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The research of water use in Spain

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A R T I C L E I N F O

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A B S T R A C T

This study details the contribution of Spanish institutions to the specialised literature on water use during the period 1957–2014; the search yielded 42,655 documents. It relies on Elsevier's Scopus database and bibliographic analysis techniques. The analysis includes all of the materials reported by Scopus (e.g., journal articles or conference proceedings). Different publication aspects have been analysed, such as type, language, subcategories, and journal type as well as the frequency of keyword appearance. The contributions are categorised geographically and by institution. The results indicate that the Spanish contribution is substantial in light of the obtained measurements. The majority of the keywords that occupy the first positions are related to water quality (Wastewater, Water Analysis, Pesticides, Heavy Metals, Adsorption, Water Quality and Wastewater Treatment). Only one keyword is related to irrigation or agriculture (Water Stress), and one is related to the environment (Drought). The institutions that publish the most are those located in the communities of Madrid, Catalonia and Andalusia, these publications represent nearly 75% of all national publications. H-index and Impact Factor have been adapted for the obtained water publications analysed. At the international level more than the half of all of the publications involve international collaboration; so the international collaborations occurred with a high number of countries (150), and with 33 countries, there were more than 100 publications. Spain largely collaborates with the USA, the United Kingdom, France, and Germany. The categories that exhibit relatively more activity within the water use field are Environmental Science, Chemistry, and Agricultural and Biological Science. The data indicate that water use research in Spain is focused on mid-level international collaboration. Public resources are more focused on the study of water quality than the study of irrigation and its use in agriculture. This outcome contrasts clearly with the fact that Spain's agricultural sector consumes most of all available water resources. This study provides an opportunity for researchers on water use to see either where new trends might come from and which are the main topics of interest in scientific community.

1. Introduction

As growth rates for global water consumption continue to outpace even global population growth, several governments, international development agencies and leading researchers have pointed to global water scarcity as a potentially serious economic, health, and even security issue (Katz, 2015). Projections of future water scarcity are numerous, so the use of water plays a fundamental role in the planet sustainability (Su et al., 2015; Xu et al., 2015). Therefore numerous studies have conducted to study for example the water footprint (Gu et al., 2015; Morillo et al., 2015; Rodriguez et al., 2015), water policy (Jiang et al., 2015) and water use (Uche et al., 2015; Sanjuan-Delmás et al., 2015; Alnouri et al., 2015). As noted, the study of water use in all of its facets (surface and ground water, wastewater, water stress, drought, water quality, irrigation, among others) is a field of substantial interest to the scientific community. It is accepted that a region's water resources correspond to its total renewable resources (surface water and groundwater). In Spain, these resources amount to approximately 111,000 hm^3/year (Ministry of Agriculture and Environment, 2013). The irrigation technology in Spain dates at least from the Roman agro-system. The Roman agro-system and irrigation networks remained largely unchanged, despite the presence of new

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technological features and cultivars (Butzer et al., 1985). The largest systems were refurbished in Islamic times, and Muslim agriculture in Spain remained characteristically Mediterranean; the irrigation infrastructure survived largely intact into the present century. At present, irrigation contributes to more than 50% of Spain's food production while occupying less than 15% of the agricultural area. One hectare of irrigated land produces, on average, approximately six times what a rain-fed hectare produces and generates an income four times greater. As example, Table 1 shows the rainfall data for Spain.

Spain's agricultural sector consumes up to 80% of all available hydric resources, and the need to increase the efficiency of current uses of water in the agricultural sector is at the core of the country's national water policy (Varela-Ortega et al., 1998). The use of bibliometric data enables us to measure, for example, university research performance (Moed et al., 1985) and research collaborations (Subramanyam, 1983; Glänzel et al., 1999) and to conduct a spatiotemporal analysis of one or several topics (Manzano-Agugliaro et al., 2013).

At present, there are four primary public research centres in Spain: the Spanish National Research Council (CSIC, in Spanish), which accounted for 17.5% of Spanish publications between 2007 and 2011 (Gómez et al., 2010), the Spanish National Research Centre for Energy, Environment and Technology (CIEMAT, in Spanish), the National Institute of Aerospace Technology (INTA, in Spanish), and the Geological and Mining Institute of Spain (IGME, in Spanish). However, most Spanish research is produced by research groups in different universities throughout the country. The different research subfields cover the entire spectrum of water use. The Scopus database was selected because it catalogues more than 49 million files, which are based on 20,500 titles and the output of 5000 publishers. In contrast to the Thomson-Reuters Science Citation Index (SCI), Scopus includes several improvements that support bibliographic analysis, such as a larger number of exportable registers, a comparative analysis of journals and trend analysis (Vieira and Gomes, 2009; Bakkalbasi et al., 2006). Scopus is accepted by the international scientific community as one of the two primary data sources for the analysis of scientific publications (Moya-Anegón et al., 2007). The primary objective of this paper is to analyse the status and trends of research in water use in the last 50 years in Spain. The paper will help the research community understand the current research environment and the trends that will occur within the research lines on water use.

2. Material and methods

Bibliometrics, which is a multifaceted endeavor encompassing subareas such as structural, dynamic, evaluative and predictive scientometrics, is one of the rare and interdisciplinary research approaches to extend to almost all scientific fields. The research objects can be all kinds of literatures themselves and the characteristics they reveal include topics, authors, publication dates, reference literatures, content and so on (Du et al., 2014). Using the internet as object and method of data collection is acceptable by the scientific community (Bryman and Bell, 2015). Scopus is the largest database of citations and abstracts of refereed literature and high-quality Web sources and had been used in environmental studies (Ferenhof et al., 2014). Although Scopus is distributed by subscription, is available with certain limitations for developing countries (Canedo Andalia et al., 2010) and entirely accessible for most university centres. Thus, Scopus has been selected for our study because of its wide availability. A complete search of Elsevier's Scopus database has been performed using the following categorical data (Saunders et al., 2012): key, authkey, title, index-terms and affilcountry. This approach enabled the location of the publications in the water* domain in which a Spanish researcher or research centre participated. The term “water” was not searched in other fields, such as the abstract. This search would have led to registers likely to be outside this paper's scope, primarily because of the common use of the term. The time range of the search was 1957–2014. The results were analysed using spreadsheets and the open-source tool OpenRefine (http://openrefine.org/), which was successfully used in previous similar works (van Hooland et al., 2013). This application is a stand-alone desktop application initially developed by Google for data clean-up and transformation to other formats. In this manner, the analysis of unsorted, conflictive or unstructured text is substantially enhanced. Highly satisfactory results were obtained that would otherwise not have been obtained because of the size of the database. It has been used the custom data export supported by the database. As can be observed, more than sufficient information is available to generate indexes and statistics for the fields of interest.

The publications on water use produced by Spanish institutions during the period 1957–2014 were assessed with respect to the following aspects: document type and language, characteristics of scientific output, publication distribution by regions and institutions, distribution subject categories and journals as well as the analysis of author and index keywords. A study on the influence of the H-, or Hirsch, index has been included. Hirsch proposes the index **h**, which is defined as the number of papers with citation number is greater or equal than **h**, as a useful index to characterise the scientific output of a researcher (Hirsch, 2005). Currently, the H-index can be applied to authors and journals as a complement to impact indexes, such as the Institute for Scientific Information Impact Factor (ISI IF) (Braun et al., 2006), for institutions (Molinari and Molinari, 2008; Mitra, 2006), and for countries (Csajbók et al., 2007). This index is considered to be a good measurement tool to assess the quality of research of an author or journal compared with traditional indexes that are based on the number of publications or the number of citations received (Alonso et al., 2009). Finally, the number of articles that were not referenced was analysed.

Table 1
Main rainfall data of Spain in 2012 (last data available; source: www.ine.es).

Geographical area	mm
North and Northwest slopes	1182
Duero watershed	455
Tajo watershed	458
Guadiana watershed	467
Guadalquivir watershed	570
South slope	520
Segura watershed	395
Jucar watershed	445
Ebro watershed	552
Eastern Pyrenees slopes	553
Spain (peninsula average)	**570**

3. Results and discussion

The search yielded 42,655 documents of diverse nature, primarily journal (36,068–84.56%) and conference papers (4443–10.42%) (Table 2). Reviews (1282–3.01%) have a lesser weight than the rest of the documents. Fig. 1 shows a distribution of the main document types according to the proportional weights. Because the majority of the publications are of the journal type and given that most international journals are published in English, English is the most used language, accounting for a total of 40,773 (95.58%) documents. Nevertheless, a substantial number of articles were published in Spanish. This phenomenon occurred because indexed journals that originate in Latin American countries are

Table 2
Distribution of research on water use in Spain according to document type, 1957–2014.

Field	Value	Percentage (%)
Article	36,068	84.412
Conference paper	4443	10.416
Review	1282	3.006
Book chapter	211	0.495
Letter	173	0.406
Editorial	89	0.209
Note	79	0.185
Article in press	62	0.145
Short Survey	54	0.127
Erratum	46	0.108
Book	13	0.030
Conference review	4	0.009
Patent	2	0.005
Undefined	191	0.448

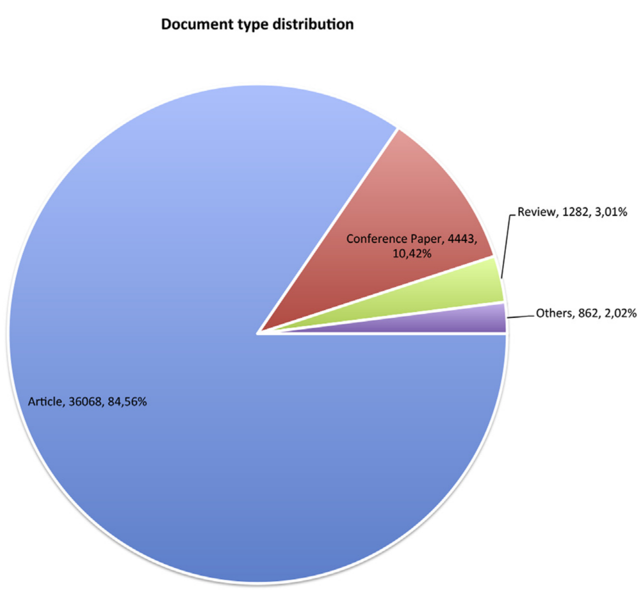


Fig. 1. Document type distribution chart for Spanish water use research, 1957–2014.

published in Spanish or a bilingual format. Table 3 shows a full breakdown for 19 languages. It is noteworthy that some of the studies were published in the native languages of Spanish regions, such as Catalan.

In Fig. 2(a), the temporal evolution of the analysed papers is shown. That is, the publications within the subject of water use in which Spanish institutions participated during 1957–2014. In Fig. 2(b), the same information is shown but in a logarithmic scale, which indicates an upward trend. The trend is exponential from the mid-1970s to the present. However, it seems that there is a reduction in the upward trend for the latest years, especially in 2013 and 2014. In addition, Fig. 2(b) shows the linear model of correlation with a coefficient $R^2 = 0.954$.

3.1. Publication distribution by regions and institutions

This section provides an almost complete, systematic and focused approach to scientific output of water use in Spanish institutions, this may serve to help in the research for a sustainable development related to water use, like other works have helped previously (Lozano et al., 2014; Lozano and Lozano, 2014; Lozano et al., 2013a,b). From the beginning, the local development of technology and knowledge in Spain has been highly uneven. There

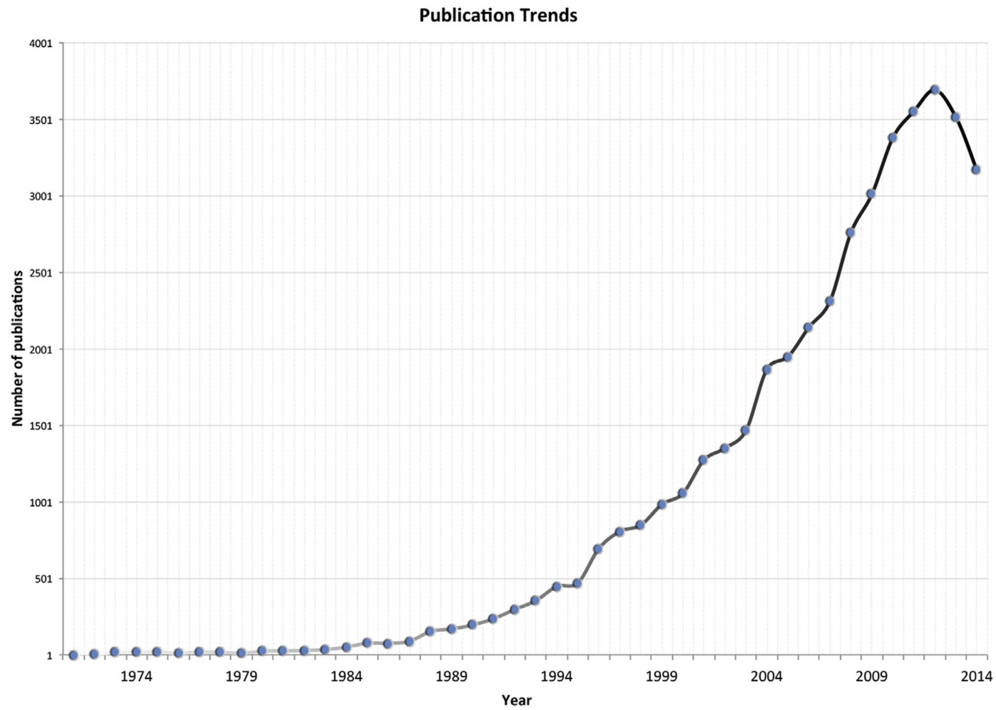
Table 3
Number of publications according to the used language.

Language	Items	Percentage (%)
English	40,773	95.588
Spanish	2044	4.792
French	124	0.291
Portuguese	34	0.080
German	18	0.042
Catalan	15	0.035
Chinese	5	0.012
Italian	5	0.012
Turkish	4	0.009
Croatian	3	0.007
Slovene	3	0.007
Japanese	2	0.005
Polish	2	0.005
Czech	1	0.002
Dutch	1	0.002
Estonian	1	0.002
Greek	1	0.002
Russian	1	0.002
Slovak	1	0.002

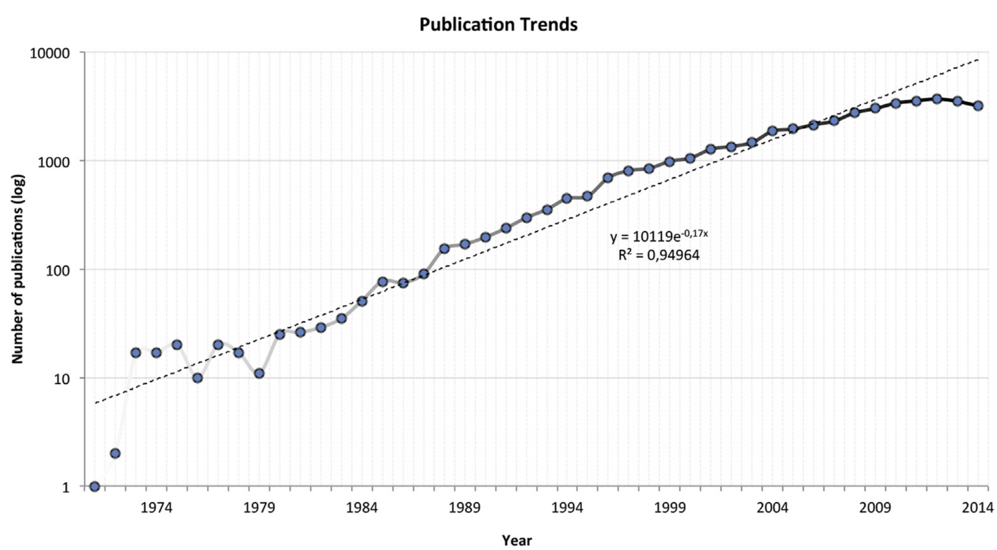
are areas of substantial development (primarily Madrid, Basque Country, Navarra and Catalonia). In Fig. 3, it can been observed that these regions have the biggest Gross Domestic Product (GDP) per capita among all the spanish regions and also some of them being higher than EU-28 in 2014. Other areas, mainly in the south, the development is poor. Fig. 4 shows an overview of the relative economic situation for every spanish region. These differences are decreasing, primarily because of the significant industrial and technological development in Spain during the last years of the 20th and the beginning of the 21st centuries. Fig. 5 shows the map of the distribution of publications on water use for each autonomous community (17 Spanish administrative regions). This figure shows that the regions of the institutions that publish the most are Madrid (11,678), Catalonia (7431) and Andalusia (5849), whereas those regions that publish the least are Asturias (541), Castilla-La Mancha (532), Baleares (400), Cantabria (378), Navarra (316) and La Rioja (53). Table 4 shows the raw data of Fig. 5 and the publications per capita along with GDPc.

The cases of Madrid and Catalonia are clear examples of economic and industrial development. Such development has not occurred in Andalusia and Galicia, which traditionally have been poor regions with fewer resources (as stated by column GDPc) but with substantial agricultural and environmental or oceanographic and marine potential, respectively. Similarly, Valencia, Castilla-y-Leon and Murcia present a significant agricultural potential.

The 20 most productive institutions have been classified in Fig. 6. The most relevant institution, and by a large margin, is the CSIC (7712–21.96%). The CSIC has several centres across Spain (owned centres, mixed centres and associated units). However, all of the centres are uniquely identified in the Scopus database. Behind the CSIC, other university centres follow, such as the University of Barcelona (2715–7.73%), the Polytechnic University of Catalonia (1659–4.72%), the University of Santiago de Compostela (1620–4.61%) and the University of Valencia (1481–4.24%). In this ranking of institutions, in addition to CSIC, are other leading institutions that include five universities from Andalusia (the Universities of Granada, Sevilla, Cordoba, Almeria and Cadiz), four from Catalonia (the University of Barcelona, the Polytechnic University of Cataluñ a, the Autonomous University of Barcelona and the University of Girona) and three universities from Madrid (the Complutense University of Madrid, the Polytechnic University of Madrid and the Autonomous University of Madrid). However, this significant showing can be justified by the fact that the CSIC collaborates significantly with these organisations and by the fact that some



(a) Linear scale



(b) Logarithmic scale

Fig. 2. Water use publication trends for Spanish institutions.

regions have a lower number of universities. The CSIC establishes its primary relations in Madrid and the regions of Catalonia and Andalusia (Gómez et al., 2013).

In order to compare the relevance and quality of the selected publications by the above 20 institutions in the water use field, two well known indexes (h-index and impact factor IF) has been adapted (Molinari and Molinari, 2008). An institution has an h-index H if H of its N papers have at least H citations each. Similarly, the impact factor for an institution is the relationship between number of total citations and number of published papers. For this research, it has been adapted both indexes for the obtained water publications analysed (see Fig. 7). It can be observed that CSIC, Universitat de Barcelona and Universidad de Santiago de Compostela have also the highest H-index and impact factor. A more detailed analysis can be made related to Universidad de Almeria, ranking the 17th position in number of publications but ranks 10th position for H-index and a remarkably 2nd position for IF. On the other hand, Universitat Politecnica de Catalunya ranks 3rd in number of publications and 4th in H-index but ranks 16th for IF. It can be concluded that number of publications of the Universidad de Almeria is not so high, but very interesting for the research community. The combination of these 2 indexes, along with the number

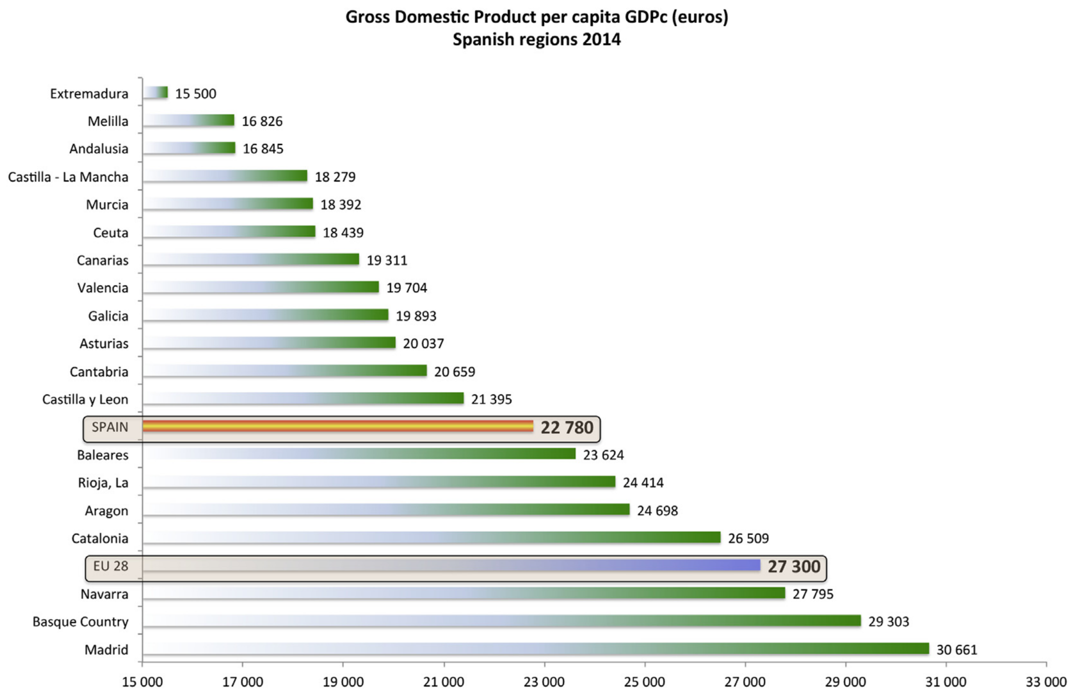


Fig. 3. Gross Domestic Product (GDP) per capita for Spanish regions in 2014.

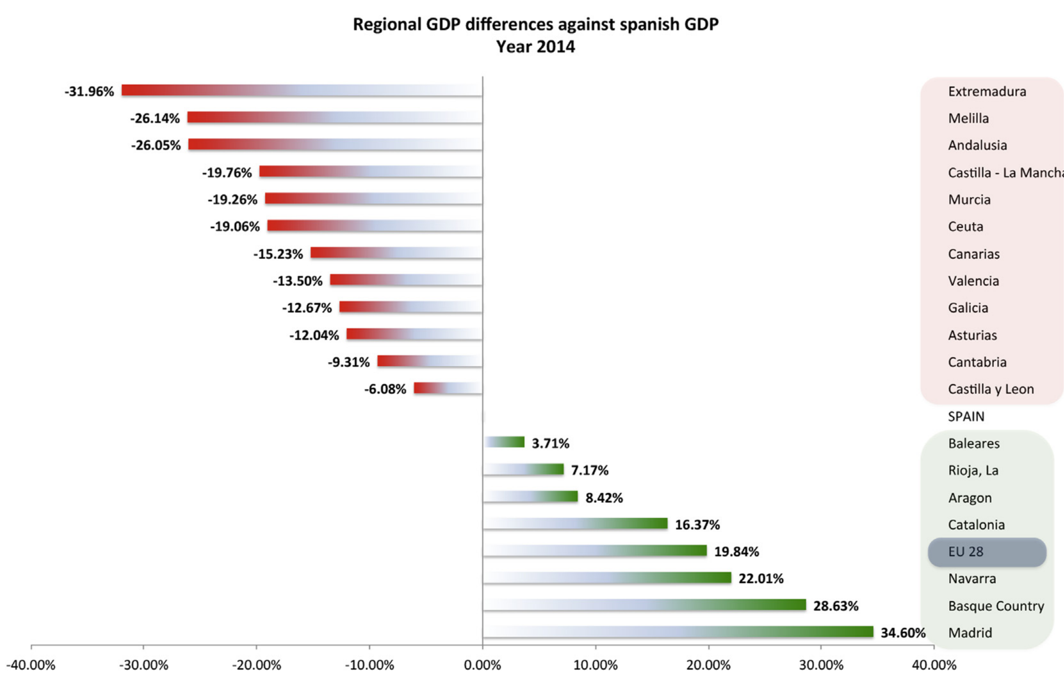


Fig. 4. Regional GDP per capita differences for Spanish regions in 2014.

of publications open new perspectives for the institutional scientific quality analysis.

Table 5 and Fig. 8 show the temporal evolution of the 10 institutions with the greatest productivity during 2003–2014. In general, there is an upward trend in the number of publications for each institution. However, during recent years, and specially in 2013 and 2014 as stated in 2(a) there has been a slowing trend and even decreases, for example, at the CSIC or the Polytechnic University of Catalonia. Table 6 and Fig. 9 show the data related to the international collaboration of researchers in Spanish institutions. Table 6 shows all of the registers associated to publications in which an institution has collaborated with a foreign institution. Of the analysed publications, 18,804 represent collaborations with foreign institutions. This number is 53.5% of the total, which indicates that more than the half of all of the publications involve international collaboration. Fig. 9 shows the information in Table 6 in a geo-localised form using colours for better comprehension. There are three countries with a very high number of collaborations (> 1500)

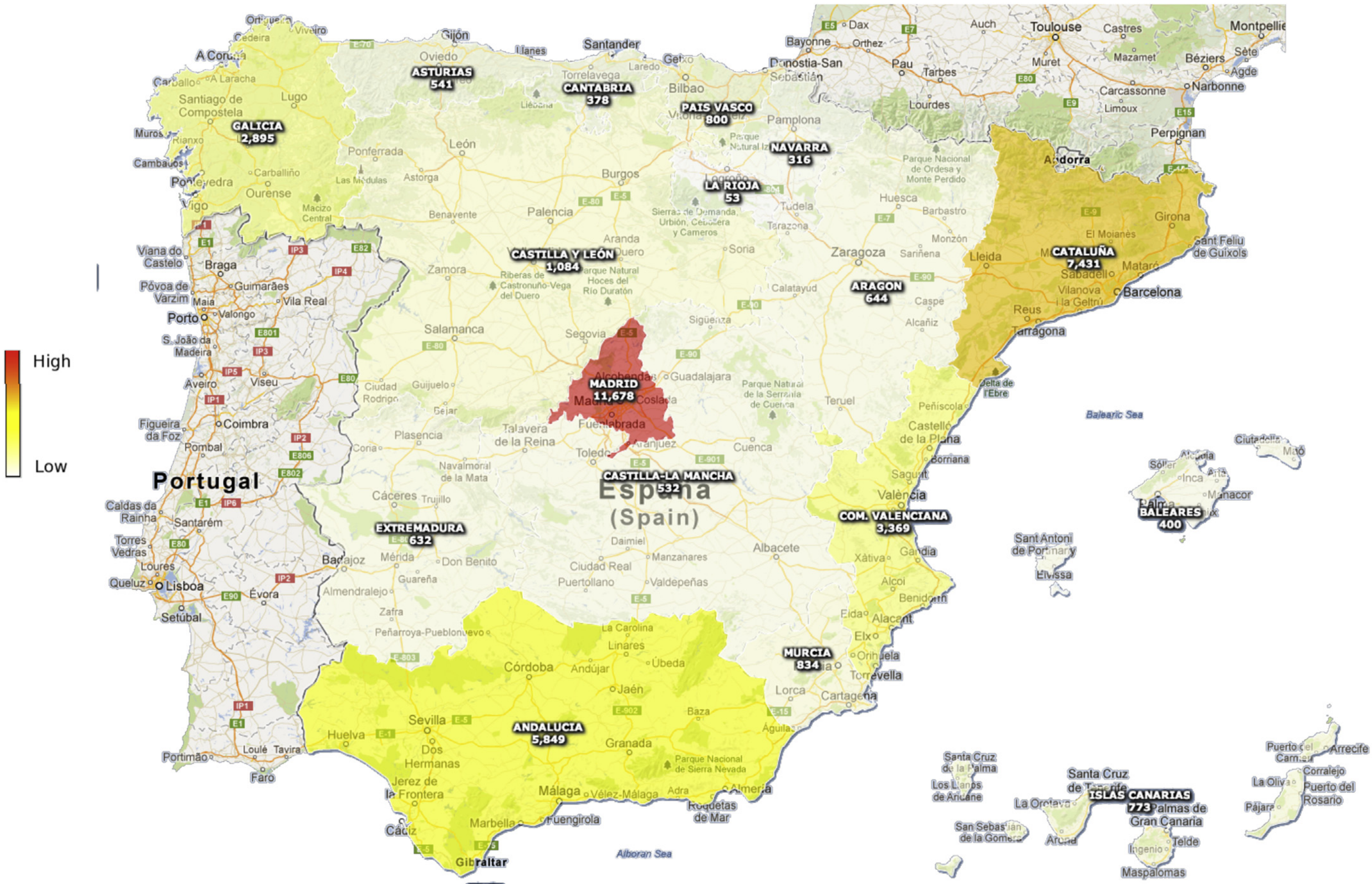


Fig. 5. Publication distribution by region. Red indicates a high level of publications, yellow indicates an intermediate level and white indicates a low level. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Population distribution for Spanish regions along with GDPc and normalised publications per capita.

Region	Population	Published Papers (PP)	GDPc	PP (per 10,000 inhabitants)
Madrid	6,498,560	11,678	30,661	17.970
Galicia	2,781,498	2895	19,893	10.408
Catalonia	7,570,908	7431	26,509	9.815
Andalusia	8,449,985	5849	16,845	6.922
Valencia	5,129,266	3369	19,704	6.568
Cantabria	593,861	378	20,659	6.365
Extremadura	1,108,130	632	15,500	5.703
Murcia	1,474,449	834	18,392	5.656
Asturias	1,077,360	541	20,037	5.022
Navarra	644,566	316	27,795	4.903
Aragon	1,349,467	644	24,698	4.772
Castilla y Leon	2,546,078	1084	21,395	4.258
Canarias	2,118,344	773	19,311	3.649
Basque Country	2,193,093	800	29,303	3.648
Baleares	1,119,439	400	23,624	3.573
Castilla – La Mancha	2,121,888	532	18,279	2.507
La Rioja	323,609	53	24,414	1.638

(the United States (2345), the United Kingdom (1956) and France (1733)), and four countries with a high number of collaborations (> 750) (Germany (1370), Italy (1297), Portugal (898) and the Netherlands (816)). Of these seven countries, six are European Union members, that is, from the locations closest to Spain. The international collaborations occurred with a high number of countries (150), and with 33 countries, there were more than 100 publications.

3.2. Distribution of output in subject categories and journals

Fig. 10 shows the classification of the papers under study according to subject. It is possible that one paper is associated with more than one category. There is a major group, which includes Environmental Science (13,611–31.91%), Chemistry (10,586–24.82%) and Agricultural and Biological Sciences (10,076–23.62%), which is followed by a group with four categories: Biochemistry, Genetics and

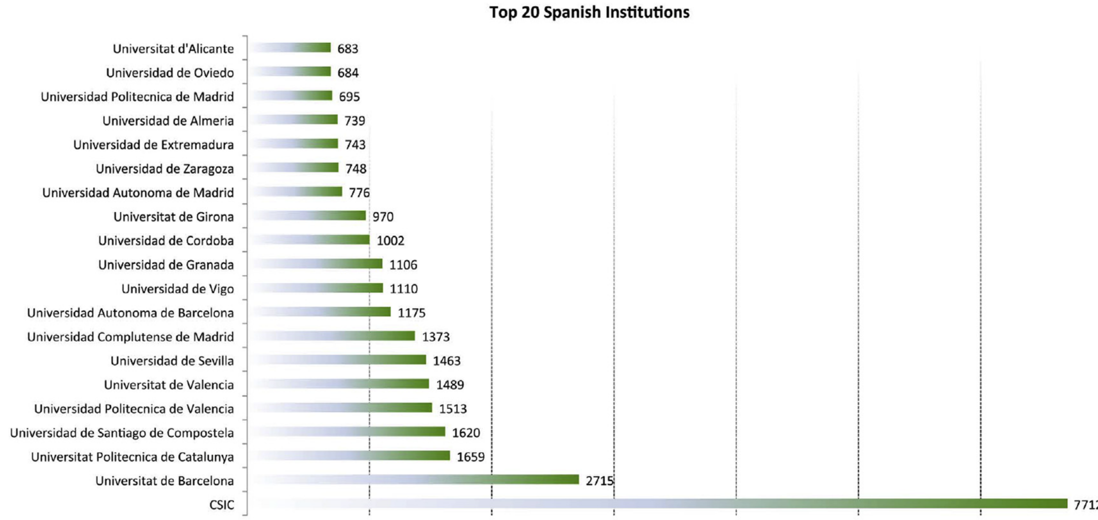


Fig. 6. Spain's 20 most-productive institutions in water use research.

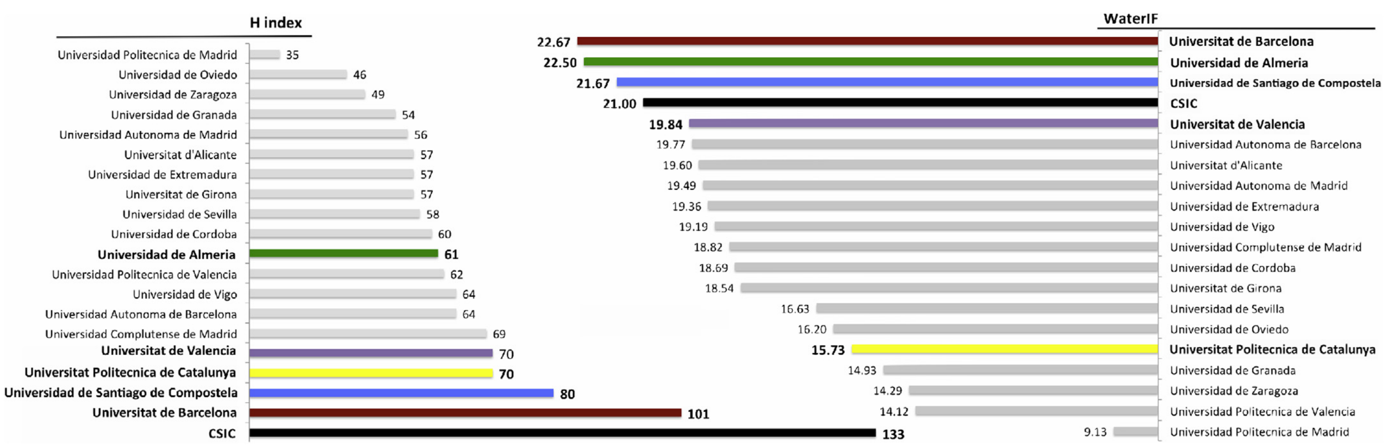


Fig. 7. H index and impact factor for institutions adapted to water use field.

Table 5
Temporal evolution of the 10 most productive institutions, 2003–2014.

Institution	Year												Total
	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	
CSIC	508	646	635	639	672	597	505	444	398	332	291	254	5921
Universitat de Barcelona	182	195	182	174	170	155	155	158	145	110	128	112	1866
Universitat Politécnica de Catalunya	130	145	149	163	132	115	131	99	87	77	69	51	1348
Universidad Politecnica de Valencia	122	138	148	154	157	125	96	80	50	55	71	43	1239
Universidad de Granada	89	89	150	136	136	104	95	86	94	71	73	68	1191
Universidad de Santiago de Compostela	68	94	115	105	109	98	108	91	104	103	78	79	1152
Universidad de Sevilla	95	123	101	110	99	121	84	70	69	75	81	55	1083
Universidad Complutense de Madrid	81	99	102	94	112	105	96	71	68	75	70	56	1029
Universidad Autónoma de Barcelona	80	115	116	152	99	98	79	65	60	58	51	56	1029
Universitat de Valencia	92	101	107	93	103	75	96	73	67	68	76	59	1010

Molecular Biology (5948–13.94%), Earth and Planetary Sciences (5847–13.71%), Chemical Engineering (5450–12.76%) and Engineering (4999–11.72%). The rest constituted a minority. One could expect the relation between the life sciences and water research. However, the chemical study of water is important, and the fields of Environmental Science, Chemistry, Biochemistry, Genetics and Molecular Biology and Chemical Engineering correspond to almost 84% of all publications, which is more than the 35% of Agricultural and Biological Sciences and Engineering. Table 7 lists the 30 journals that publish the most results by researchers in Spanish institutions in 2011. The main quality indexes associated with the publications has been indicated (2011 was choosen randomly because quality index vary year by year). The leading publications (by number of publications, i.e. items) were the Journal of Chromatography A, Water Research, Analytica Chimica Acta, Water Science and Technology and Tecnologia del Agua.

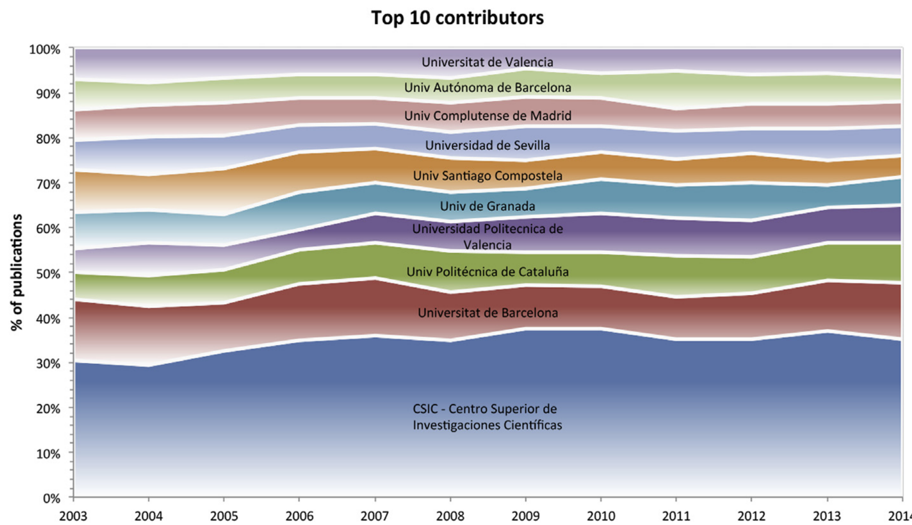


Fig. 8. Temporal evolution of the 10 most productive institutions, 2003–2014.

Table 6
Relationship of countries that collaborate with Spanish institutions in water use research and the number of joint contributions, 1957–2014.

Country	Items
United States	2345
United Kingdom	1956
France	1733
Germany	1370
Italy	1297
Portugal	898
Netherlands	816
Mexico	553
Belgium	450
Switzerland	449
Sweden	449
Argentina	422
Canada	414
Brazil	401
Chile	314
Australia	311
Denmark	304
Japan	242
Greece	241
Poland	239
Austria	224
Norway	220
Finland	195
Colombia	181
China	177
Cuba	153
Morocco	149
Russian Federation	143
Czech Republic	136
Ireland	132
India	125
Venezuela	120
Israel	120
Tunisia	87
Romania	84
Hungary	82
New Zealand	82
Turkey	71
Bulgaria	60
South Africa	59
Slovakia	56
Slovenia	51
Uruguay	49
Iran	45
Saudi Arabia	43
South Korea	39

Table 6 (*continued*)

Country	Items
Ukraine	39
Estonia	37
Algeria	35
Costa Rica	34
Taiwan	31
Monaco	31
Egypt	29
Croatia	27
Peru	24
Lithuania	24
Cyprus	21
Singapore	19
Luxembourg	19
Hong Kong	16
Iceland	16
Thailand	14
Serbia	12
Syrian Arab Republic	12
Puerto Rico	11
Bolivia	10
Ecuador	10
United Arab Emirates	10
Malaysia	9
Panama	9
Georgia	9
Pakistan	8
Nicaragua	8
Lebanon	8
Iraq	7
Jordan	7
Kenya	7
Qatar	7
Bangladesh	6
Mauritania	6
Albania	5
Philippines	5
Senegal	5
Latvia	5
Indonesia	5
Uganda	5
Oman	4
Moldova	4
Greenland	4
Nigeria	4
Burkina Faso	4
Sri Lanka	3
Namibia	3
Palestine	3
Bermuda	3

Table 6 (*continued*)

Country	Items
Belarus	3
Angola	3
Libyan Arab Jamahiriya	3
Kuwait	3
Macedonia	3
Malta	3
Bosnia and Herzegovina	2
Montenegro	2
El Salvador	2
French Polynesia	2
Papua New Guinea	2
Botswana	2
Faroe Islands	2
Sudan	2
Swaziland	2
Bahrain	2
Trinidad and Tobago	2
Honduras	2
Guatemala	2
Viet Nam	2
Yugoslavia	2
Zambia	2
Tanzania	1
Dominican Republic	1
Seychelles	1
Grenada	1
Gibraltar	1
Mozambique	1
Mauritius	1
Netherlands Antilles	1
Barbados	1
Cameroon	1
New Caledonia	1
Falkland Islands (Malvinas)	1
Ethiopia	1
Bahamas	1
Guinea-Bissau	1
Nepal	1
Liberia	1
Andorra	1
Eritrea	1
Equatorial Guinea	1
Paraguay	1
Jamaica	1
Laos	1
Brunei Darussalam	1
Maldives	1
Democratic Republic Congo	1
Martinique	1
Cote d'Ivoire	1
Congo	1
Yemen	1
Central African Republic	1
Cape Verde	1
Zimbabwe	1

These journals belong overwhelmingly to publishers in only three countries: the United States, the United Kingdom and the Netherlands. There are exceptions, such as one Spanish (Tecnologia del Agua) and one Belgian (Acta Horticulturae) journal. However, these two journals do not have an impact index (ISI FI). Fig. 11 shows the details of the relation between the Thomson-Reuters Journal Citation Reports (JCR) index, the Elsevier SCImago Journal Rank (SJR) indicator and the H-index (Hirsch, 2005) for the 30 journals that publish Spanish research. JCR is on the X-axis, and the SJR is on the Y-axis. Finally, the area of each bubble is proportional to the H-index. The larger the area is, the better the H-index. One can observe that there is no clear trend in the correlation of the three indexes. There are publications, such as the Journal of Chemical Physics or the Journal of Physical Chemistry B that present a high H-index but a medium index in the JCR and SJR. However, the linear correlation in this field between the JCR and the SJR index is clear, which has been observed in other comparative studies of these indexes for other disciplines (Schöpfel and Prost, 2009). According to the findings of other authors, both indexes generate similar rankings. That is, they exhibit similar behaviour in terms of sorting the journals and are therefore interchangeable (Torres-Salinas and Jiménez-Contreras, 2010). However, the H-index is a highly unstable impact function and highly sensitive with respect to applying input element scaling (Gagolewski and Mesiar, 2012).

3.3. Analysis of author and index keywords

Keyword analysis in scientific papers is of substantial interest for tracking and searching trends within the branches of science and engineering (Choi et al., 2011; Li et al., 2009). Typically, authors indicate a set of words or key expressions (known as keywords) to frame their publication in the field or subject that they consider more related to the topic being treated. Additionally, the editor usually contributes additional keywords (index keywords or index terms) obtained through the thesauri databases according to the treated topic in the text of the publication. As a result of our research, a total of 57,344 different keywords have been found from 1957 to 2014 in the field of water use. To obtain this number, it was necessary to perform a refinement of the data supplied by Scopus. Initially, this number was larger. The number of analysed publications for this period was 42,655. Among them, only 31,610 have author keywords, whereas the remaining publications (10,131) do not provide this information. Regarding index keywords, only 2250 publications had with no assigned keywords, whereas 40,405 had such keywords. An initial count of the author keywords yielded 141,305. Of these, 62,102 are unique, although there exist many variants in terms of how each author writes the keyword. For example, “Mass spectrometry” can be found as “mass-spectrometry”, “mass spectrometry” or “Mass Spectrometry”, generating different versions of the same concept. To solve this problem, the open source tool OpenRefine has been used, which facilitates text clustering and merging with some degree of similarity based on algorithms designed for this purpose (Elmagarmid et al., 2007; Bozkaya and Ozsoyoglu, 1999). After applying the refinement algorithms, a final number of 57,344 unique keywords has been obtained. Within these unique keywords, 48,740 (84.99%) appear one or two times at most, which indicates a lack of continuity in the research or a broad variety of research approaches (Chuang et al., 2007). Table 8 shows the 50 most relevant keywords during the analysed period.

From Table 8, it can be observed that the term *water* is the one most often repeated. This outcome is logical and expected because of the analysis that is performed. However, of the next 10 keywords, with the exception of the word “Spain” (it is logical that this word appears, given the study's regional scope), seven are related to water quality (Wastewater Water Analysis, Pesticides, Heavy Metals, Adsorption, Water Quality and Wastewater Treatment). Only one keyword is related to irrigation or agriculture (Water Stress), and another one is related to the environment (Drought). Therefore, it can be clearly observed how water quality, perceived from a chemical viewpoint, is an important subject for water research in Spain. This outcome agrees with the most preferred journal by Spanish researchers: the Journal of Chromatography A. “Irrigation” appears in position 15, although Spain's agricultural sector consumes up to 80% of all available hydric resources. Thus, the public resources for research are more focussed on the study of water quality than irrigation and agriculture. In most instances, keywords are formed of two or three words,

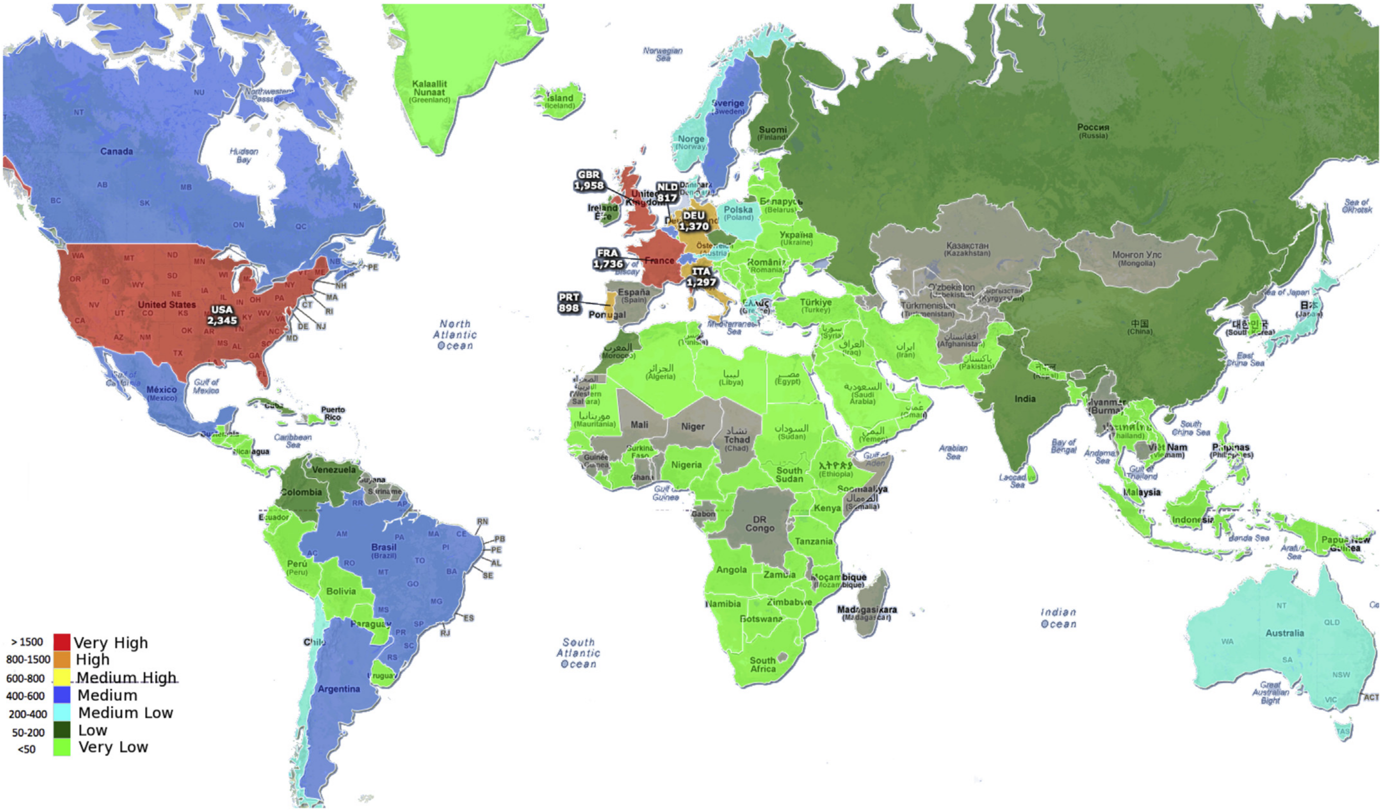


Fig. 9. Intensity of the collaboration of the countries that participate jointly with Spanish institutions within the analysed publications.

which causes a greater dispersion in the appearance frequency of certain terms, such as "water", "environmental" or "treatment". To achieve a more complete view, the compound keywords were decomposed to their base words. In this case, 27,608 words derived from 52,072 initial keywords are obtained. Table 9 shows the result of the applied refinement. As in the case of compound keywords, "irrigation" remains in the same position (15). However, "Spain" descends to position 25, and "Drought" descends to position 48. In contrast, "environmental" appears at position 7. The first positions are always occupied by keywords related to the chemistry of water or its treatment (analysis, wastewater, treatment). Fig. 12 shows the trends for the five terms most often used

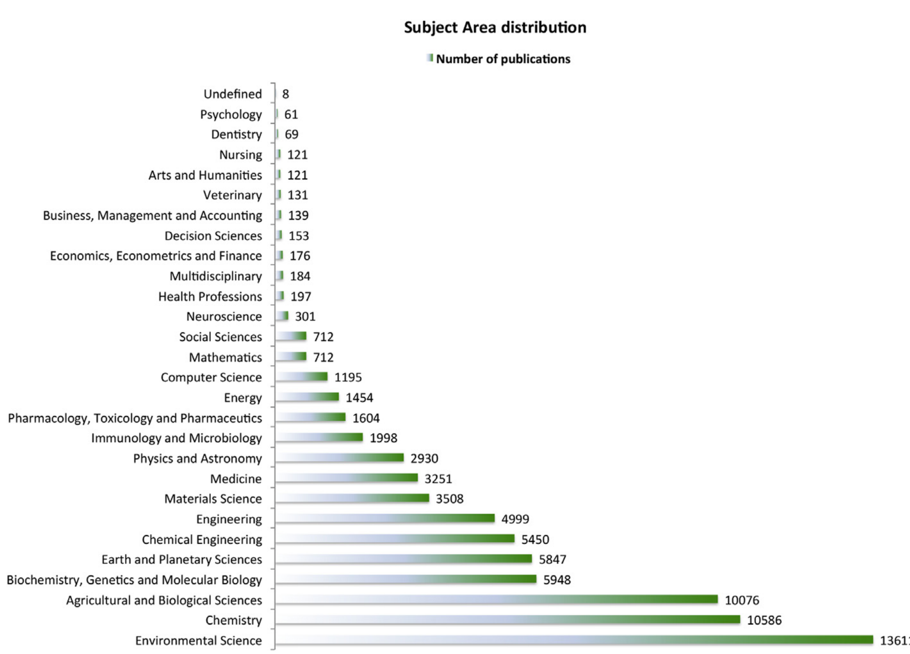


Fig. 10. Publication distribution according subject classified by Scopus.

Table 7
List of top 30 international journals that publish research by Spanish institutions.

Journal	Items	JCR	SJR	H Index	Total Docs (2011)	Total Refs.	Country
Journal of Chromatography A	786	4.531	2.099	138	1150	43,144	Netherlands
Water Research	583	4.865	2.446	145	677	26,876	United Kingdom
Analytica Chimica Acta	580	4.555	1.525	105	662	28,326	Netherlands
Water Science and Technology	486	1.122	0.531	81	740	15,624	United Kingdom
Tecnologia Del Agua	467	0	0	0	0	0	Spain
Chemosphere	462	3.206	1.674	117	937	37,398	United Kingdom
Science of the Total Environment	395	3.286	1.537	108	678	31,746	Netherlands
Journal of Hazardous Materials	350	4.173	1.656	97	1517	57,134	Netherlands
Talanta	322	3.794	1.238	88	887	31,578	Netherlands
Desalination	310	2.59	0.936	66	880	28,471	Netherlands
Environmental Science and Technology	293	5.228	2.672	197	1591	55,736	United States
Bioresource Technology	263	4.98	1.979	118	1721	50,859	United Kingdom
Agricultural Water Management	245	1.998	1.159	49	199	7937	Netherlands
Marine Pollution Bulletin	242	2.503	1.067	78	468	18,946	United States
Journal of Physical Chemistry B	232	3.696	1.501	238	1711	87,929	United States
Analytical and Bioanalytical Chemistry	231	3.778	1.168	82	1122	42,354	Germany
Journal of Agricultural and Food Chemistry	219	2.823	1.212	152	1671	60,148	United States
Langmuir	215	4.186	1.722	194	1959	86,925	United States
Journal of Chemical and Engineering Data	205	1.693	0.766	66	727	21,767	United States
Applied and Environmental Microbiology	202	3.829	1.577	197	1158	48,963	United States
Journal of Hydrology	197	2.656	1.505	102	529	24,672	Netherlands
Journal of Colloid and Interface Science	197	3.07	1.001	116	1067	44,555	United States
Journal of Chemical Technology and Biotechnology	196	2.168	0.861	60	208	7621	United Kingdom
Industrial and Engineering Chemistry Research	178	2.237	0.902	112	1546	54,967	United States
Analyst	176	4.23	1.34	87	696	28,119	United Kingdom
Bulletin of Environmental Contamination and Toxicology	175	1.018	0.559	40	272	4981	United States
Hydrobiologia	173	1.784	0.863	71	402	21,514	Netherlands
Journal of Chemical Physics	166	3.333	1.482	210	2707	129,359	United States
Water Air and Soil Pollution	161	1.625	0.711	59	528	21,785	Netherlands
Acta Horticulturae	160	0	0.223	13	2151	31,322	Belgium

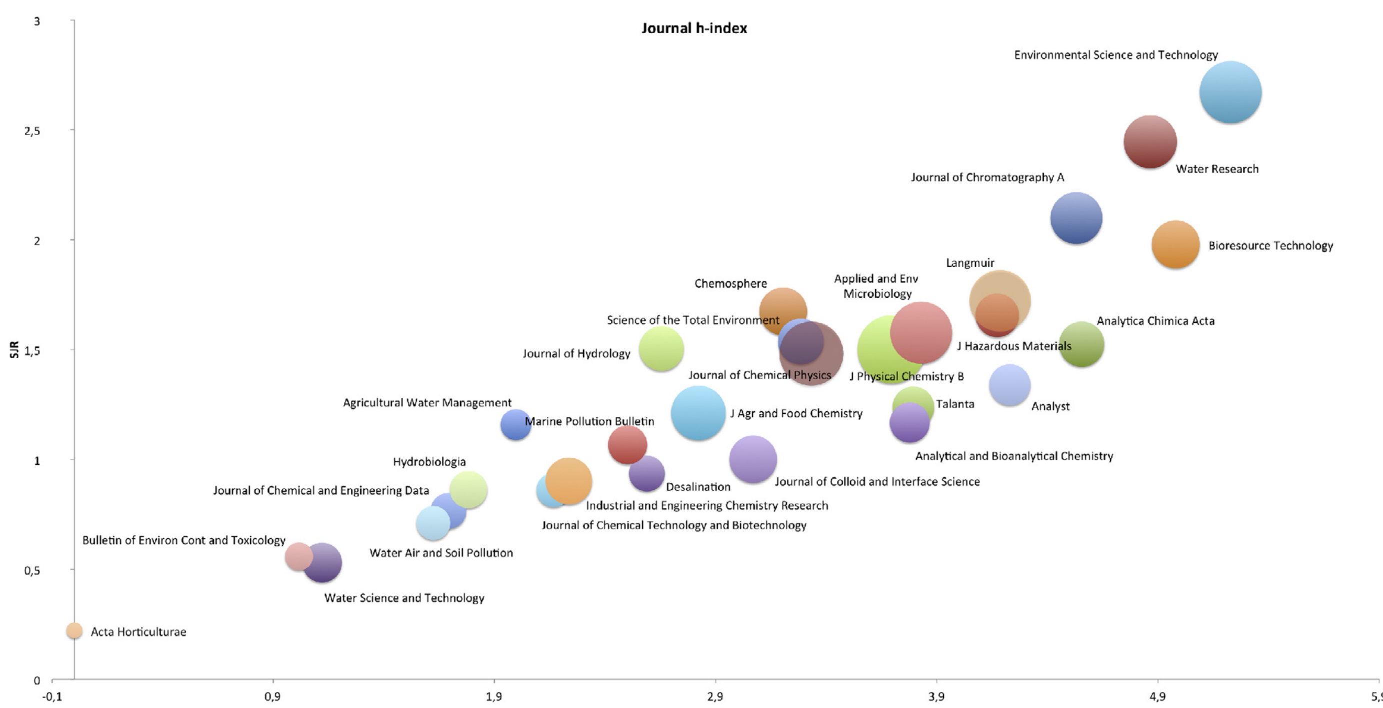


Fig. 11. Ranking of the 30 journals according to different indexes. Item is the number of articles published in the journal, JCR is the Journal Citation Report from Thomson Reuters, and SJR is the SCImago Journal Rank indicator from Elsevier. A larger area implies a greater importance within the ranking.

during the period analysed: Water, Analysis, Wastewater, Treatment and Soil. It can be observed a clear upward trend in the mid-1990s, and this evolution continues until the present. This outcome indicates that the treated topics are of substantial interest to the scientific community.

4. Conclusions

In this study, it has been highlighted numerous data regarding the contribution of Spanish institutions to scientific advances in the field of water use during the period 1957–2014. It has been found a

Table 8
Relationship of the 50 most-used keywords.

Keyword	Items	%	Ranking
Water	617	1.18	1
Wastewater	439	0.84	2
Water analysis	418	0.80	3
Pesticides	382	0.73	4
Spain	325	0.62	5
Heavy metals	313	0.60	6
Water stress	265	0.51	7
Drought	259	0.50	8
Adsorption	236	0.45	9
Water quality	233	0.45	10
Wastewater treatment	228	0.44	11
Modelling	222	0.43	12
Solid-phase extraction	221	0.42	13
Environmental analysis	207	0.40	14
Irrigation	201	0.39	15
Drinking water	182	0.35	16
Temperature	181	0.35	17
Water framework directive	181	0.35	18
Toxicity	179	0.34	19
Mediterranean	178	0.34	20
Groundwater	176	0.34	21
Seawater	174	0.33	22
Kinetics	170	0.33	23
Salinity	164	0.31	24
Pharmaceuticals	156	0.30	25
Liquid chromatography	150	0.29	26
Water treatment	150	0.29	27
Ozone	147	0.28	28
Climate change	146	0.28	29
Photosynthesis	141	0.27	30
Sewage sludge	138	0.27	31
Pollution	137	0.26	32
Cadmium	132	0.25	33
Sediments	131	0.25	34
Copper	127	0.24	35
Mediterranean Sea	125	0.24	36
Sediment	125	0.24	37
Waters	125	0.24	38
Stomatal conductance	124	0.24	39
Water use efficiency	124	0.24	40
Activated carbon	120	0.23	41
Activated sludge	116	0.22	42
Photocatalysis	116	0.22	43
Soil	116	0.22	44
Fish	112	0.22	45
Mass spectrometry	111	0.21	46
Reverse osmosis	110	0.21	47
Solid-phase microextraction	109	0.21	48
Anaerobic digestion	108	0.21	49
Arsenic	108	0.21	50

Table 9
Relationship of words used within author keywords.

Keyword	Items	%	Ranking
Water	7918	5.84	1
Analysis	1956	1.54	2
Wastewater	1307	1.03	3
Treatment	961	0.76	4
Soil	955	0.75	5
Extraction	829	0.65	6
Environmental	812	0.64	7
Mediterranean	773	0.61	8
Flow	751	0.59	9
Acid	743	0.59	10
Model	676	0.53	11
Quality	669	0.53	12
Liquid	667	0.53	13
Carbon	662	0.52	14
Irrigation	635	0.50	15
Chromatography	619	0.49	16
Stress	599	0.47	17
Organic	598	0.47	18
Spectrometry	593	0.47	19
Surface	589	0.46	20
Pollution	551	0.43	21
Management	546	0.43	22
Pesticides	531	0.42	23
Sludge	515	0.41	24
Spain	497	0.39	25
Metals	494	0.39	26
River	491	0.39	27
Oxidation	485	0.38	28
Properties	472	0.37	29
Gas	470	0.37	30
Mass	470	0.37	31
Modelling	470	0.37	32
System	841	0.36	33
Solid-phase	448	0.35	34
Membrane	447	0.35	35
Compounds	446	0.35	36
Temperature	438	0.34	37
Energy	431	0.34	38
Sea	428	0.34	39
Plant	420	0.33	40
Activity	414	0.33	41
Control	410	0.32	42
Heavy	408	0.32	43
Adsorption	407	0.32	44
Removal	396	0.31	45
Sediment	395	0.31	46
Potential	379	0.30	47
Drought	371	0.29	48
Efficiency	367	0.29	49
Growth	362	0.29	50

total of 42,655 publications in 28 different categories. The increment in the number of publications has been exponential during this period, with a special emphasis occurring in the categories of Environmental Science, Chemistry and Agricultural and Biological Sciences. The research performed has primarily been published in international journals (84.41%) and conferences (10.41%), with English as the predominant language (more than 95%). The institutions that publish the most are those located in the communities of Madrid (33.24%), Catalonia (21.15%) and Andalusia (16.65%). These publications represent nearly 75% of all national publications. The institution that publishes the most is a public autonomous organisation, the National Council for Spanish Research (CSIC, in Spanish). Alone, the CSIC accounts for nearly 20% of all of the scientific production of the country. The remaining institutions are public universities, such as the University of Barcelona, the University of Santiago de Compostela or the Polytechnic University of Catalonia. H-index and Impact Factor have been adapted for the obtained water publications analysed. The combination of these 2 indexes, along with the number of publications open new perspectives for the institutional scientific quality analysis. Spain collaborates chiefly with the country's main commercial partners: the USA and the UE. The United States, the United Kingdom, France and Germany are the countries with the largest number of shared publications. Despite the significant relations at all levels that bind Spain and Latin America, there is no strong collaborative link with the Hispanic countries, with the exception of Mexico. The keyword analysis for the studied publications reveals a significant dispersion in their use. The majority of the keywords that occupy the first positions are related to water quality (Wastewater, Water Analysis, Pesticides, Heavy Metals, Adsorption, Water Quality and Wastewater Treatment). Only one keyword is related to irrigation (Water Stress), and one is related to the environment (Drought). Therefore, it can be clearly observed how water quality from a chemical perspective is an important subject for the water research in Spain. This outcome corresponds with the journal most preferred by the Spanish researchers: the Journal of

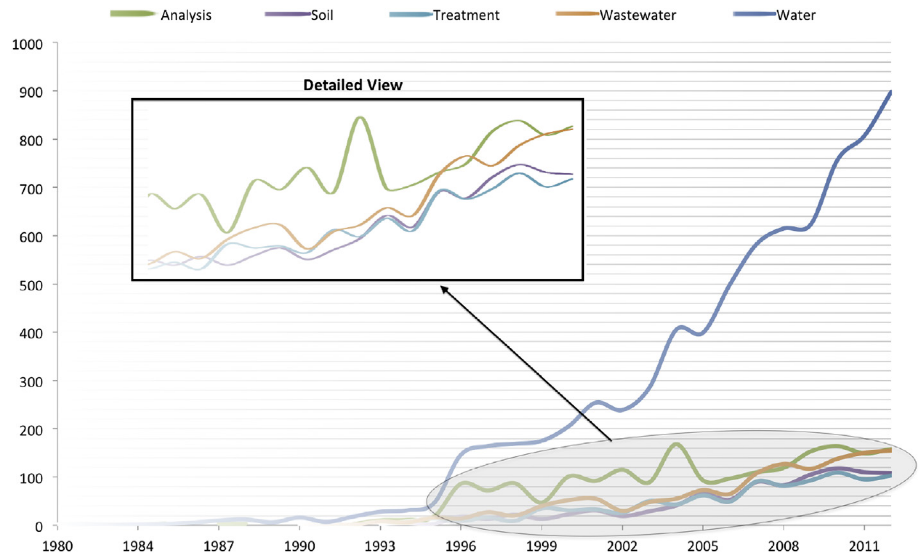


Fig. 12. Evolution of the five most frequently used words within the author keywords for the water use field, 1957–2014.

Chromatography A. Additionally, categories related to chemistry correspond to 84% of all publications. In sum, this paper demonstrates that the Spanish contribution in the subject of water use corresponds to medium-level international collaboration. Public resources are more focused on the study of water quality than the study of irrigation and its use in agriculture. This outcome contrasts clearly with the fact that Spain's agricultural sector consumes up to 80% of all available hydric resources. This study will guide the researchers on water use to see either where new trends might come from.

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