semi*arid OR subhumid AND erosion AND Argentina	81
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification	41
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land	23
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land AND degradation	18
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land AND land management	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land AND land access	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil	24
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND degradation	11
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND management	5
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND properties	5
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND sealing	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development	8
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND economy	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND policy	2
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND gender	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND food	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND poverty	0
Total number of retrieved references	218
Final database, excluding unsound references	72

1998–2002, 2003–2007 and 2008–2012 – in order to observe temporal evolution. Diversity of themes was evaluated by Shannon–Wiener's index (Spellerberg & Fedor, 2003) using DIVERSITY 2·2 software.

The articles were then characterized in terms of composition of author groups and main themes addressed. In order to identify these main research themes, the 296 different keywords (all of them included in the Supporting Information) in the 72 articles retrieved from the database were grouped into 12 categories (Table II). Nevertheless, further analyses

were conducted only with ten categories to avoid redundancy (e.g. 'location') or lack of relevance (e.g. 'not defined'). In order to establish the ties between themes and articles, a social network analysis was performed. UCINET 6·414 and NETDRAW 2·123 were the software programs used. The associations between main themes were identified by principal component analysis considering 72 articles (cases) by ten themes (variables). PC-ORD-6 and SPSS-21 software programs were used.

RESULTS

Temporal Evolution

According to the searching criteria, since 1993, the number of publications strongly increased over time (Figure 1). Applying Shannon–Wiener's index (Spellerberg & Fedor, 2003) allows

Table II. Groups of 12 categories elaborated with 296 keywords appearing in the database ranked by the number of times mentioned in the database

Main themes	No. of category mentions	No. of keywords included per category
1. Soil analysis ('soil analysis')	69	62
2. Erosion–soil degradation ('eros-sdg')	57	33
3. Ecology–vegetation–biodiversity ('eco-veg-bd')	52	48
4. Desertification–drylands ('des-dryl')	48	22
5. Land management–land use ('land use')	45	39
6. Statistics–modelling–indicators ('stat-mod')	38	33
7. Location[a]	32	14
8. Policy–socioeconomic ('poli-soc')	14	14
9. Climate ('climate')	10	10
10. Water ('water')	10	8
11. n.d.[a]	8	8
12. Geology–geomorphology ('geol-geom')	5	5
Total	388	296

[a]Not used in the analysis to avoid redundancy (location) or not relevant (n.d.).
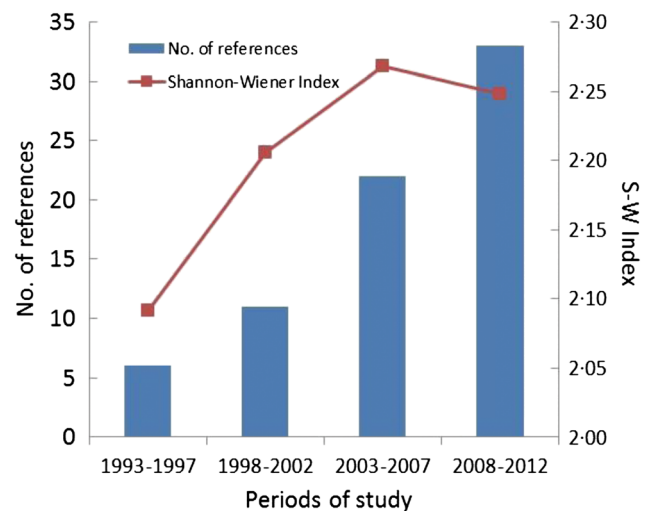

Figure 1. Number of articles published since 1993 to 2012 (left axis) grouped per periods, and the corresponding diversity index (right axis) per period (S-W: Shannon & Wiener).

observing that the diversity of themes shows a significant increase between the first 5-year period – 1993/1997 – (2·09) and the next two 5-year periods – 1998/2002 and 2003–2007 – (2·21 and 2·27, respectively). During the last period, 2008–2012, the diversity of themes decreased (2·25).

Authors' Origin and Eco-regions

Eighty-five percent of the analysed papers have been produced by research teams where Argentinean scientists participate. In 69% of cases, these studies come from groups exclusively composed of Argentinean researchers, whereas 15% are the result of cooperation with foreign institutions. The remaining 16% include studies conducted exclusively by foreign authors, without participation of their Argentinean peers. Preponderant among the latter are studies from the USA (nine of 13 cases), followed by researchers from Europe (Spain, France and Belgium), Latin America (Brazil and Chile) and New Zealand (all of them with one case/publication per country). These data are in keeping with those reported by different national and international studies that analyse the evolution of scientific productivity in Argentina and/or South America. Consistently, with a trend ratified at national level (MINCyT, 2009, 2013), Van Noorden (2014) indicates that when publications are co-authored by South American and foreign authors, the peers from the USA are prevalent.

In turn, the fact that the first authors in domestic research teams are from Buenos Aires (50%) is also in line with the data provided by official Argentinean agencies (MINCyT, 2009). These data show a persistent concentration of researchers and publications around the city and province of Buenos Aires, where the high concentration of resources (MINCyT, 2009, 2013) is acting as a driving force.

The largest proportion of papers is concentrated in the Monte, an eco-region of plains and plateaus, and in the Patagonian steppe (Figure 2). The rest is distributed, with lower values, in the eco-regions of Dry Chaco, Espinal, Monte of Mountains and Depressions and Puna, although not all of these regions are affected by desertification processes, particularly rainforests.

Main Themes

Most of the keywords are related to the biophysical approach: soil analysis, soil erosion and degradation or
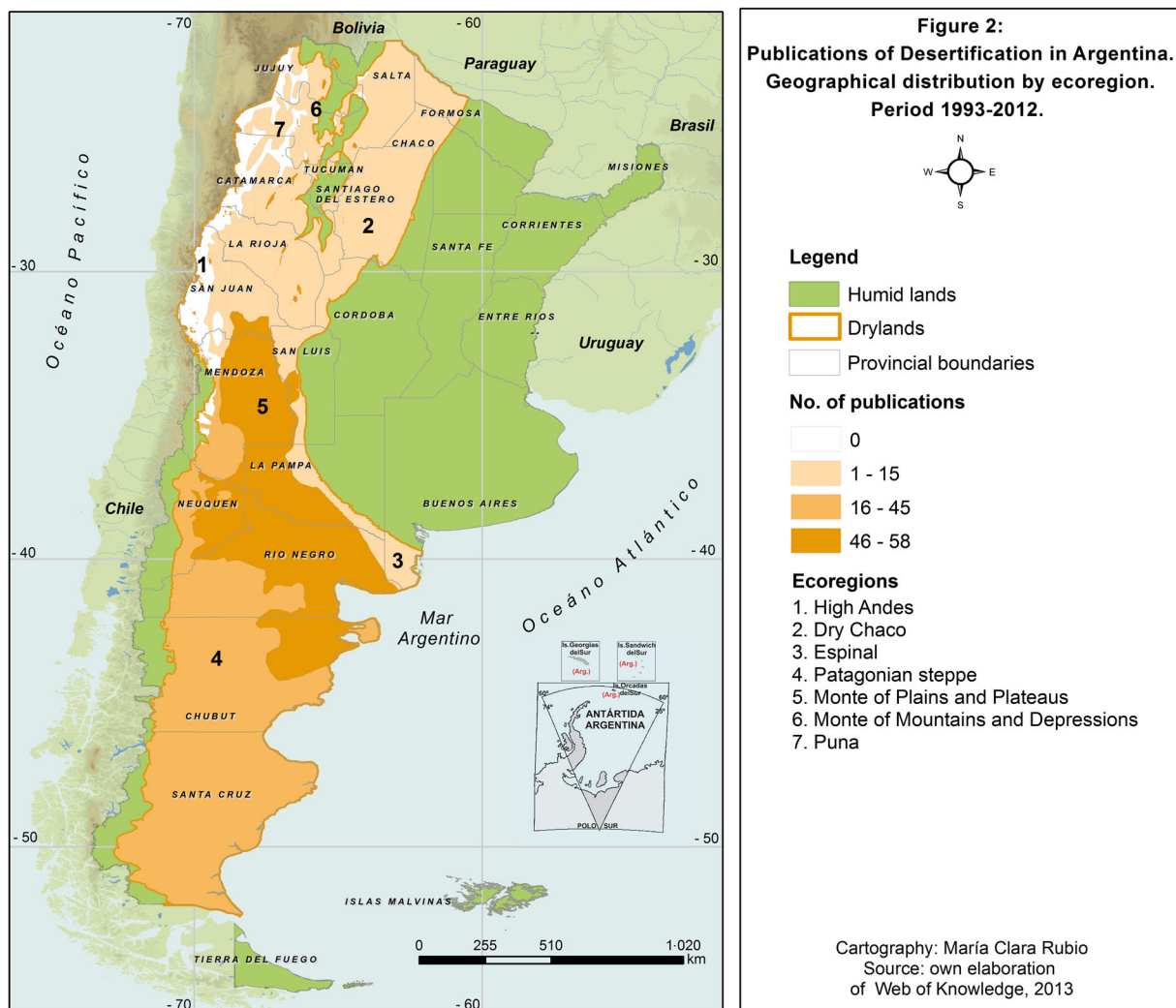

Figure 2. Argentinian Ecoregions.

ecology, vegetation and biodiversity (Table II). The 'desertification and drylands' theme is fourth in rank of importance. Other topics, among them social and political dimensions, are not so much dealt with (14 keywords out of a total of 296).

Network analysis for articles by themes allows representing the different topics, and their relative importance and interconnections in the analysed publications (Figure 3). This importance is valued for their *degree* (the count of the number of ties between articles and themes). On the one hand, the most cited main themes are erosion and soil degradation ('eros-sdg', degree: 36) and desertification and drylands ('des-dryl', 36), followed by 'land use' (31), ecology, vegetation and biodiversity ('eco-veg-bd', 30), and soil analyses ('soil-analys', 29). In turn, policy and socio-economy ('pol-soc-econ', 12), 'climate' (7), 'water' (7), and geology and geomorphology ('geol-geom', 3) appear as the least addressed topics. On the other hand, the diversity of themes in the articles is represented by their corresponding node size, the most diverse articles being found in the Patagonian steppe and Monte and Pampa eco-regions.

In order to identify associations among the main themes, we applied a principal component analysis that captures up to 33% of variance with the first two components (Figure 4). The horizontal axis is related to research on desertification and drylands. The right side of this axis is defined by the main themes regarding the tools used by scientists to manage or represent data such as statistics, models or geographic systems. A tight relationship is found between desertification ('des-dryl') and the tools used to analyse natural processes (statistical methods and models, 'stat-mod'); this can be seen as an attitude of researchers prone to using and mentioning the instruments of science to address desertification problems. The group of themes is completed with variables describing biotic interactions (ecology, vegetation, biodiversity and water) and indicators of erosion and soil degradation. Other variables that are usually used for regional descriptions
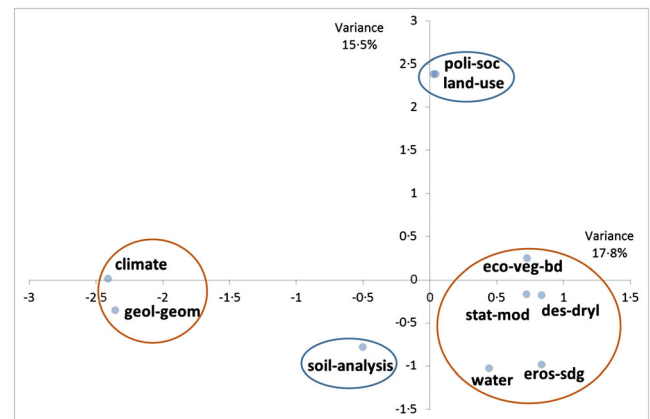

Figure 4. Principal component analysis of main themes.

such as soil characteristics, climate or geomorphology are on the opposite side of the axis. The second principal component (vertical axis) extracts 15·5% of variance and separates the main themes related to land use and policy or socioeconomic issues from those related to soil analysis.

DISCUSSION

Knowledge construction processes cannot be considered detached from the places where they are accomplished. The place or site, in turn, should be understood as a broad category, not merely physical or only indicative of a geographic location, but as spatiality linked to history and to the structural and particular conditions characterizing the contexts in which researchers approach the study of reality (Ramos *et al.*, 2004). Part of these contexts is the resources that scientists have at their disposal, the working conditions that they face, the theoretical–methodological proposals available in academic communities and the pre-existing agreements, among other things, linked to what is involved in doing science, what the requirements to be met by good
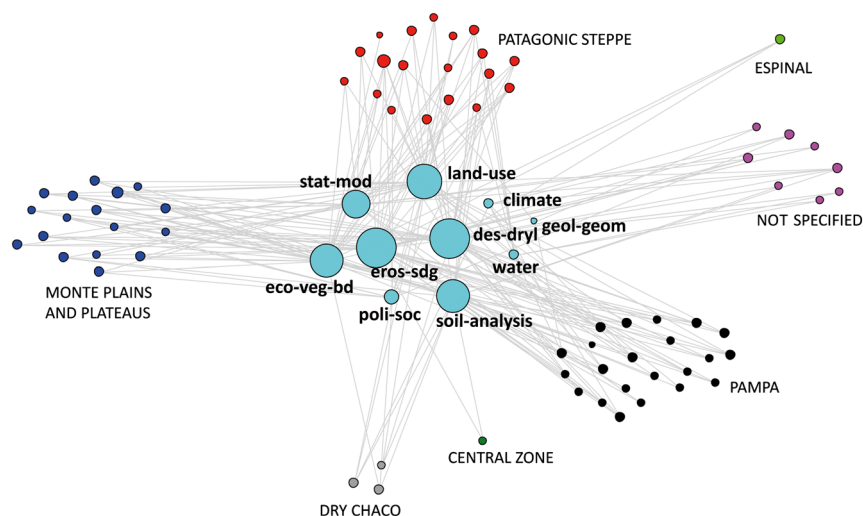

Figure 3. Ties between articles and themes. Articles are grouped by ecoregions. The node size of themes represents their relative importance, i.e. number of mentions as keywords in the articles. The node size of the articles represents its diversity of themes.

quality science are and the criteria that distinguish the publishable from the unpublishable in the different available means of knowledge dissemination. This opens the possibility to dodge the judgment of 'existing knowledge', assuming, plain and simple, that capture of publications in international databases reflects the capacity of scientists. It is possible to note, besides, that productivity-measuring methods are not devoid of their own logics of construction. Quite to the contrary, just as the most internationally visible databases are the result of previous consensus and show a particular selection of what is in existence, beyond them, there is unreported knowledge whose lack of citation does not make it lose its quality as 'knowledge'.

In this sense, it is highly probable that knowledge generated from Argentina in relation to desertification and dryland degradation exceeds that contained in the international databases consulted, a fact that not only makes us think of the context conditions that explain current trends but also invites us to reflect on their quality and validity even when they cannot be reflected in the windows provided by WoS.

The first publications coincide with the establishment of the UNCCD, and, since then, publications exhibit a moderate growth up to the start of the millennium, growing less pressed afterwards. From the thematic viewpoint, the first papers show higher concern for isolated elements of the natural environment (soil, water, vegetation and wildlife), and, over time, a greater presence is observed of studies integrating successive levels of complexity and interaction. In this sense, it is possible to infer that institutionalization of the UNCCD not only produced an increase in scientific production related to desertification but also resulted in consideration of a greater variety of themes, slowly but progressively correcting the resourcist view that prevailed in the past (Abraham, 2003).

For an interval of 19 years, the WoS database reports 82 papers, a figure that yields an average value of desertification-related production in Argentina of 4·3 studies per year, a figure that seems to be low. In spite of this, Argentina has research groups that have increased their efforts to develop the topic and that have delved deep into it over time. Collaborative research has acted in two directions: strengthening its own research groups and enhancing their alliance with foreign researchers. Indeed, the production of studies of desertification in the country is extensive and diverse and has backgrounds that extend back to the late 1970s (Matallo, 2005; Abraham *et al.*, 2014).

The fact is that the WoS database does not capture the entirety of studies linked to desertification in Argentina. These studies are available, mostly in Spanish, from Argentina's and Latin America's databases, and they are not included among those offered by WoS. This evidence is consistent with that observed by Van Noorden (2014) who notes that South American investigations fail to attract international citations, among other things, because they are published in journals not indexed in major databases. As a result, some Latin American authors who have made seminal contributions to the understanding of drylands, having published most of their work in Spanish and/or in books (Torres Guevara, 2000; Matallo, 2001; Abraham, 2003, 2006, 2009; Abraham *et al.*, 2005; Morales, 2005, to mention just a few), do not appear in the citation database and, consequently, are scarcely cited at international level. Complementarily, there are no studies published in Argentinean journals, and only one appears in a Latin American journal, in this case from Mexico (Marizza *et al.*, 2010).

Thus, it is likely that Latin America's and Argentina's contributions are being undervalued in the international sphere, not because they are of little significance or relevance but because they are published, in a great proportion, in non-indexed journals (Van Noorden, 2014). These corroborations are probably denoting a certain narrowness of the major citation databases, which could be attenuated by expanding links with databases that are more sensitive to capturing studies published in other languages, journals and regions.

Considered in their geographical distribution across the national territory and excluding rainforest for natural reasons, prevailing studies on desertification are centralized in three major Argentinean eco-regions facing critical desertification processes (SayDS, 2002): Patagonian steppe (32%), Pampas (31%) and Monte (27%). In all these regions, research efforts regarding DDLD started early because desertification in their territories was an environmental problem of great magnitude, affecting their productivity and social foundations. Moreover, in these regions, there are institutions with experience in the study of drylands that were created before the UNCCD was established (*Instituto Nacional de TecnologíaAgropecuaria*, in 1956; *Centro Nacional Patagónico*, in 1970; *Instituto Argentino de Investigación de Zonas Áridas*, in 1972; and *Centro de Recursos Naturales Renovables de la Zona Semiárida*, in 1980, among others). For the time being, investigations conducted in Chaco and Puna, two eco-regions also seriously affected by desertification, are not listed in WoS, even though, as in the previous cases, they had scientific capacities on DDLD before the creation of the UNCCD (Abraham *et al.*, 2011).

The analysis of the reported papers also shows great predominance of interests linked to the biophysical dimensions of desertification and a clearly peripheral position with respect to interests related to its human, political, economic, social and cultural dimensions. This is revealed in the fact that none of the 72 studies incorporates gender, food or poverty dimensions and that only one of them includes the notion of economy and two include the notion of policy. The orientation taken by the analysed studies justifies the trends indicated by the UNCCD recommending the integration of visions reflecting the inherent complexity of desertification into studies of the topic (Akhtar-Schuster *et al.*, 2010; Low, 2013; Poulsen, 2013).

An analysis of keywords in these papers corroborates the foregoing considerations. These studies are in a high proportion related to soil, erosion and soil degradation. Further research should enable establishing whether these studies take into account the category 'land use' in a broad or

narrow sense; that is, as a driving force that could be an explanatory factor of the orientation taken by agricultural and livestock rearing practices at a given time or as the soil's capacity to support agriculture and livestock activities.

Finally, it is necessary to point out that outside of science, a sustainable management of drylands depends on the addition of another knowledge, which is not traditionally assimilated into this field but which, however, is a key factor in facing the challenge to think/act in the context of society/nature relationships. Previous analyses associated to scientific knowledge are indicative of how science has thought/analysed a topic, but are not supposed to assume that they are the 'exclusive or right' way to think/approach the issue/problem. So, to the challenge of making visible the production of scientific knowledge not captured by international databases should be added the challenge of acknowledging and visualizing the wide array of knowledge existing in the region, many times categorized as traditional, which tells us of the society/nature linkage and which might make substantial contributions to sustainable management processes.

Desertification should be a science within the reach of the affected dimensions – physical–biological, socioeconomic and political – and decision makers and should find a crucial point that could translate into the design of more assertive sustainable land management actions. Overall, the analysed papers are hardly available to the affected communities and decision makers in Argentina, not only because they have been published in a foreign language but also because they fail to bring together dimensions of analysis that are integrated in the real world. Available studies of soil, water, wildlife and even those considering soil–productivity–vegetation relations are of undoubted scientific quality and contribute to the understanding of desertification processes. But they fail to overcome, at least for the time being, the barriers imposed by disciplinary boundaries, let alone advance in an integrated understanding of desertification processes. In this sense, Argentina does not escape the global trend warned at the UNCCD and in Argentina's NAP because although the country is working on consolidating a solid and competitive System of Science and Technology, it still faces the challenge to achieve better channels of linkage.

CONCLUSIONS

With the establishment of the Convention, Argentina's production on DDL shows an increased number of publications visible in WoS and, at a slower pace, an increase in the complexity of the topics approached. A gradual incorporation of new dimensions in the analysis is observed, among which the production-rangeland association stands out; however, medullary contributions regarding socioeconomic and political dimensions are yet to be seen. Still, even though the studies considering socioeconomic dimensions are few in number compared with the national total, it must be pointed out that compared with the Spanish case (also considered in this special issue), the trends in Argentina are encouraging.

The data show that there is a critical mass of researchers and institutions devoted to the study of desertification in the country and alliances with foreign researchers. In turn, the eco-regions showing critical desertification processes are being widely analysed at present, and this is related to the existence of research centres and researchers focused on studying the topic in these regions. Nevertheless, the analysed databases fail to reflect an important number of national-level studies, published in Spanish in Argentinean and Latin American books and in scientific journals that are not indexed in international databases.

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