Knowledge Inventory for hydrogeology research
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KINDRA DELIVERABLE D1.1

INITIAL PROPOSAL FOR A HARMONIZED TERMINOLOGY AND METHODOLOGY

Summary:
To have a preliminary proposal for harmonized terminology and methodology, a review of groundwater related research projects has been conducted for positioning the KINDRA project in an international context. Two lists of keywords characterizing research on groundwater, from policy documents and from groundwater related scientific literature, have been identified and ranked by performing searches and geographical distribution. Finally, keywords have been linked to the main three categories 'topics, themes and activities'. These results will be refined and developed during further step (D1.2 due at M6).

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Project acronym:	KINDRA
Project title:	Knowledge Inventory for hydrogeology research
Grant Agreement number:	642047
Call identifier:	H2020-WATER-2014-one-stage
Topic:	WATER-4a-2014
Start date of the project:	01/01/2015
Duration:	36 months
Website:	www.kindraproject.eu

This report has been produced with financial support from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 642047. The contents of this report are the sole responsibility of the KINDRA Consortium and can under no circumstances be regarded as reflecting the position of the European Union. The Executive Agency for Small and Medium-sized Enterprises (EASME) is not responsible for any use that may be made of the information it contains.

DOCUMENT PREPARATION SHEET

please do not include this sheet in the publishable version of the deliverable

Lead beneficiary:	Università degli Studi di Roma La Sapienza
Other beneficiaries:	GEUS, University of Miskolc
Due date:	2015-03-31 (M3)
Nature:	Report
Diffusion	Public

Revision history	*Delivery date*	*Author*	*Summary of changes*
Version a	2015/04/17	van der Keur P., Hinsby K.	
Version b	2015/04/22	Petitta M.	Revision of text, rewriting of executive summary and conclusion
Version final	2015/04/30	all Partners	

Approval status			
Function	*Name*	*Date*	*Signature*
Reviewer 1	P. Szucs	26/04/2015	
Reviewer 2	M. Petitta	26/04/2015	
WP leader	M. Petitta	04/05/2015	
Project leader	M. Petitta	05/05/2015	

Diffusion List	
Name, partner-name	*e-mail*
All participants + project repository	
Panel of Experts	

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1. EXECUTIVE SUMMARY

This report presents a preliminary classification of groundwater related R&D results and activities by keywords derived from EU directives and the most important scientific journals publishing groundwater research. In order to have a comprehensive understanding on the groundwater theme, it is necessary to create an overview of our scientific knowledge covering European countries. Such comprehensive coverage will result in an accurate assessment of the state of the art in hydrogeology research in various geographical and geo-environmental settings, allowing for direct comparison and exploitation of synergies. The first step in identifying research gaps and formulating recommendations for the future is to build a harmonized approach for classifying and reporting the European groundwater research efforts.

This task requires the identification of keywords and categories for an effective and useful classification, allowing the recognition of the pertinence of groundwater related topics in the field of general water research. To establish a common terminology, various academic, industrial and research classification schemes are reviewed to create a hierarchical structure and a selected list of key-words from relevant EU directive documents, i.e. the Water Framework Directive (WFD, European Commission, 2000), its daughter directive the Groundwater Directive (GWD, European Commission, 2006) and the Blueprint to Protect Europe's Water Resources (BWR, European Commission, 2012) as well as scientific literature that will be fundamental to identify relationships and intersections between topics, themes and activities. The experience of project partners has been used to draft an initial conceptual framework (keywords, categories, hierarchy).

Strong contribution is anticipated from the Joint Panel of Experts (JPE) for amendments and revision. Contributions and comments by the JPE are not integrated in the preliminary initial classification presented in this report, but are implemented in the final terminology and classification (D1.2) finalised by Month 6 after a final internal circulation for comments, revision and suggestions.

The work presented here (Task 1.1) will be fundamental to the structure of the European Inventory of Groundwater Research (EIGR), which will contain information for each European country covered by the project partners (in particular EFG Third Parties), including research & innovation results and knowledge improvements derived from projects directly or indirectly supported by EC.

A review of groundwater related research projects has been conducted for positioning the KINDRA project in an international context. KINDRA is creating an inventory of groundwater related knowledge and this includes research available from ongoing and previous EU funded projects and

therefore it becomes relevant to link KINDRA to such activities for populating the developed EIGR with data using a Hydrogeological Research Classification System (HRC-SYS).

For developing the common terminology on which to base the EIGR through HRC-SYS, keywords characterizing research on groundwater related topics, themes and activities have been identified in two ways: (1) from policy documents, WFD, GWD and Blueprint documents, and (2) from groundwater related scientific literature, as described earlier.

This resulted in two lists of keywords reflecting both approaches. To assess the importance and pertinence of the keyword they have been ranked by performing searches via the Web of Science and Google Scholar search engines. In the former case, search statistics have been derived reflecting the ranking of keywords, e.g. citations and H-index. In addition to these analyses the geographical distribution of research has been included to map gaps and trends in groundwater related research across Europe, represented by EFG in the KINDRA project.

Finally, keywords have been grouped into categories and linked to the main categories ‘topics, themes and activities’ for the proposed classification scheme. The methodology and preliminary results presented in this report will be refined and checked with important input from the JPE members and developed into the final harmonized terminology and methodology for classification and reporting hydrogeology related research in Europe (D1.2 due at M6).

2. REVIEW OF PREVIOUS AND CURRENT INTERNATIONAL PROJECTS RELATED TO GROUNDWATER CLASSIFICATION SCHEMES

The main goal of this project is to create a unique knowledge-inventory first i.e. a database on groundwater research results, activities, projects and programmes deemed essential for the identification of the state-of-the-art, future perspectives and research gaps. KINDRA objectives will allow the correct management and policy development of groundwater at EU scale, as recommended also by the Blueprint Document (EC, 2012).

The framework requires (i) the identification of keywords and categories for an effective and useful classification, and the (ii) the definition of a common terminology allowing the recognition of the pertinence of groundwater related topics in the field of general water research. In doing so, it is useful to examine and review ongoing and previous projects related to various academic, industrial and research classification schemes for to the (ground)water topic. This represents a necessary step for developing a hierarchical structure from a selected list of key-words fundamental to identify relationships and intersections between topics, themes and activities related to groundwater research.

Both the classification system HRC-SYS and the European Inventory of Groundwater Research EIGR represent the main products of the KINDRA project have a common methodological base to classify the results according to a harmonized terminology and give the possibility to access the classification system by different external users (user sensitive). It is therefore useful to assess the state of the art in hydrogeology research in various geographical and geo-environmental settings, allowing for direct comparison and the exploitation of synergies.

This section deals with the preliminary consultation concerning related research projects methodological approaches useful to and support scientific advancement in KINDRA lifetime. By reviewing the main research and technology developments on water management, a preliminary research has been carried out focusing on the scientific methods exploited by projects under the FP6 and FP7 and other European programmes.

The following main information sources deemed useful for next steps in KINDRA research, are presented in the following list:

- Several EU-funded projects have been explored indicated in KINDRA DoW (GABARDINE, GENESIS, RISK-BASE, WADE, CIRCE, BRIDGE, AQUATERRA, AQUAREHAB, WATERDISS 2.0) as listed in table 2.1:

ID	BRIEF DESCRIPTION
GABARDINE	Groundwater artificial recharge Based on Alternative sources of water: advanced integrated technologies and management) is a FP6 project.
GENESIS	Groundwater and Dependent Ecosystems: new scientific and technological basis for assessing climate change and land-use impacts on groundwater) is a FP7 project.
RISK-BASE	Coordination Action on Risk Based Management of River Basins is a FP6 project.
WADE	Floodwater recharge of alluvial aquifers in dryland environments) is a FP6 project related to artificial recharge in arid area by floodwater.
CIRCE	Climate change and Impact Research: The mediterranean Region) is a FP6 project aimed at developing for the first time an assessment of the climate change impacts in the Mediterranean area.
AQUATERRA	Understanding river-sediment-soil-groundwater interactions for support of management of waterbodies is an integrated FP6 project .
AQUAREHAB	Development of rehabilitation technologies and approaches for multipressured degraded waters and the integration of their impact on river basin management) is a FP7 project which developed rehabilitation technologiescope with several pollutants for soil, groundwater and surface water to
BRIDGE	Development of Background cRiteria for Identification of Groundwater thrEsholds (EC, 2008). The project was running during the period 2004-2006 to provide scientific support to the development of the Groundwater Directive (European Commission, 2006).
WATERDISS2.0	Dissemination and uptake of FP water research results) is a FP7 project having the aim of disseminate research results from other projects generally related to water issues, including the following projects more directly focused on groundwater.

Table 2.1 EU-funded projects indicated in KINDRA DoW

- Projects databases:

WISE-RTD Water Knowledge Portal (http://www.wise-rtd.info/en) forwards to resources, e.g. websites with focus on information relevant for the implementation of the European Water Policy. The linked websites contain a wide range of information such as guidance documents, synthesis reports, reviews, experiences of projects on implementation, selections of ICT tools, methodologies and results of national and EC funded research projects. Information is presented from all over Europe (and even beyond), at European, national and regional level as well as for river(sub-)basins.

CORDIS (http://cordis.europa.eu/home.en.html) is the European Commission's primary public repository and portal to disseminate information on all EU-funded research projects and their results in the broadest sense. Grant information is provided for each project, including reference, acronym, objective, title, total cost, EC contribution, start date, end date, duration, Call Id, Topic, Funding Scheme, legal basis.

ECO-INNOVATION DATABASE bridges the gap between research and the private market for uptake and replication (http://ec.europa.eu/environment/eco-innovation/discover/programme/index_en.htm)

It helps good ideas for innovative products, services and processes that protect the environment become fully-fledged commercial prospects, ready for use by business and industry. In doing so the initiative not only helps the EU meet its environmental objectives but also boosts economic growth.

CIRCA (https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp) is the Communication and Information Resource Centre for Administrations, Businesses and Citizens, containing results of activities and meetings of Common Implementation Strategy (CIS) Working Groups, including the Groundwater one.

- Environmental agencies/institutions (reports & guidelines)

The European Environment Agency (EEA, http://www.eea.europa.eu/) is an agency of the European Union. Their task is to provide sound, independent information on the environment. They represent a major information source for those involved in developing, adopting, implementing and evaluating environmental policy, and also the general public.

The United States Environmental Protection Agency (EPA, http://www.epa.gov/) conducts environmental assessment, research, and education. It has the responsibility of maintaining and enforcing national standards under a variety of environmental laws, in consultation with state, tribal, and local governments. The agency also works with industries and all levels of government in a wide variety of voluntary pollution prevention programs and energy conservation efforts.

The European Water Association (EWA, http://www.ewa-online.eu/) is an independent non-governmental and non-profit making organisation dealing with the management and improvement of the water environment. The aim of EWA is to provide a forum for the discussion of key technical and policy issues affecting the growing European region. This is done through conferences, workshops, meetings and special working groups of experts all organised on an international basis together with regular publications.

Nevertheless, ICT water cluster (http://ict4water.eu/) and LIFE programme (http://ec.europa.eu/environment/life/) Projects have been also under consideration. ICT activity includes ten sister projects on ICT and Water Management. They all enhance interoperability between water information systems at EU and national levels and efficiency of water resources management. LIFE programme represents an efficient EU's financial instrument supporting environmental, nature conservation and climate action projects.

In this preliminary research the projects resumed in Table 2.2 have been explored

- ICT water cluster projects

ID	BRIEF DESCRIPTION
DAIAD	Real-time high granularity water monitoring & knowledge extraction
EFFINET	Advanced metering, user demand profiles, fault detection and predictive control techniques
ICeWater	Infrastructure for smart metering and real-time monitoring
ISS-EWATUS	Awareness of water consumption via social media platform
iWIDGET	Water consumption patterns and demand forecasting
SmartH2O	Behavioural data via smart meters and an online social participation application
UrbanWater	Advanced metering, real-time communication of consumption, adaptive pricing
WATERNOMICS	Demand response and open business models through personalized water data
WISDOM	Improved resource efficiency and business operations by ICT
WatERP	Open standards management platform for water supply distribution chains

Table 2.2 ICT water cluster project list

An exception to this project's list, is represented by HAIR (HArmonized environmental Indicators for pesticide Risk) which is a FP6 EU founded project. Even if groundwater topic here is not covered, HAIR may be of interested for its successful ability in establishing a consistent database structure for a standardized set of indicators.

- LIFE programme. Projects have been selected taking into account two criteria: (i) a time period, from 2006 which is the year of GWD implementation until the present day (2015), and (ii) the related topics (water and/or groundwater) (Table 2.3).

ID	BRIEF DESCRIPTION
LIFE CLEANSED	Innovative integrated methodology for the use of decontaminated river sediments in plant nursing and road building
WARBO	Water re-born - artificial recharge: innovative technologies for the sustainable management of water resources
MY FAVOURITE RIVER	Sustainable use of and identification with the River Neckar in co-operative governance (national, municipal and regional level)
CLEANWATER	Integrated system for protect and analyse the status and trends of water threatened by nitrogen pollution
WATER	Strengthening the scientific foundation of water quality programs
MAGPlan	Management plan to prevent threats from point sources on the good chemical status of groundwater in urban areas
Sus Treat	Use of immanent energy for sludge treatment - a central step towards self-sustaining sewage flow management
WATLIFE	Enhancement of Public Awareness of the Importance of Water for Life, its Protection and Sustainable Use in Accordance with the WFD
WALPHY	Design of a decision tool for hydromorphological restoration of water bodies in Walloon Region
WATER CHANGE	Medium and long term water resources modelling as a tool for planning and global change adaptation. Application to the Llobregat Basin.
SEMEAU	Application of the Water Framework Directive by the implementation of an expert system providing a total modelling of a water mass
TRUST	Tool for regional - scale assessment of groundwater storage improvement in adaptation to climate change (TRUST)
M^3	Application of integrative modelling and monitoring approaches for river basin management evaluation
INCOME	Improved management of contaminated aquifers by integration of source tracking, monitoring tools and decision strategies
AQUALIFE	Development of an innovative and user-friendly indicator system for biodiversity in groundwater dependent Ecosystems

Table 2.3 LIFE programme project list

Additional inputs derived also by an ongoing research performed by João Wang de Abreu, Blue Book Trainee at European Commission, who is identifying the relationship between KINDRA and past projects (Fig. 2.1).

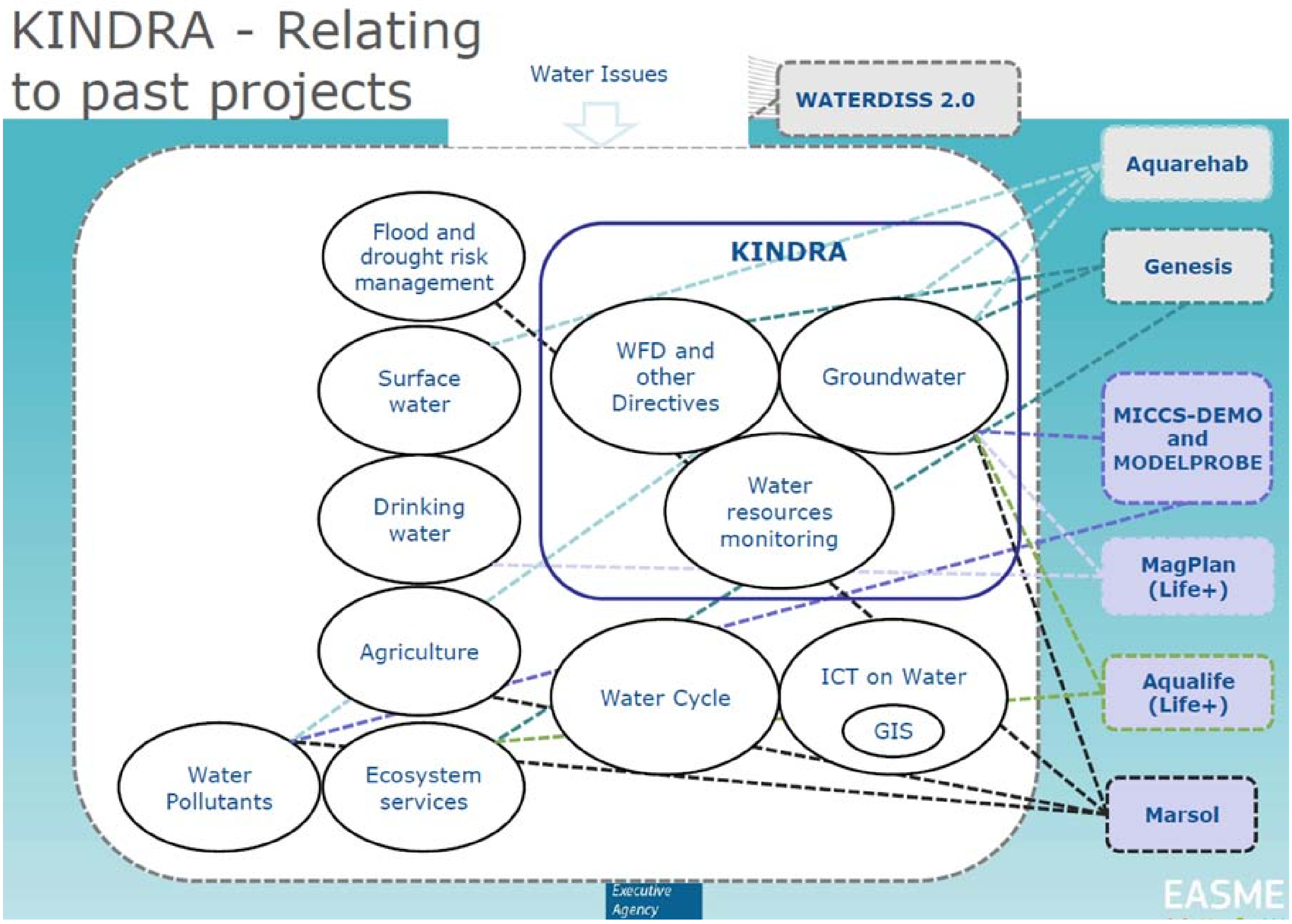

Figure 2.1 KINDRA related to past projects. From Easme meeting (February 21, 2015), João Wang de Abreu.

According to Wang de Abreu findings, KINDRA results are related to WFD, GWD and other directives on water and water resources monitoring topics (Fig. 2.1). Taking account of this, KINDRA intends to enlarge its area of expertise in order to better fulfill the final objectives of the projects.

On the basis of this framework, comments and suggestions from the European Commission same as from the Executive Agency for SMEs (EASME) have been also taken into account:

- Create close collaboration between science, policy and industry

KINDRA is working on this matter, e.g. reviewing the SPI-Water cluster three EC FP7 projects dealing with Science-Policy Interfacing in water management: STREAM, WaterDiss2.0 and STEP-WISE.

In particular, attention is given to STREAM and to its scope to tackle the issue water research awareness gap.

- Build synergies with previous and/ or parallel projects, creating coordinated efforts to achieve greater impact and efficiency.

On this regard, a bridge has been established among KINDRA and other projects. At the moment, worthy of notice are WatERP (FP7) and Widest (H2020) projects, both under the coordination of BDigital Technology Centre. Special attention is given to the WatERP ontology designed taking into account the taxonomy created for the water supply distribution chain. In this case, a direct link between researchers (e.g. Gabriel Anzaldi Varas) is already made, encouraging a concrete and fruitful exchange of information.

The research conducted by now allowed to establish fundamental basics for further steps in KINDRA development. Extensive results will be presented in next activities within Task 1.1.

3. GROUNDWATER KEYWORDS SEARCH ON INTERNATIONAL RESEARCH DATABASES

Building a Hydrogeological Research Classification System - HRC-SYS – for groundwater R&D results requires the identification and classification of main keywords within groundwater policy documents and research. Relevant keywords are needed to classify and report the European groundwater research; this is a basic step in identifying research gaps and formulating recommendations for the future.

The main keywords are classified into categories (topics, themes and activities) for the development of an inventory (European Inventory of Groundwater Research and Innovation-EIGR) of policy related and scientific knowledge in hydrogeological research that is the overall objective of KINDRA project.

The list of keywords is fundamental to identify relationships and intersections between topics, themes and activities.

In order to develop a common terminology, the identification of main keywords has to take stock of existing knowledge, taking into account the implementation needs of WFD (Water Framework Directive) and GWD (Groundwater Framework Directive) and the recommendations by the Blueprint Document (EC, 2012) to safeguard Europe´s water resources.

The first step in defining the main keywords is then the Identification of relevant keywords from WFD, GWD and Blueprint documents.

The main keywords were first identified by inspecting documents and selecting keywords from expert judgement (for the WFD and GWD) and subsequently analyzing the statistics on searches on relevant keywords from existing knowledge (papers, books, chapters, reports, etc…).

The two databases and search engines adopted for the research of the relevant keywords are the well acknowledged Web of Sciences (WoS) by Thomson Reuters and the popular Google Scholar. While WoS refers to ISI publications only, GS has a broader search range, including book chapters, proceedings, reports and thus both search engines give different data that can be analyzed. WoS includes various statistics, among those: numbers of papers (or hits), total citations, average citations, H – index, Highest citations.

The researches and the analyses of data are the two next step after the identification of relevant keywords from WFD, GWD and Blueprint documents.

The results are diagrams showing the collected data and tables in which the keywords are organized in Topics, Themes, Activities (Chapter 5: Preliminary Harmonized Terminology and Classification).

3.1 IDENTIFICATION OF RELEVANT KEYWORDS FROM THE EU WATER FRAMEWORK DIRECTIVE, THE GROUNDWATER DIRECTIVE AND THE BLUEPRINT TO PROTECT EUROPE'S WATER RESOURCES

The KINDRA project has as overall objective the creation of an inventory of knowledge related to hydrogeological research and the use of this inventory to identify critical research challenges required for the implementation of the Water Framework Directive (WFD, European Commission, 2000)) including the Groundwater Directive (GWD, European Commission, 2006). Keywords are necessary to create the inventory: they are the way to search inside the EIGR (European Inventory of Groundwater Research an Innovation). The information could be compared at any given time with that of the past and with the ongoing researches activities to verify the status of the research agendas and the implementation of the WFD and GWD and other key directives (the nitrate directive, REF, etc.).

The reasoning behind using keywords identified in the WFD and GWD, and the recent **B**lueprint to Protect Europe's **W**ater **R**esources (BWR, European Commission, 2012), for classification of groundwater research, and using the periods 2000-2006 and 2006-2015 for citation analyses, is furthermore that this approach provides information that can be used for assessment of the directives importance as research drivers. Further, it makes it easy to evaluate the relevance of and group groundwater research in relation to the objectives of the WFD and GWD, and Science-Policy feedback within water research, policy and management. In addition the holistic thinking in the WFD and GWD provides good possibilities of demonstrating the important links in the water-food-energy nexus and between surface and subsurface waters and dependent or associated terrestrial and aquatic ecosystems. Hence, it emphasizes the importance of groundwater in the hydrological cycle not only for drinking water and other legitimate uses but also for sustaining terrestrial and aquatic ecosystems in a changing climate where freshwater availability is under pressure.

The identification of groundwater related research keywords from the EU WFD, GWD, and BWR was performed by GEUS and based on expert judgement. GEUS has been involved in EU groundwater research projects since 1995 and in the Working Group on Groundwater within the Common Implementation Strategy (CIS) of the Water Framework Directive since 2004. Initially, as part of the BRIDGE (**B**ackground C**RI**teria for I**D**entification of **G**roundwater Thr**E**sholds) project, which was a research project providing technical support to the development of the Groundwater Directive, and at a later state representing other research projects (e.g. CLIWAT, www.cliwat.eu), GEUS, and lately the Water Resources Expert Group of the EuroGeoSurveys.

The selected keywords are simply based on expert judgement, and they have not been ranked or evaluated by any statistical procedures before they were applied in the Web of Science and Google Scholar searches.

This approach cannot stand alone, however, as it may not cover all relevant groundwater research areas especially the most recent. Therefore, it has to be supplemented by identification of important keywords and topics from the most important scientific journals, which e.g. can be identified by use of the Journal Citation Reports.

The identification of relevant keywords takes into account firstly the WFD because of the purpose of the KINDRA project: the project focuses on groundwater, that is the “hidden” part of water cycle, and takes stock of several top-priority research issues that are fundamental for the implementation of WFD. The daughter directive on groundwater GWD (Groundwater Directive, 2006) reinforce the importance of groundwater inside the WFD.

The purpose of WFD ECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000)(DIR, establishing a framework for Community action in the field of water policy, is “to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater”.

The GWD (DIRECTIVE 2006/118/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006) on the protection of groundwater against pollution and deterioration “establishes specific measures as provided for in Article 17(1) and (2) of Directive 2000/60/EC in order to prevent and control groundwater pollution”(Art. 1, co 1).

According to the requirements of the Water Framework and Groundwater Directives it is necessary to improve the understanding of the relations between groundwater quantitative and chemical status and ecological status of groundwater dependent terrestrial and associated aquatic ecosystems.

The Blueprint Document (EC, 2012) is another fundamental document that has to be considered in the framework of the development of a knowledge-inventory of groundwater research from projects and programmes. The inventory is essential for the identification of the state-of-art, future trends and research gaps; it is at the base of the correct management and policy development of groundwater recommended by policy documents like the Blueprint for Water.

A list of relevant keywords has been produced to support the development of an Hydrogeological Research Classification System - HRC-SYS, identified and extracted from the Water Framework and Groundwater Directives and the Blueprint Document. This is the first step to define the main Keywords to be used for the EIGR (Tab. 3.1.1).

abstraction agriculture Ammonium aquatic ecosystems Arsenic biological status Cadmium characterisation chemical status chloride climate changes coastal waters dependent ecosystems deterioration drinking water droughts e-flows ecological flows ecological status ecoregions ecosystems ecotoxicology electrical conductivity	energy production environment environmental flow extraction floods groundwater bodies Groundwater Directive hazards human health human toxicology Hydrogeological cycle hydrological cycle indicators industry innovations integrated management integrated water resources management intrusions land subsidence land use Lead management mapping marine waters measures	Mercury mitigation models monitoring Natural background nitrate over-use overuse pesticides pharmaceuticals policy pollution protection Quality quantitative status Quantity Review river basins rivers salinity salt water scarcity shale gas status storage stygofauna	Sulphate surface water interaction sustainable sustainable water use synthetic substances techniques terrestrial ecosystems territorial waters Tetrachloroethylene threshold tourism transboundary transitional waters treatment trends Trichloroethylene vulnerability Water Framework Directive water services water supply water table decline wetlands

Table 3.1.1: List of keywords from WFD (Water Framework Directive), GWD (Groundwater Framework Directive) and BWR (Blueprint to Protect Europe's Water Resources).

3.2 RESEARCH OF KEYWORDS USING WEB OF SCIENCES AND GOOGLE SCHOLAR

Different databases and search engines can be considered when performing a search: Web of Sciences (Thomson Reuters), Google Scholar and Scopus (Elsevier) are search engines / databases frequently employed for scientific researches.

Web of Sciences (WoS) is a database produced by ISI (Institute for Scientific Information); it is an online subscription-based scientific citation indexing service. This database includes only peer-review papers from Scientific Journals, which are approved as high quality scientific journals by the ISI. In WoS each paper is linked to the other and everyone has a complete list of references. This database is a really powerful instrument of research because of its facilities for citation analyses. It is a citation index database.

Google Scholar is a Google´s search engine for academic searches. There are no statistical facilities to be used and it only provides the total number of hits on a particular searched topic. The number of hits includes, in this case, not only papers but also abstracts, reports and book chapters.

Scopus is a multidisciplinary database and an instrument of citation indexing as Web of Sciences, but with slightly less features.

The research of keywords has been performed at this stage only using Google Scholar and Web of Sciences but comparisons with other databases such as Scopus will be considered.

In the research of keywords both Google Scholar and Web of Sciences have been used. The reason is that the first research engine is broader than the second and comparing the numbers of hits, coming out searching a particular keyword (for every keyword) in both the databases, it is possible to see whether keywords from directives are reflected in both Google Scholar and Web of Sciences.

Figure 3.2.1 shows the interface of Google Scholar research engine. The research of keywords have been performed in this first case only choosing the time period, 2006-2015, and inserting the word groundwater *plus* the keyword (for every keyword) in the field of research. Before searching for each keyword the word groundwater has been searched alone to evaluate the total number of hits for this topic. The start of the time period is 2006 because this is the year in which the GWD was enacted. The search has not been linked to geographical regions, and statistics are not available for the results from Google Scholar searches. The number of results found with this research engine has been very high because this database consider not only peer-review papers but every kind of publications including publications without any quality assurance. However, the total number of publications do indicate the relevance of the topic and the ratio between the number of hits on a given keyword in Google Scholar (GS) and WoS may provide information on the relevance of the topic for management and research. A high number of GS and WoS hits combined with a high GS/WoS ratio may indicate a high relevance for management, while high numbers of GS and WoS hits combined with a relatively small ratio may indicate a high research relevance of the topic / keyword.

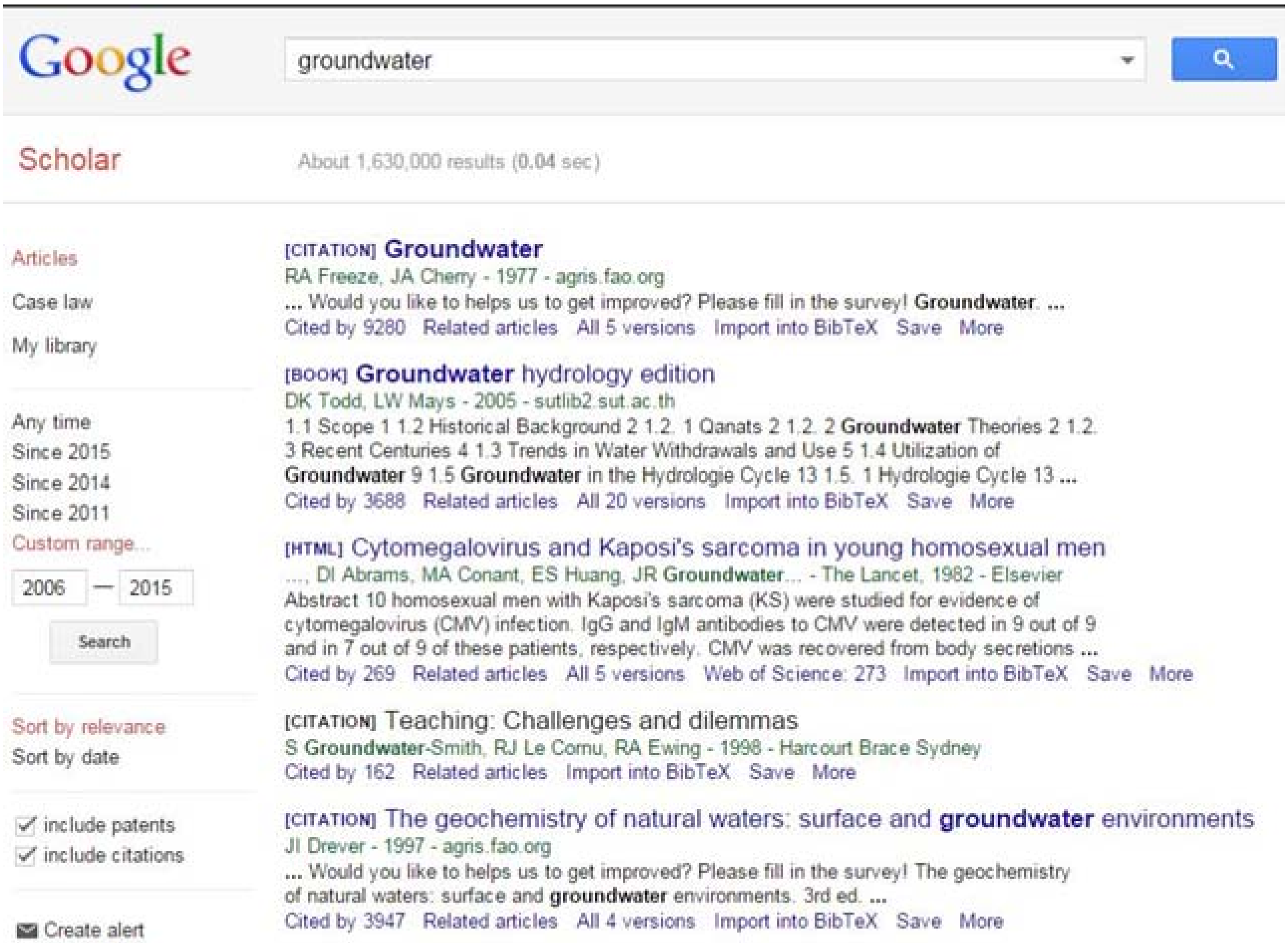

Fig. 3.2.1: Google Scholar interface.

In Web of Sciences the researches have been performed using the option “advanced search” (Fig. 3.2.2).

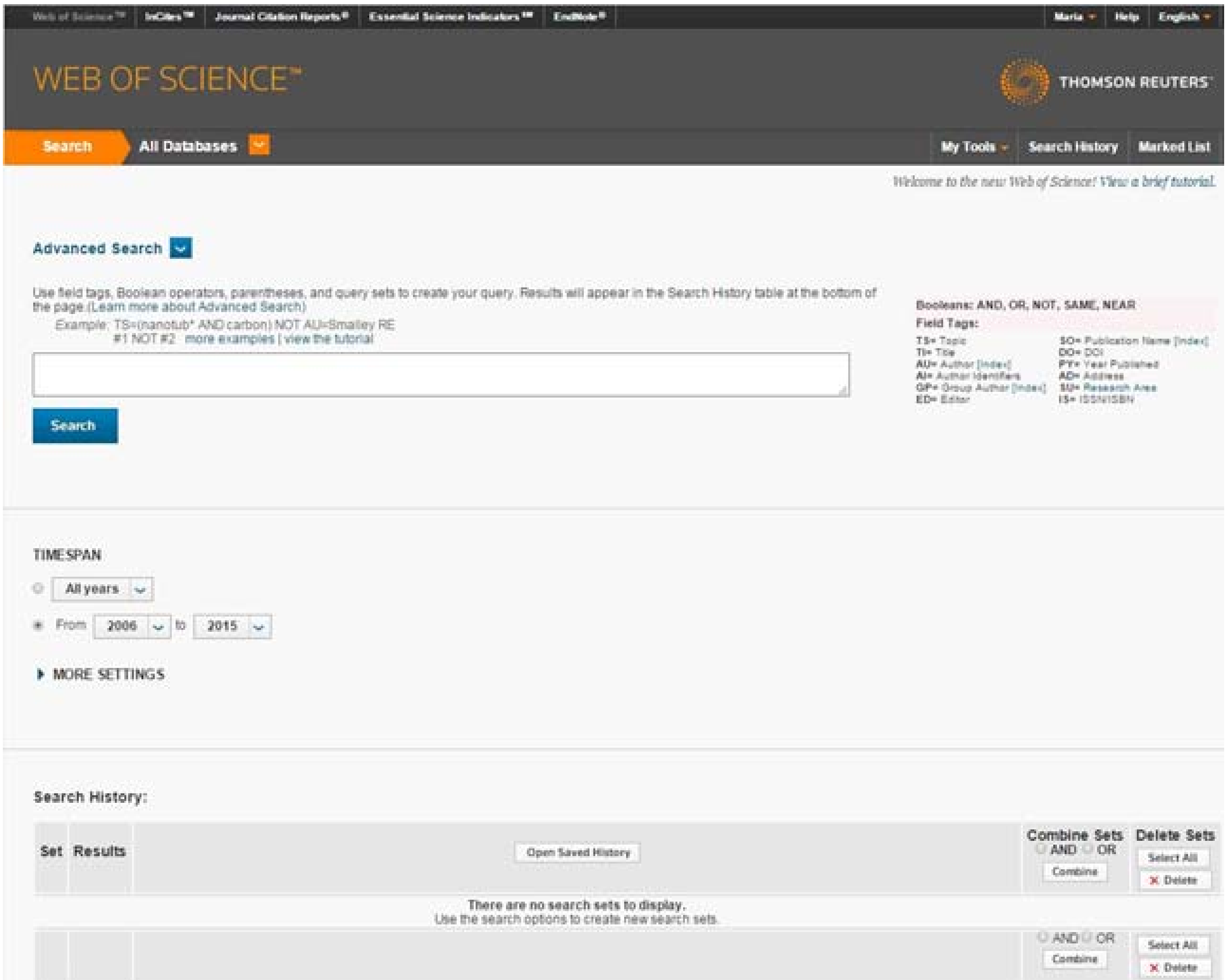

Fig. 3.2.2: Web of Sciences interface.

The reference period considered for the keyword search is 2006-2015. The boolean indices have been used to refine the research. Using the Field tag TS (=Topic) the search is performed searching the selected keywords in “abstract”, “keywords indication” and “title”. By using WoS it has been possible to geographically link the searches by inserting the name of the Member State (Country) as part of topic (TS), which results in keywords linked to the MS, e.g. ‘groundwater abstraction’ in ‘Belgium’. The other Field tag to make the search is AD, which indicates the “affiliation MS of author” this results e.g. in ‘groundwater abstraction’ performed by an author with research affiliation in ‘Belgium’.

In Tables 3.2.1a,b are the schemes of the methodology applied to search in WoS: AD (country of affiliation) have been added after that the research have been performed only for topic (TS). The number of hits using only the index “TS” has been indicated with the indicator “text”.

TS	Example
GW	<Groundwater>
GW AND Country	<Groundwater> AND <Belgium>
GW AND Keyword	<Groundwater> AND <Environment>
GW AND Keyword AND Country	<Groundwater> AND <Environment> AND <Belgium>

Table 3.2.1a. Search in WoS for keywords and country in text

TS AND AD	Example
GW	<Groundwater> AND AD=<Belgium>
GW AND Country AND AD=Country	<Groundwater> AND <Belgium> AND AD=<Belgium>
GW AND Keyword AND AD=Country	<Groundwater> AND <Environment> AND AD=<Belgium>

Table 3.2.1b.Search in WoS and author country of affiliation

Web of Sciences is a powerful instrument of research principally because it gives the possibility to have not only the number of results but also the Citation Report that includes different statistical indices: sum of the times cited, sum of the times cited without self-citations, citing articles, citing articles without self-citations, average citations per item, h-index and highest citations with the average citation per year.

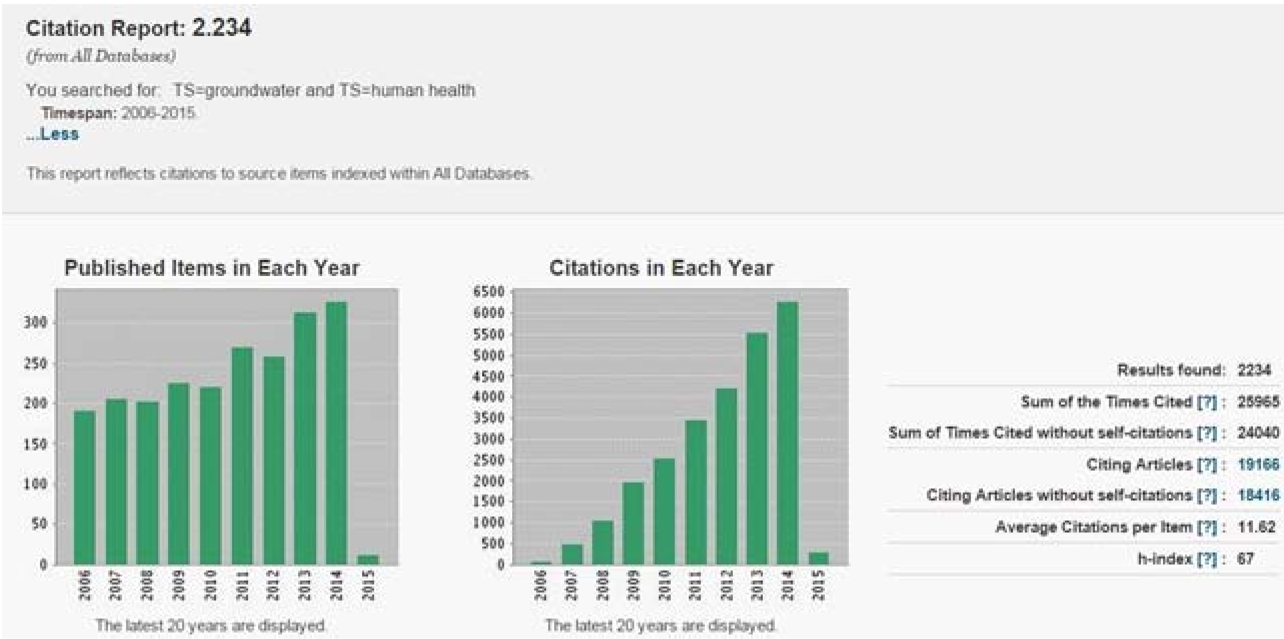

Fig. 3.2.3: Facilities for statistical analyses in Web of Sciences (example).

The Citation Report provides aggregate citation statistics for a set of search results. These statistics include (by Web of Sciences Help):

· The total number of results found (Results Found field);

· The total number of times all records have been cited (Sum of Times Cited field);

· The total number of citations to all results found in the results set minus any citation from articles in the set (Sum of Times Cited without Self-Citations field);

· The total number of citations to any of the items in the set of search results (Citing Articles field);

· The citing articles minus any article that appears in the set of search results (Citing Articles without Self-citations field);

· The average number of times a record has been cited (Average Citations per Item field);

· The total number of times a record has been cited for all years in the results set (Total column);

· The h-index count that is based on the list of publications ranked in descending order by the Times Cited count. A h-index of 67 as shown in the figure above means that there are 67 papers with more than 67 citations.

The statistical data considered for the identification of the main keywords have been, in addition to the results found, the sum of the times cited, citing articles, average citations per item, h-index and highest citations.

Web of Sciences provides also the possibility to use the tool EndNote that can be used to save selected papers and produce a bibliography.

3.3 SELECTED RESULTS OF KEYWORD SEARCHES

The analyses of data, collected by the use of Web of Science search engine, have been done by sorting and ranking the groundwater keywords from the WFD, GWD and Blueprint document. The sorting considered at this step is only for the data collected without considering the geographical aspect of the researches, i.e. the link of keyword to geographical location in abstract and keyword list or the national affiliation of author. The scope has been to identify and rank the relevant keywords as further elaborated below.

Sorting of keywords by (WoS):

· *Total number of papers in which the keyword appears*

· *Total citations of journals in which the keyword appears*

· *average citations of papers in which the keyword appears*

· *H-index*

· *Highest number of citations*

Sorting the keywords by different criteria the top ten change (Fig. 3.3.1 to Fig. 3.3.5).

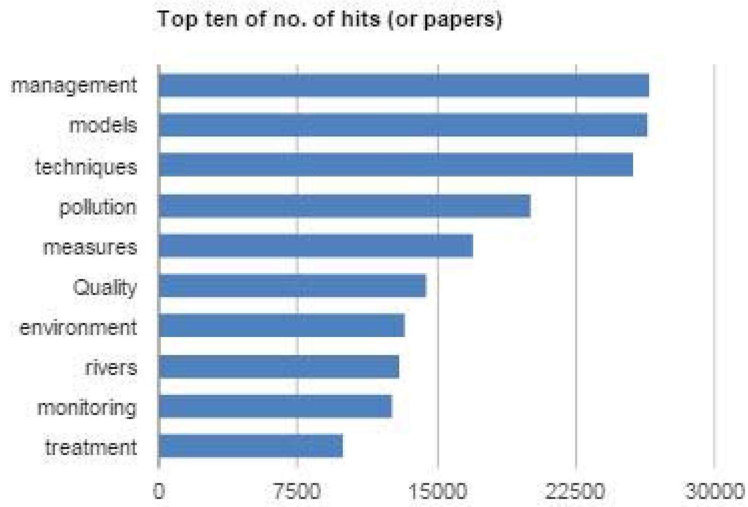

Figure 3.3.1: Top ten of keywords ranked by number of papers for TS=groundwater and keyword.

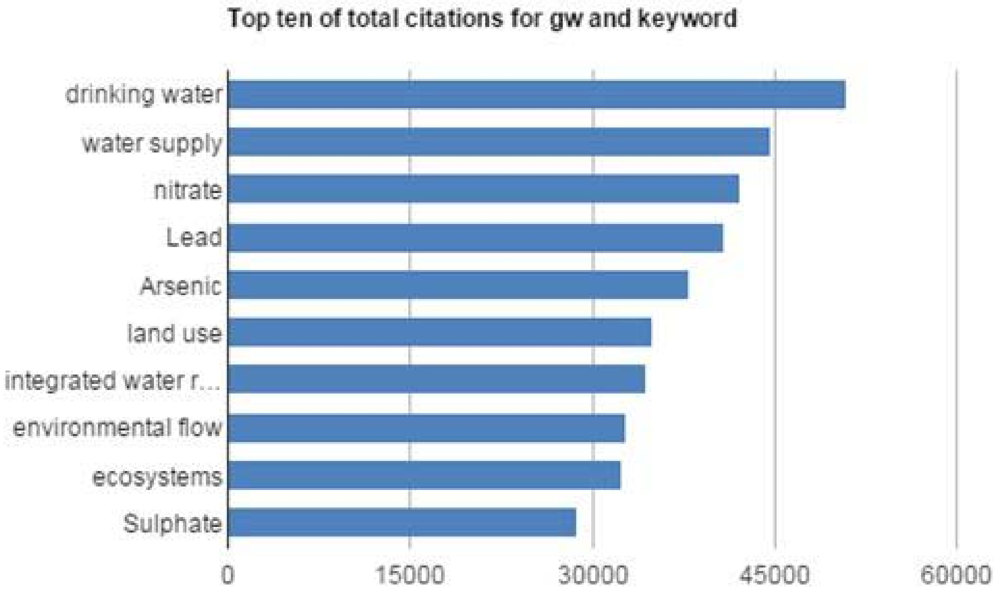

Figure 3.3.2: Top ten of keywords sorted by total citations for TS=groundwater and keyword.

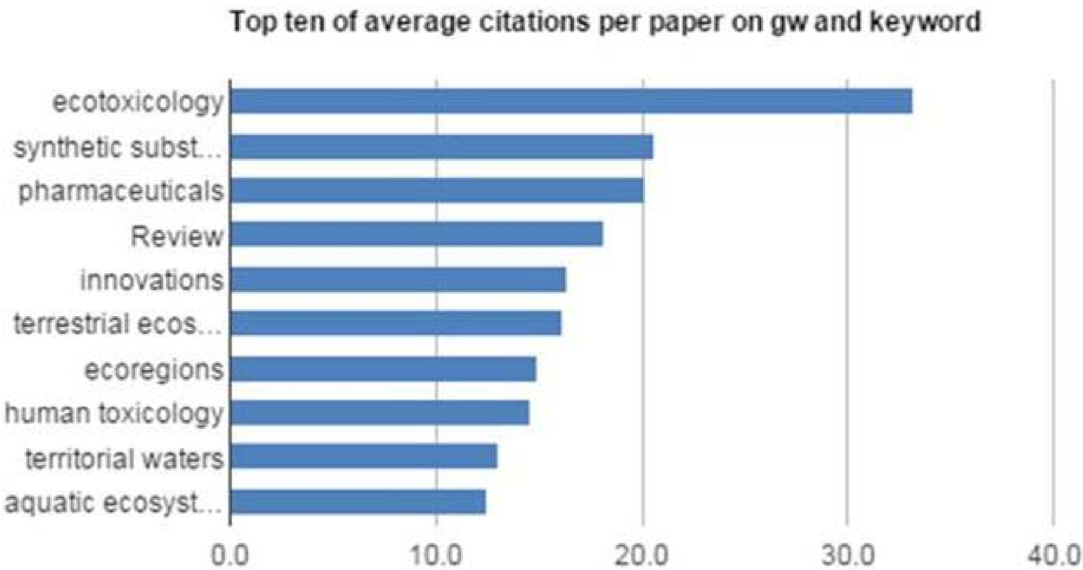

Figure 3.3.3: Top ten of keywords for all papers ranked by average citations for TS=groundwater and keyword.

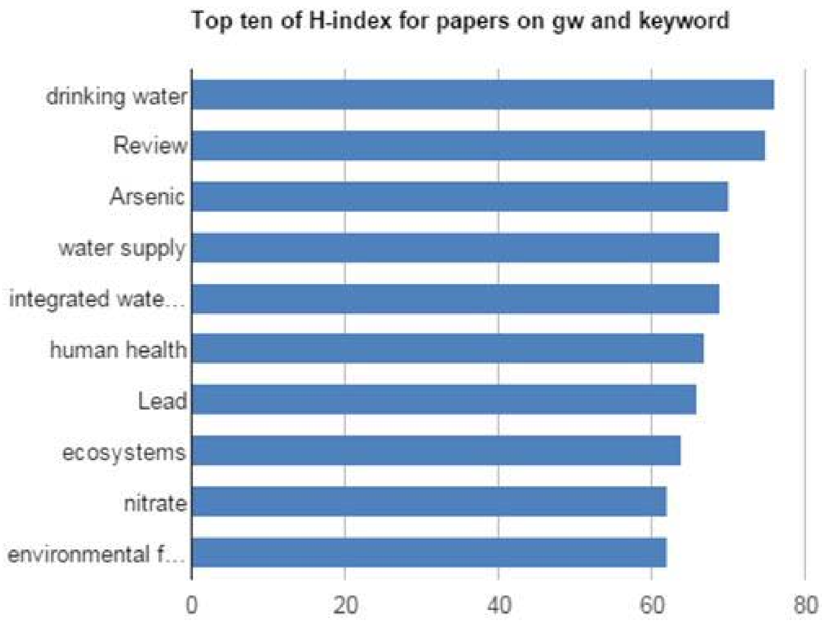

Figure 3.3.4: Top ten of keywords ranked by H-index for TS=groundwater and keyword.

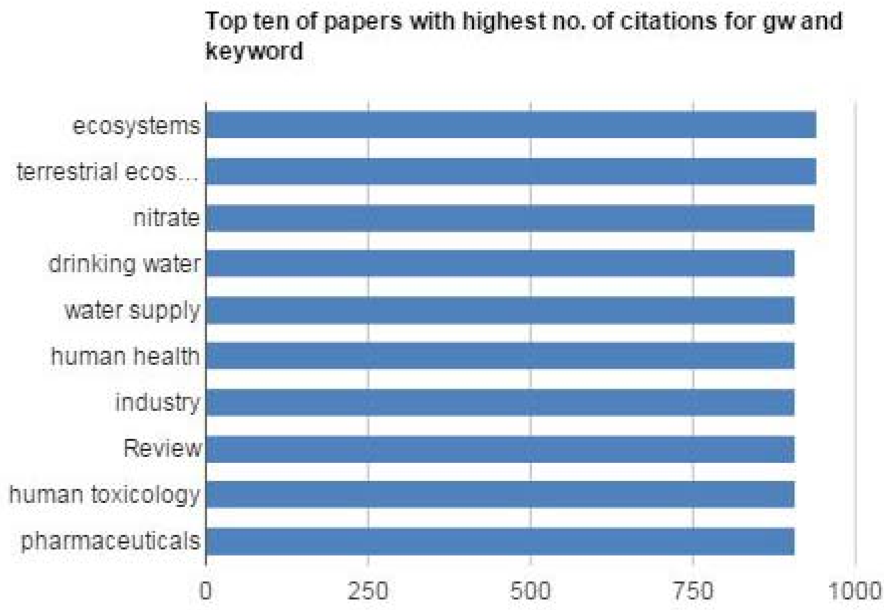

Figure 3.3.5: Top ten of keywords for all journals ranked by highest citation for TS=groundwater and keyword

Figure 3.3.1 to 3.3.5 all reflect the importance and relevance of the groundwater keyword in combination with other keywords which have been identified in the WFD, GWD and Blueprint documents. While Figure 3.3.1 provides the number of papers (hits), a numerical measure, in which the keywords appear, Figure 3.3.2 to 3.3.5 related to citations and impact show rather more qualitative measures for the importance and relevance of keywords in the scientific literature. It is remarkable that the ranking of keywords for the different criteria used is rather different which suggests that further inspection and comparison with other search engines may be needed.

The top ten of the main keywords searched using WoS change again sorting the keywords considering the geographical aspect of the papers. The main keywords identified considering the affiliation of the author (Fig. 3.3.6) are the same of those identified by considering the research for topic, the difference is only in the number of hits.

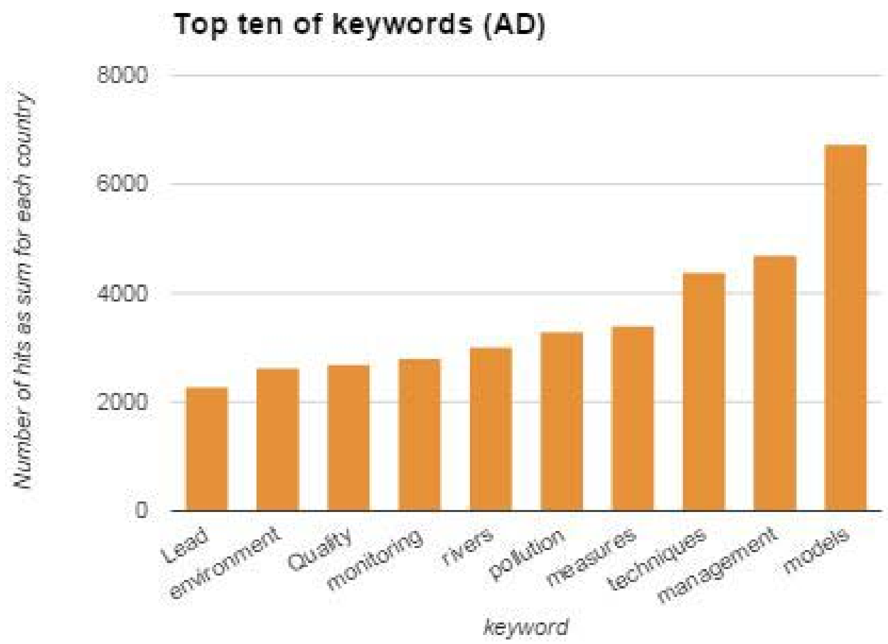

Figure 3.3.6: Top ten of keywords sorted by number of hits for TS=groundwater + keyword and AD=Country. The height of the columns is the sum of all results found for the same keyword for all MS countries included in the analysis.

Considering the data related to Google Scholar and the ratio between the number of hits found using this search engine and the number of papers found with the use of Web of Sciences another ranking emerges. This is an indication of the most important keywords related to groundwater considering not only peer reviewed papers but every kind of available research.

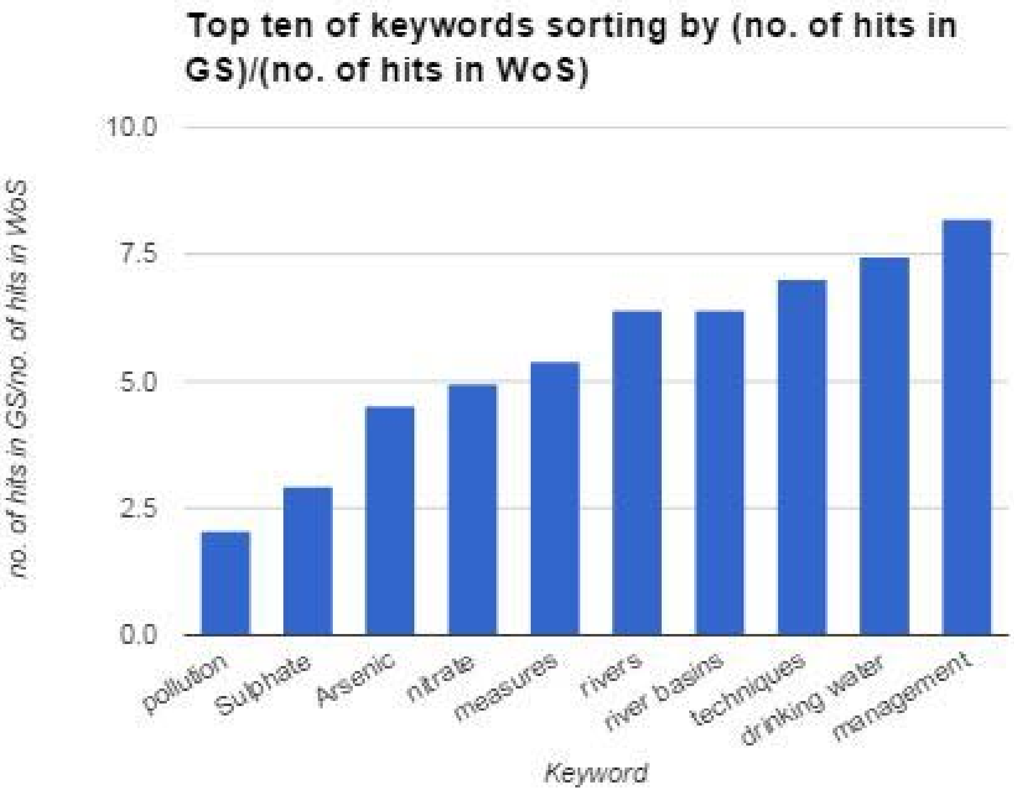

Figure 3.3.7: Top ten list sorting by no. of hits in GS/no. of hits in WoS. It indicates the keywords with the highest ratio between the results found using the two search engines and it is clear that GS always generates more hits than WoS

3.4 SELECTED RESULTS FOR SEARCHES RELATED TO MS COUNTRIES

The results visualized in diagrams showing the collected data and tables in which the keywords are organized in Topics, Themes and Activities (Chapter 5: Preliminary Harmonized Terminology and Classification).

In this paragraph selected results, of the methodology applied, are presented.

After the identification of relevant keywords from WFD, GWD and Blueprint documents and the analyses of the statistics resulting from the searches from existing knowledge (papers, books, chapters, reports, etc…) using Google Scholar; and Web of Sciences as research engine, different types of diagram (pie diagrams and histograms) have been used to synthesize the collected data. Diagrams are a good way in which large data amounts can be visualized in a simple way to be better understood and made accessible. The pie diagrams in figure 3.4.1 and 3.4.2 showed the contribution to the search on groundwater topic for 32 selected Countries, EU member states and some others, (Tab. 3.4.1) expressed as percentage of total number of hits, i.e number of papers.

Austria	Lithuania
Belgium	Luxembourg
Bulgaria	Malta
Croatia	Netherlands
Cyprus	Poland
Czech Republic	Portugal
Denmark	Romania
Estonia	Russia
Finland	Serbia
France	Slovakia
Germany	Slovenia
Greece	Spain
Hungary	Sweden
Ireland	Switzerland
Italy	Ukraine
Latvia	United Kingdom

Table 3.4.1: Countries included for the geographical distribution of the research

The percentage for each country has been calculated dividing the total number of hits for each country for the sum of all hits. The total number of hits for each country is the sum of the hits found searching TS=groundwater AND keyword and AD= Country (i.e. author institute affiliation) (Fig. 3.4.1) and TS=groundwater AND keyword AND Country (i.e. keywords for which the country appears in the searched journal abstract or keyword line) (Fig. 3.4.2).

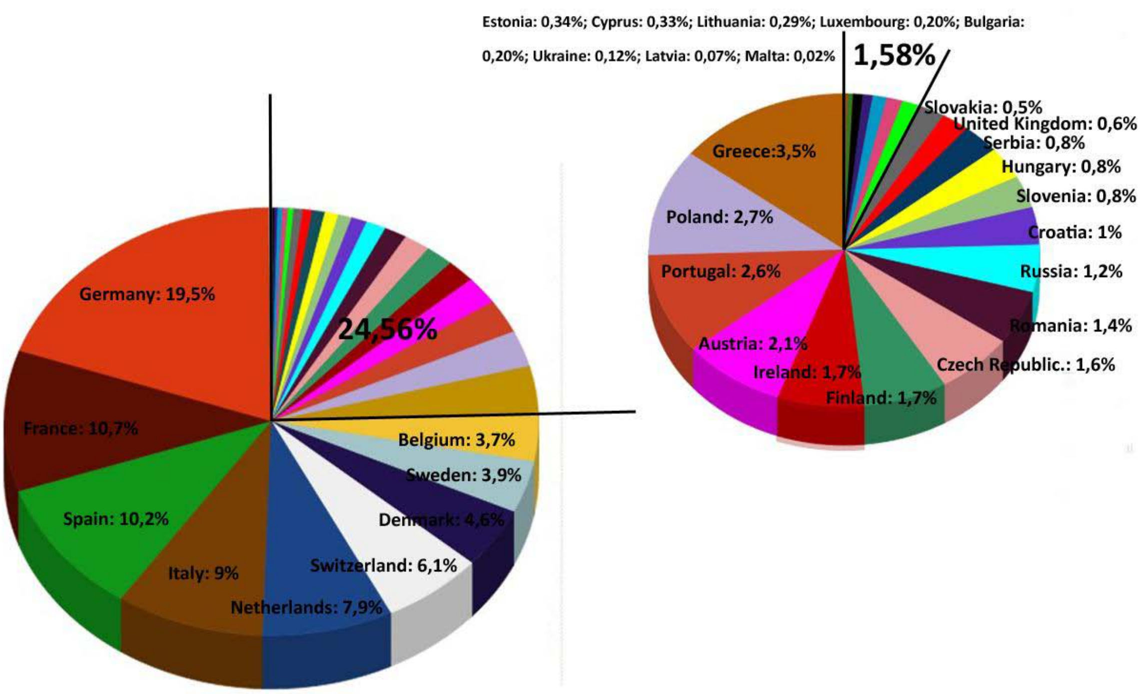

Figure 3.4.1: The pie diagram shows the percentage of Hits for TS=Groundwater AND Keyword and AD=Country.

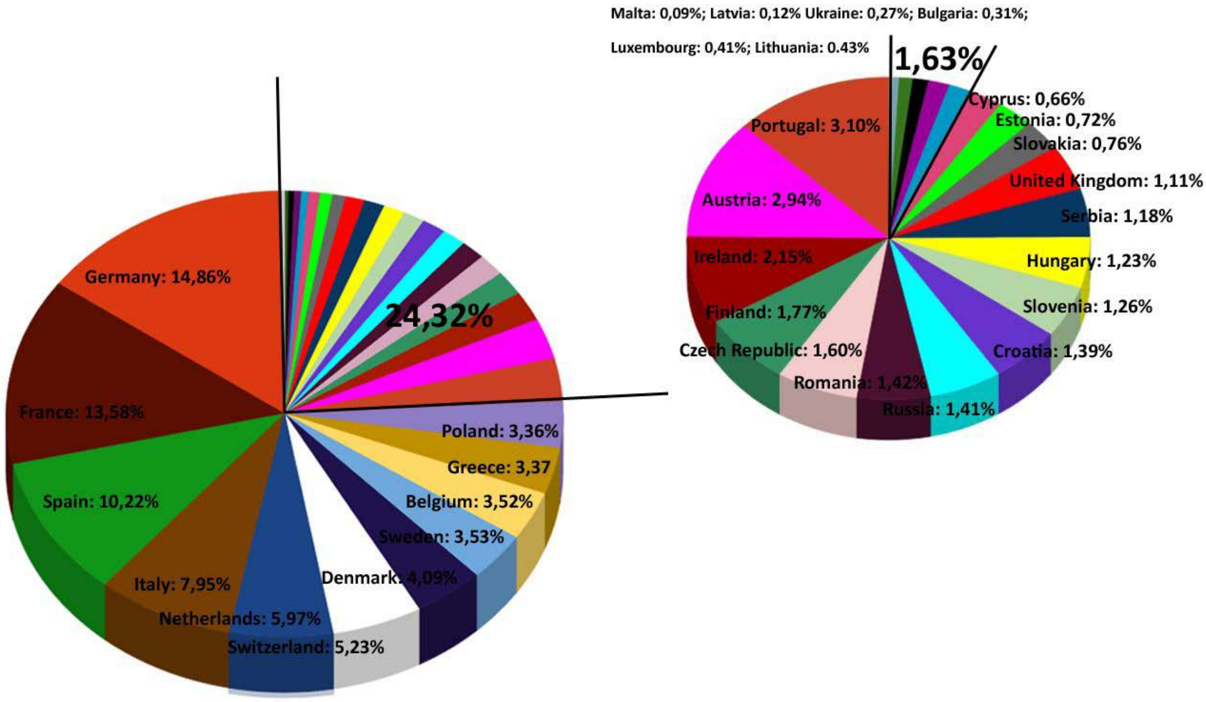

Figure 3.4.2.:The pie diagram shows the percentage of Hits for TS=Groundwater AND Keyword AND Country.

The data presented in the pie diagrams have been both reported also on a histogram (Fig. 3.4.3). Figure 3.4.3 shows both the knowledge associated with each country considering the name of the Country as part of a topic (Hits (text)) or as affiliation of the author's institute (Hits(AD)). Interestingly, for by far most countries the number of hits for groundwater, keyword and affiliation of author institute is (far) larger than for keyword and the name of the country linked to the keyword. This suggests that a large bulk of work done by researchers from the included countries is on research without geographic association, which seems plausible.

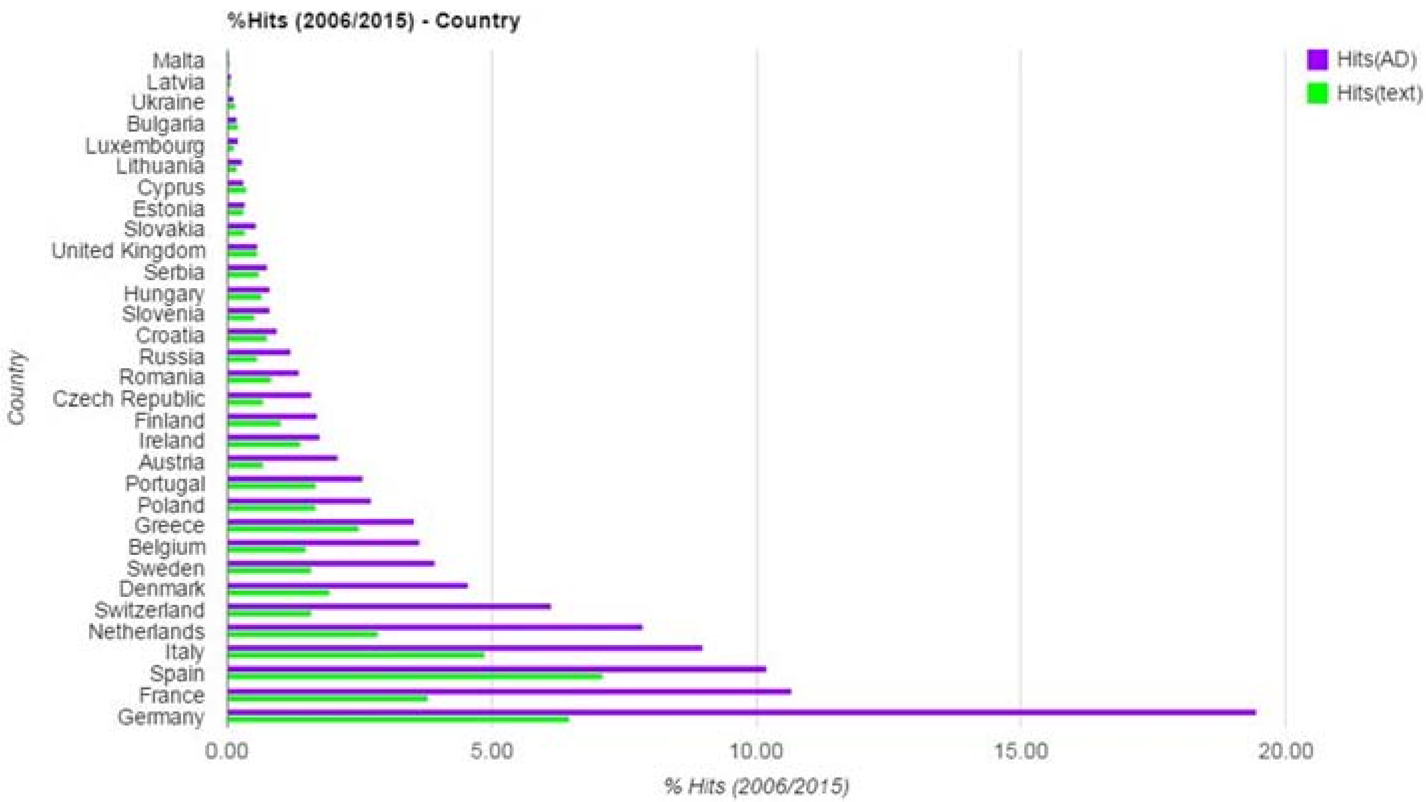

Figure 3.4.3: The histogram shows in green the percentage of Hits for TS=Groundwater Keyword Country and in violet the percentage of Hits for TS=Groundwater Keyword and AD=Country for the time period 2006/2015.

Developing this methodology for the identification of main keywords or terminology it is needed to consider which threshold value for the results should be taken in the choice of the main keywords? Clearly, the number of keywords is reduced with when the threshold value is set higher and vice versa. This requires more analysis to assess how keywords depend on the threshold value. It can be imagined that relevant keywords for the building of the Harmonized Terminology and Classification from other literature, e.g. reports, than scientific may unintentionally disappear when the threshold is set too high. Figures 3.4.4 and 3.4.5 show two different numbers of keyword changing the threshold value from 1000 (Fig. 3.4.4) to 500 (Fig. 3.4.5) hits to illustrate this.

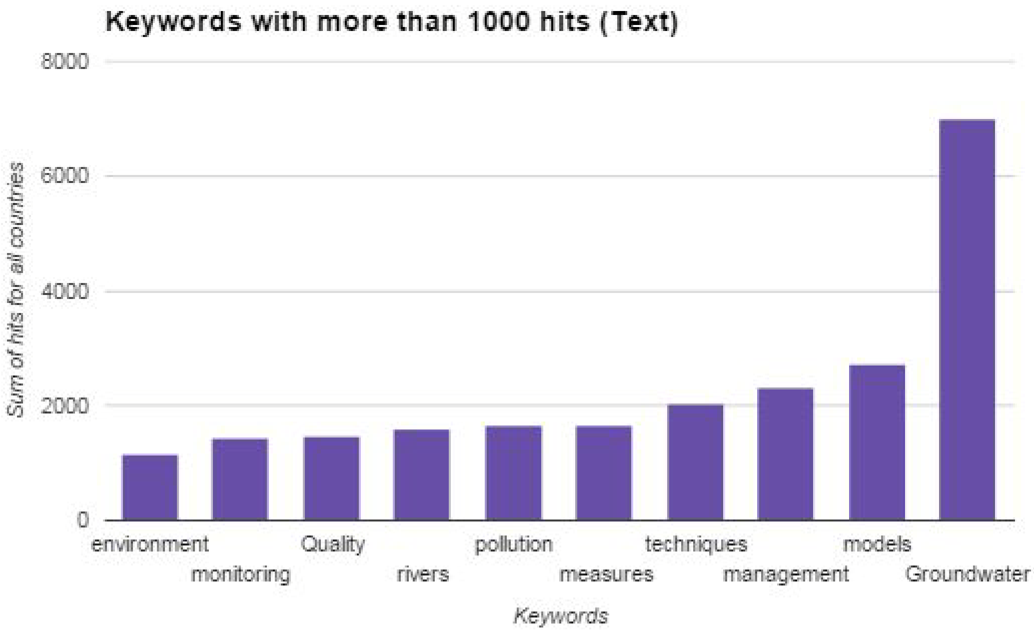

Figure 3.4.4: The histogram shows the main keywords considering 1000 as threshold value for the number oh hits.

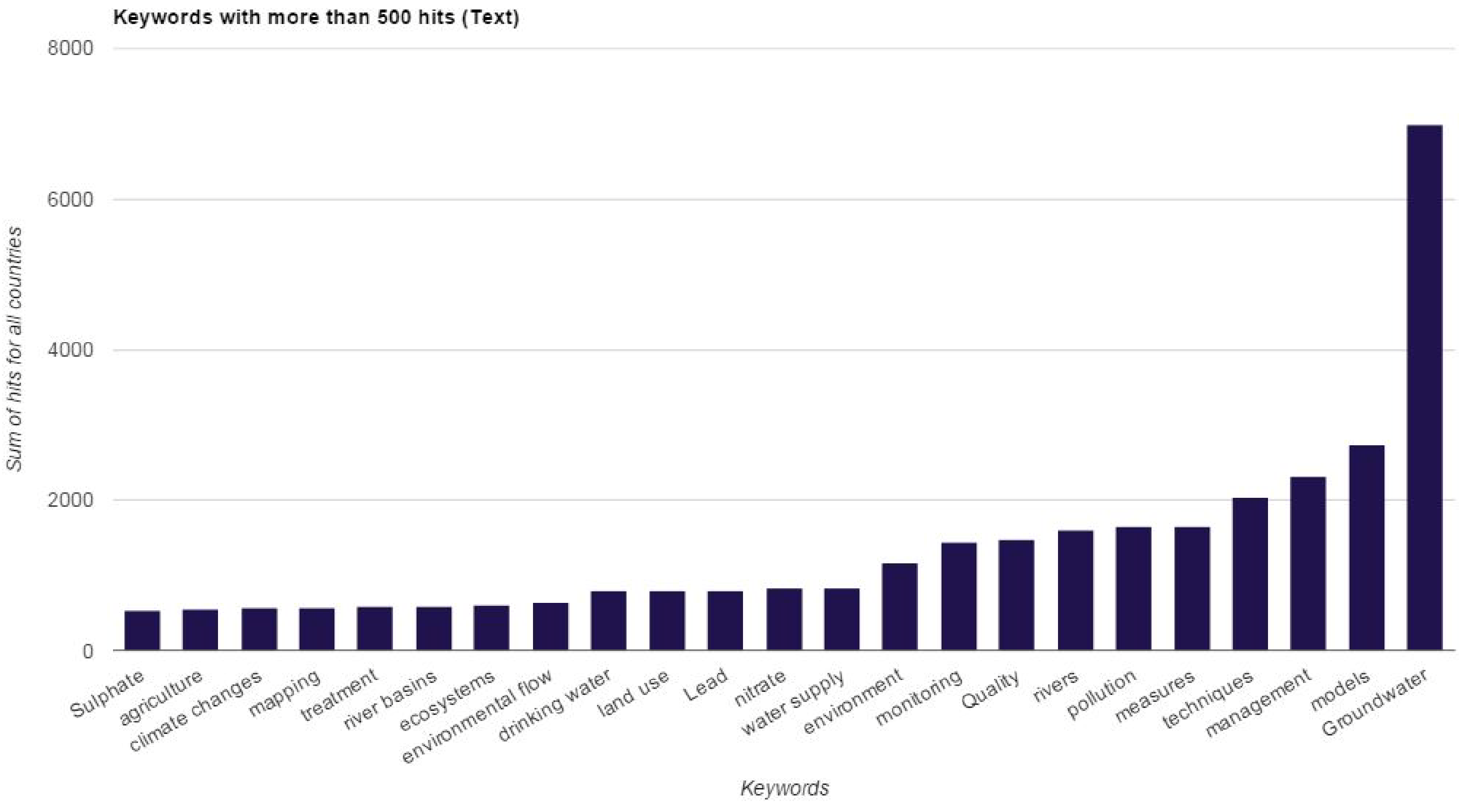

Figure 3.4.5: The histogram shows the main keywords considering 500 as threshold value for the number of hits.

4. KEYWORD OCCURRENCE IN INTERNATIONAL PEER-REVIEWED JOURNALS DEALING WITH GROUNDWATER

4.1 IDENTIFICATION OF RELEVANT KEYWORDS FROM SCIENTIFIC JOURNALS

In order to realize a common terminology both in policy documents, i.e. WFD, GWD and Blueprint (see chapter 3) and scientific literature, the identification of main keywords also has to take stock of existing knowledge, taking into consideration the keyword occurrence in the most important international peer-reviewed journals dealing with groundwater resources. In a similar way as was done for the policy documents in the previous chapter, the main keywords are identified analyzing the data from searches on relevant scientific papers. Clearly, there are many journals dealing with hydro-geology. The way to deal with this is to prepare a classification to identify high impact or most influential groundwater journals. Based on an international ranking comparison, the scientific journals included in the Table 4.1.1. have the highest impact factor ("reputation") among researchers dealing with hydro-geological research topics. The right column expresses the impact factors of the included journals. Among these journals, we can for instance highlight Hydro-geology Journal, Ground Water, Journal of Hydrology and Water Resources Research as well known examples.

Table 4.1.1: List of (ground)water science journals with Impact Factor (IF)

Scientific Journals	
ADVANCES IN WATER RESOURCES	2.8
CATENA	2.5
ECOHYDROLOGY	2.6
ENVIRONMENTAL EARTH SCIENCES	1.6
GROUND WATER	2.0
GROUNDWATER	2.0
GROUND WATER MONITORING AND REMEDIATION	1.3
HYDROGEOLOGY JOURNAL	1.7
HYDROLOGY AND EARTH SYSTEM SCIENCES	3.6
HYDROLOGICAL PROCESSES	2.7
HYDROLOGY RESEARCH	1.9
JOURNAL OF CONTAMINANT HYDROLOGY	2.7
JOURNAL OF HYDRAULIC RESEARCH	1.3
JOURNAL OF HYDROLOGIC ENGINEERING	1.6
JOURNAL OF HYDRO ENVIRONMENT RESEARCH	3.0
JOURNAL OF HYDROLOGY	2.7
SCIENCE OF THE TOTAL ENVIRONMENT	3.2
VADOSE ZONE JOURNAL	2.4
WATER AIR AND SOIL POLLUTION	1.7
WATER RESEARCH	5.3
WATER RESOURCES	0.4
WATER RESOURCES MANAGEMENT	2.5
WATER RESOURCES RESEARCH	3.7

As a next step, detailed searches were carried out to identify the most frequently used and most important keywords in these scientific journals focusing on the volumes of the last 10 years. It is worth noticing that the Hydrogeology Journal published by Springer provides authors with a complete list of the most commonly used keywords. Comparing this proposed list to the obtained search results, it turned out that the 81 most important keywords from the scientific journals with high impact factor are also in the keyword list of the Hydro-geology Journal. This is a very convincing match and check of the applied approach. Therefore the following keyword list (Table 4.1.2.) is accepted as a reference to characterize the relevant keywords from scientific journals.

The most common keywords in the selected internationally acknowledged (ISI) journals shown in table 4.1.1 are listed in Table 4.1.2.

Table 4.1.2: The list of the most common keywords extracted from scientific journals.

Agriculture	Heterogeneity
Alluvium aquifers	Hydraulic properties
Analytical solutions	Hydrochemical modeling
Aquifer	Hydrochemistry
Aquifer vulnerability	Hydrologic cycle
Aquitard	Infiltration
Arid regions	Island hydrology
Arsenic	Karst
Artesian waters	Laboratory experiments/measurements
Artificial recharge	Landfills
Assessment	Legislation
Bioremediation	Matrix diffusion
Carbonate rocks	Microbial processes
Chlorinated hydrocarbons	Mining
Climate change	Multiphase flow
Coastal aquifers	Nitrate
Compaction	Numerical modeling
Conceptual models	Organizations
Contamination	Paleohydrology
Crystalline rocks	Permeability
Developing countries	Radon
Drinking water	Rainfall
Earthquake	Remote sensing
Ecology	Runoff
Floodplain	Salinization
Floods	Saturation
Flow regime	Scale effects
Fracture rocks	Solute transport
Geographic information systems	Stable isotopes
Geomorphology	Subsidence
Geophysical methods	Tracer tests
Geostatistics	Unsaturated zone
Groundwater	Urban groundwater
Groundwater age	Volcanic aquifer
Groundwater flow	Vulnerability mapping
Groundwater hydraulics	Waste disposal
Groundwater management	Water budget
Groundwater monitoring	Water supply
Groundwater protection	Wetlands
Groundwater recharge	Yield
Health	

4.2 RESEARCH OF KEYWORDS USING WEB OF SCIENCES

For the search of the keywords, which are included in the Table 4.1.2. we used the Web of Science database. The detailed description of the search engine and database is summarized in Chapter 3.2. The research of the keywords has been performed for two time periods. The longer period is from 2006 to 2015 and for the search of most recent publications we used a shorter period (2013-2015). The searching of the keywords have been made by "advanced search" option, and using boolean operators (and, or etc.) and field tags (e.g. TS =topic, py=publication year etc.). The search for hits on the topics groundwater and pollution is therefore: ts=groundwater and ts=pollutants.

The Web of Science has an essential analysis tool: the citation report, that helps to measure research impact of a topic (keyword), which contains the number of results, sum of the times cited, number of citing articles, average citation per item and h-index. The definitions of the Citation Report's elements can be found in Chapter 3.2. Other tools in WoS are available and will be explored in the next step.

An example of the method of the searching in the selected journals included:

"TS=(groundwater) AND SO=(ADVANCES IN WATER RESOURCES OR CATENA OR ECOHYDROLOGY OR ENVIRONMENTAL EARTH SCIENCES OR GROUND WATER OR GROUNDWATER OR GROUND WATER MONITORING AND REMEDIATION OR HYDROGEOLOGY JOURNAL OR HYDROLOGY AND EARTH SYSTEM SCIENCES OR HYDROLOGICAL PROCESSES OR HYDROLOGY RESEARCH OR JOURNAL OF CONTAMINANT HYDROLOGY OR JOURNAL OF HYDRAULIC RESEARCH OR JOURNAL OF HYDROLOGIC ENGINEERING OR JOURNAL OF HYDRO ENVIRONMENT RESEARCH OR JOURNAL OF HYDROLOGY OR SCIENCE OF THE TOTAL ENVIRONMENT OR VADOSE ZONE JOURNAL OR WATER AIR AND SOIL POLLUTION OR WATER RESEARCH OR WATER RESOURCES OR WATER RESOURCES MANAGEMENT OR WATER RESOURCES RESEARCH)"

In the search of the keywords in scientific journals the search has not been included the geographical distribution of the results. The detailed investigation of the geographical distribution of the paper and authors will be carried out in the next phase of the research.

4.3 ANALYSES OF KEYWORDS CHARACTERISTICS

This chapter contains the evaluation and graphical presentation of the keyword search results for scientific journals by the use of Web of Science search engine. Two main types of analyses have been conducted:

1. We have sorted the keywords by the elements of the citation statistics. The bar chart shows the results of the ranking, the most important "top 10" keywords for two time periods can be found on the Figures 4.3.1-4.3.5.
2. We have performed trend analysis also for the results of the longer time period (2006-2015). The Figures 4.3.6-4.3.9 show the correlation between the number of hits and the elements of the citation statistics.

The last figure in this chapter (Figure 4.3.10) shows the relationship between the elements of citation statistics in 3D. The size of the "bubbles" is proportional to the value of h-index.
In case of Figure 4.3.1, the top 10 keywords are the same for both time periods, but the importance (number of hits) is changing. In order to improve comparability we determined the average number of hits (no of published papers) per year for the top 10 keywords in case of a longer and shorter search period; the difference has been summarized in Table 4.3.1. It can be inferred that the importance for every keywords is increased in the last 3 years. Some caution must be exercised in interpreting the data as recent keywords in journal may not have been cited due to the limited and recent time period. The average number of published papers per year for "climate change" has increased the most i.e. by 30%, indicating that there is an increasing interest in research related to groundwater and climate change. For "numerical modeling" this value is practically identical for both periods (0.4% changing).

When we ranked the keywords by the total citation (Figure 4.3.2.), the top 10 keywords are different in the time periods: the keyword "drinking water" appeared in the longer searching period (2006-2015), but in the recent years it has less priority. In the period 2013-2015 the 10th keyword is the "numerical modeling" so it may be inferred that the importance of this keyword has increased. The average number of total citation per year for the top 10 keywords can be found in Table 4.3.2. There is a significant change in the average number of total citations per year of the considered time periods. In recent years the values have decreased for all keywords with 74-85%. This tendency is similar for all parameters related to average citations per item (Figures 4.3.3-4.3.4-4.3.5.)

It can clearly be observed that between the number of hits vs. the total citation (Figure 4.3.6.) and the number of hits vs. the number of citing articles (Figure 4.3.7.) the correlation is linear. The h-index approaches a maximum value, with a logarithmic trend with respect to the number of hits with high coefficient of determination (R^2=0.87) (Figure 4.3.8.). Between the average citation per item vs. the number of hits there was no clear correlation (Figure 4.3.9.).

Table 4.3.1. The comparison of the average number of published /year for the top 10 keywords sorted by the number of hits in the WoS.

Keyword	**Av. num. of hits/year (2006-15)**	**Av. num. of hits/year (2013-15)**	**Difference [%]**
Groundwater	974.1	1083.3	10.1
Aquifer	646.2	671.7	3.8
Rainfall	631.2	663.3	4.8
Runoff	621.0	641.3	3.2
Assessment	599.4	775.7	22.7
Groundwater flow	510.1	546.3	6.6
Climate change	452.9	646.7	30.0
Contamination	381.5	427.7	10.8
Floods	365.9	412.7	11.3
Numerical modeling	365.5	367	0.4

Table 4.3.2. The comparison of the average number of hits/year for the top 10 keywords sorted by the total citation in the WoS

Keyword	Av. num. of hits/year (2006-15)	Av. num. of hits/year (2013-15)	Difference [%]
Aquifer	5859.3	1083.3	- 84.0
Assessment	7143	671.7	-76.3
Climate change	5425.9	663.3	-74.6
Contamination	4334.3	641.3	-82.6
Floods	4174.1	775.7	-82.0
Groundwater	9286.7	546.3	-81.6
Groundwater flow	4933.0	646.7	-82.9
Rainfall	7440.5	427.7	-84.7
Runoff	8068.6	412.7	-84.2
Drinking water	4113.5	-	-100
Numerical modeling	-	567.3	100

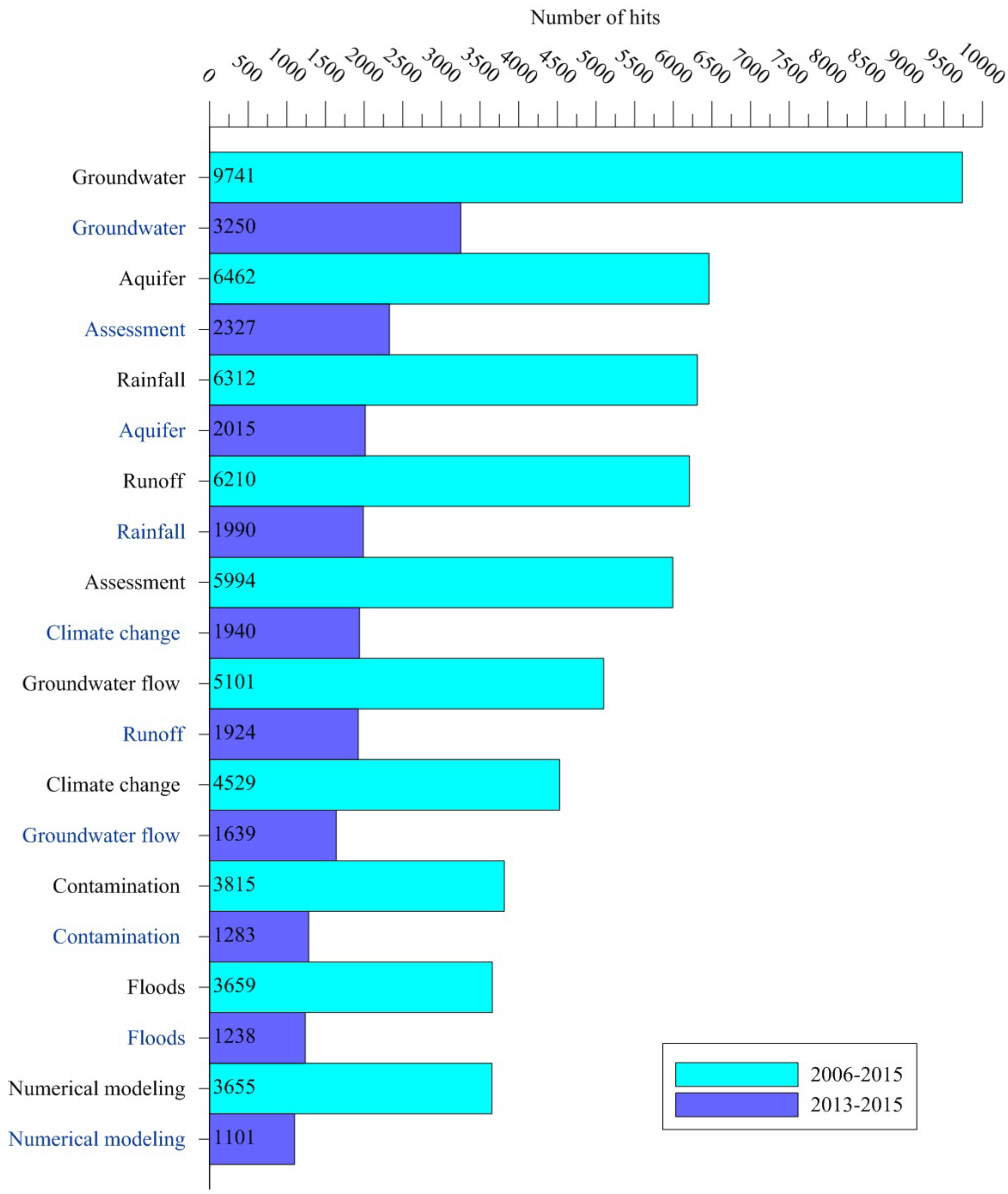

Figure 4.3.1: The top 10 keywords sorted by the number of hits in the WoS

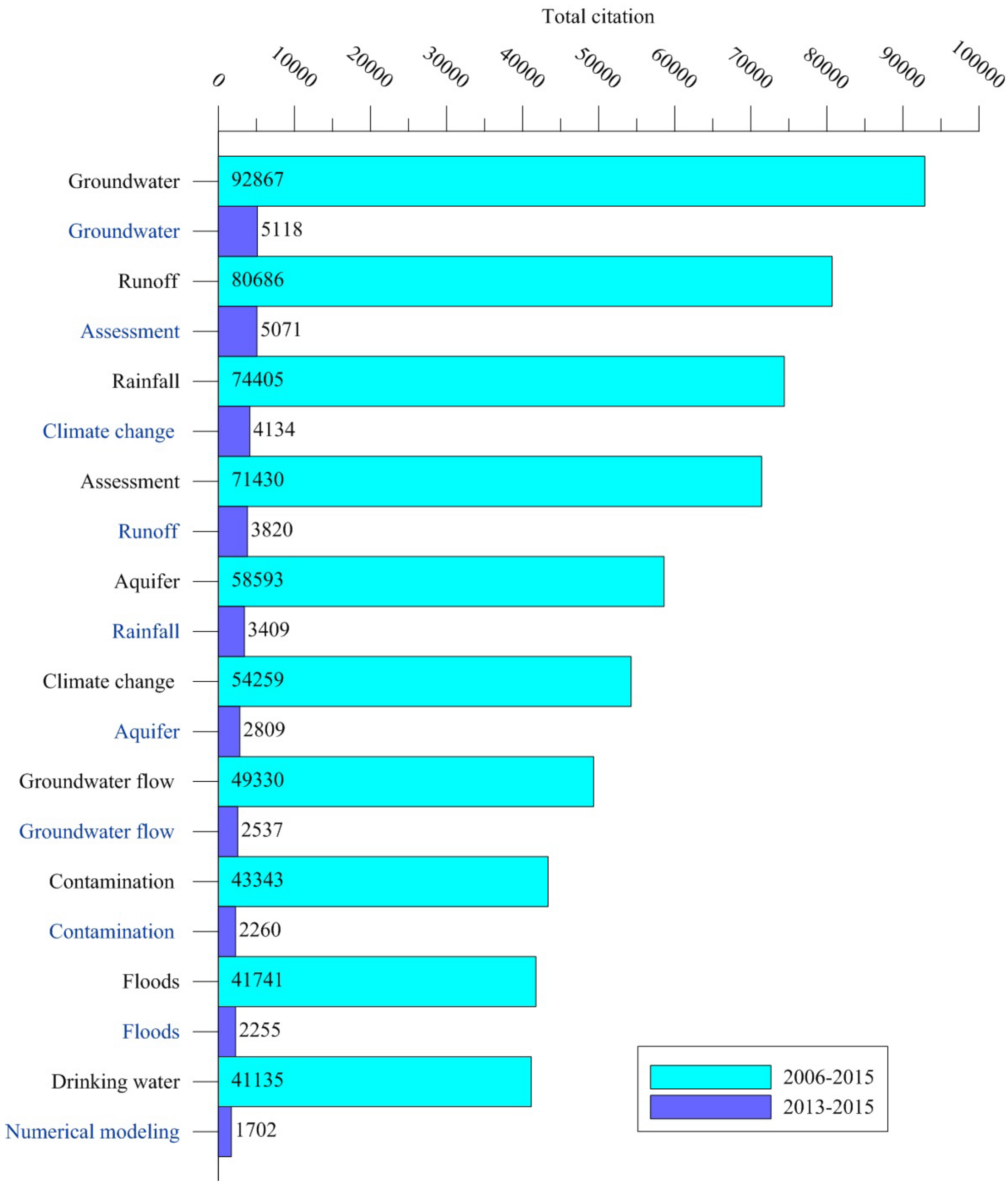

Figure 4.3.2: The top 10 keywords sorted by the number of total citation in WoS

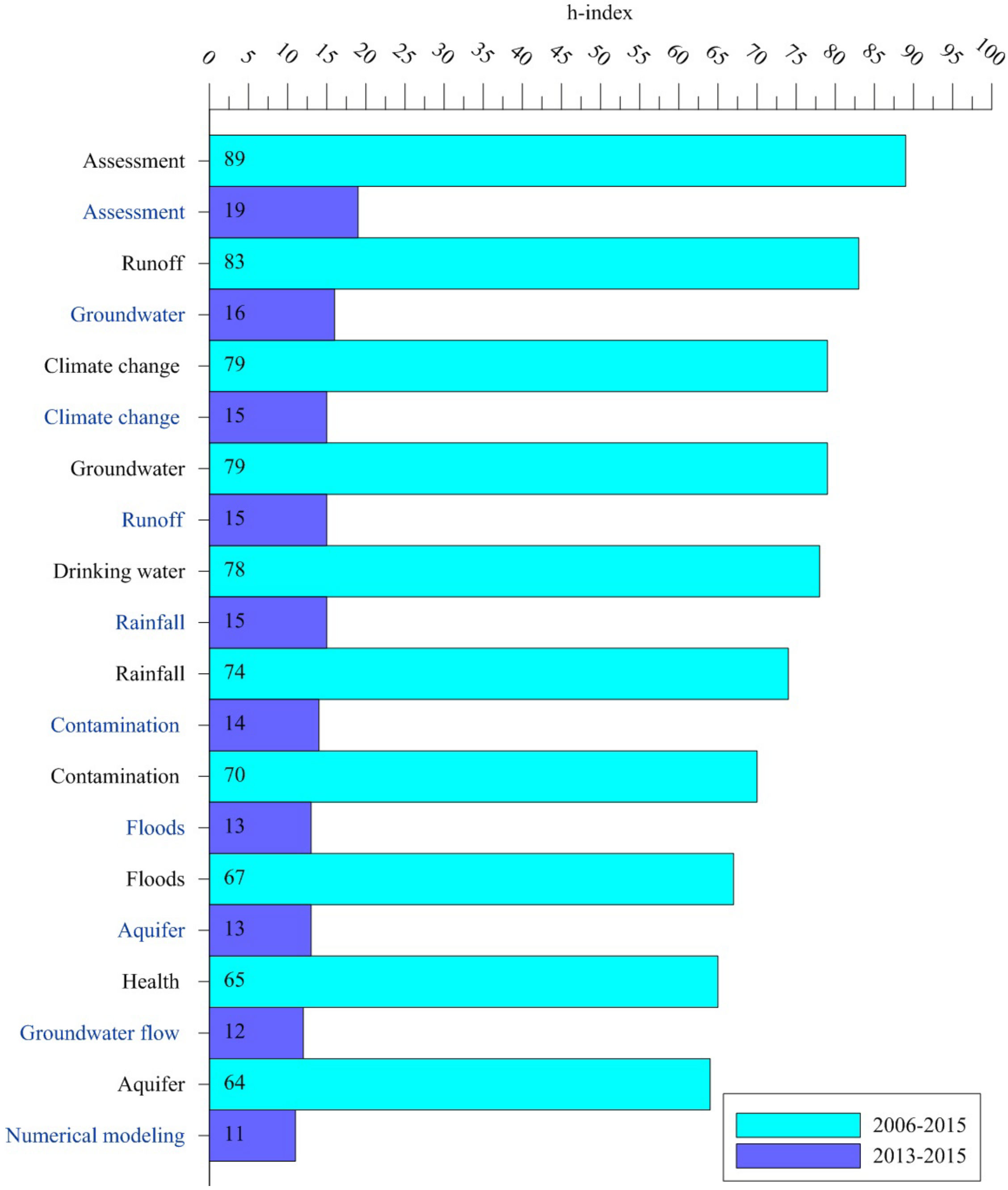

Figure 4.3.3: The top 10 keywords sorted by the h-index in the WoS

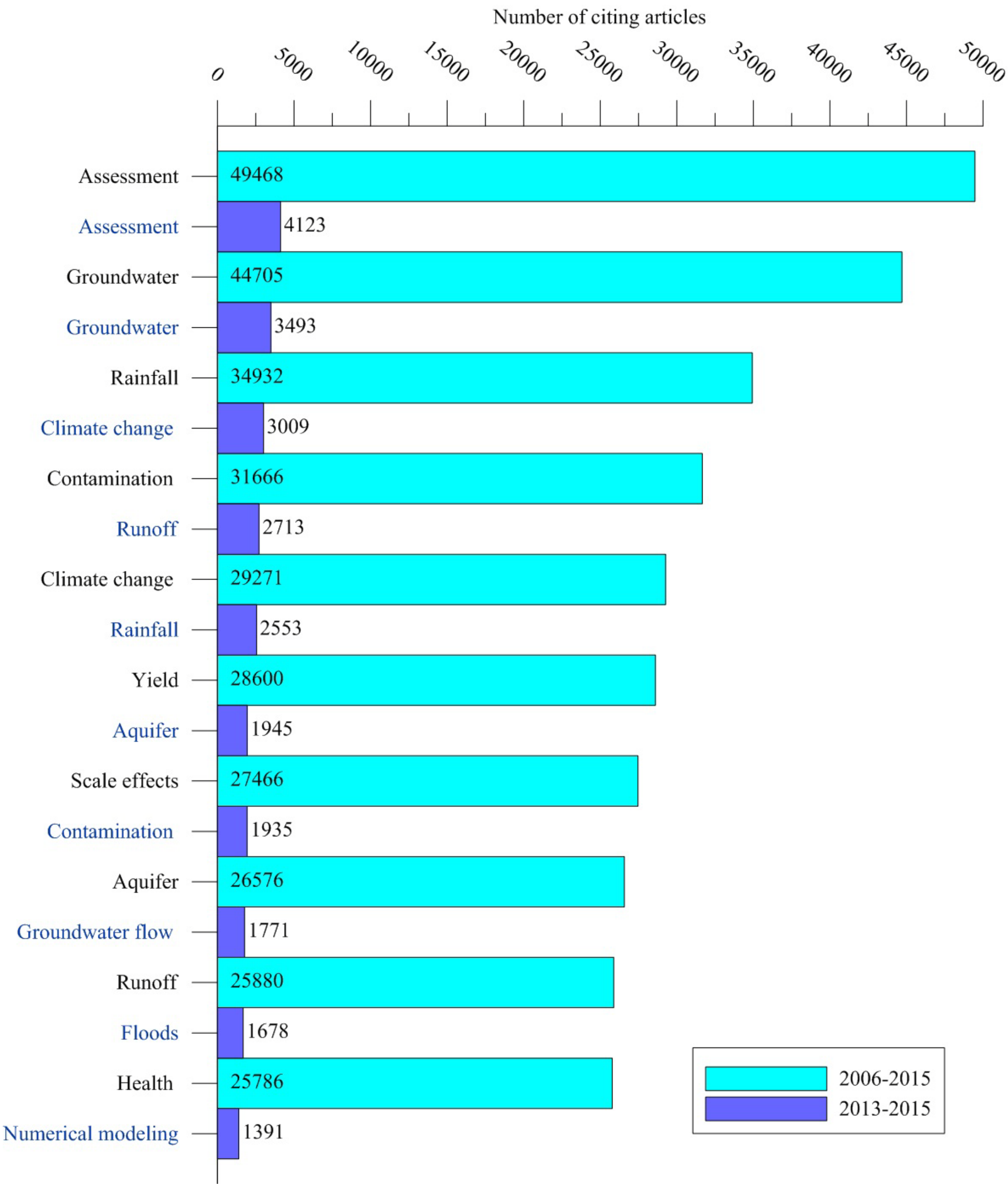

Figure 4.3.4: The top 10 keywords sorted by the number of citing articles in the WoS.

Figure 4.3.5: The top 10 keywords sorted by the average citation per item in the WoS.

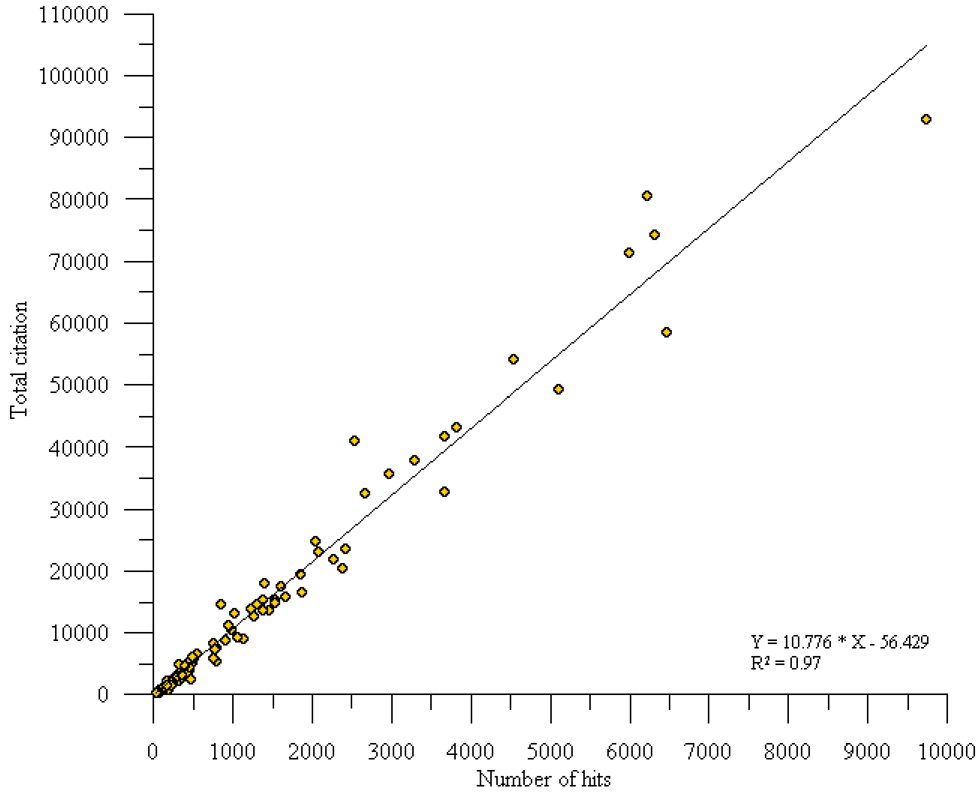

Figure 4.3.6: The correlation between the number of hits and the total citation.

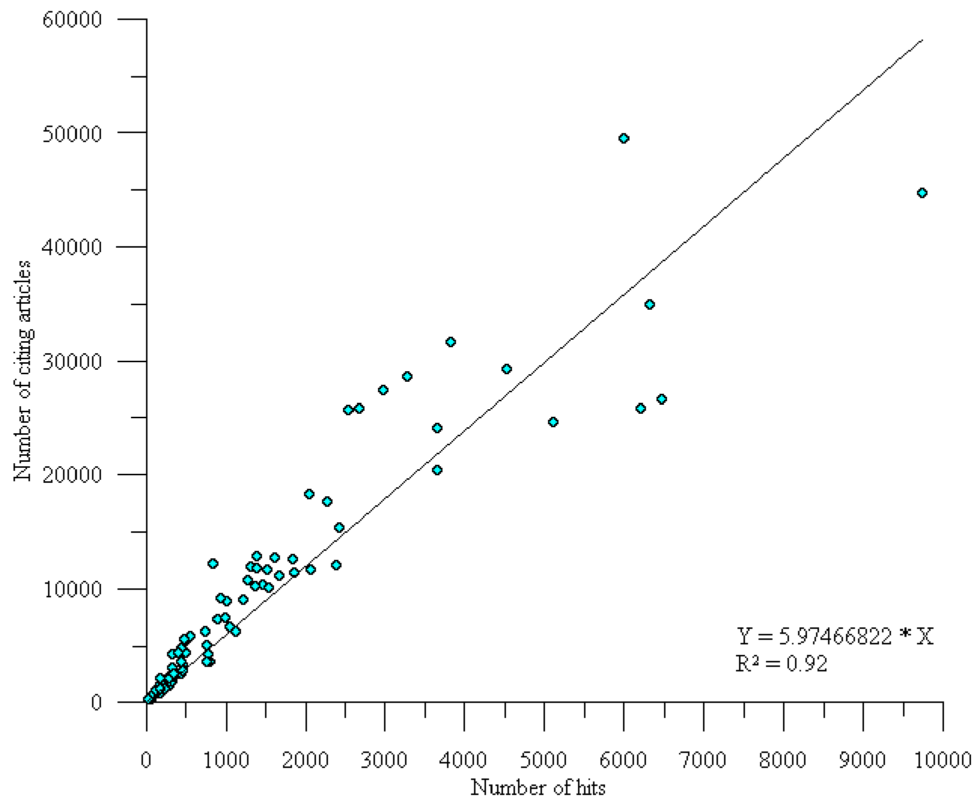

Figure 4.3.7. The correlation between the number of hits and the number of citing articles.

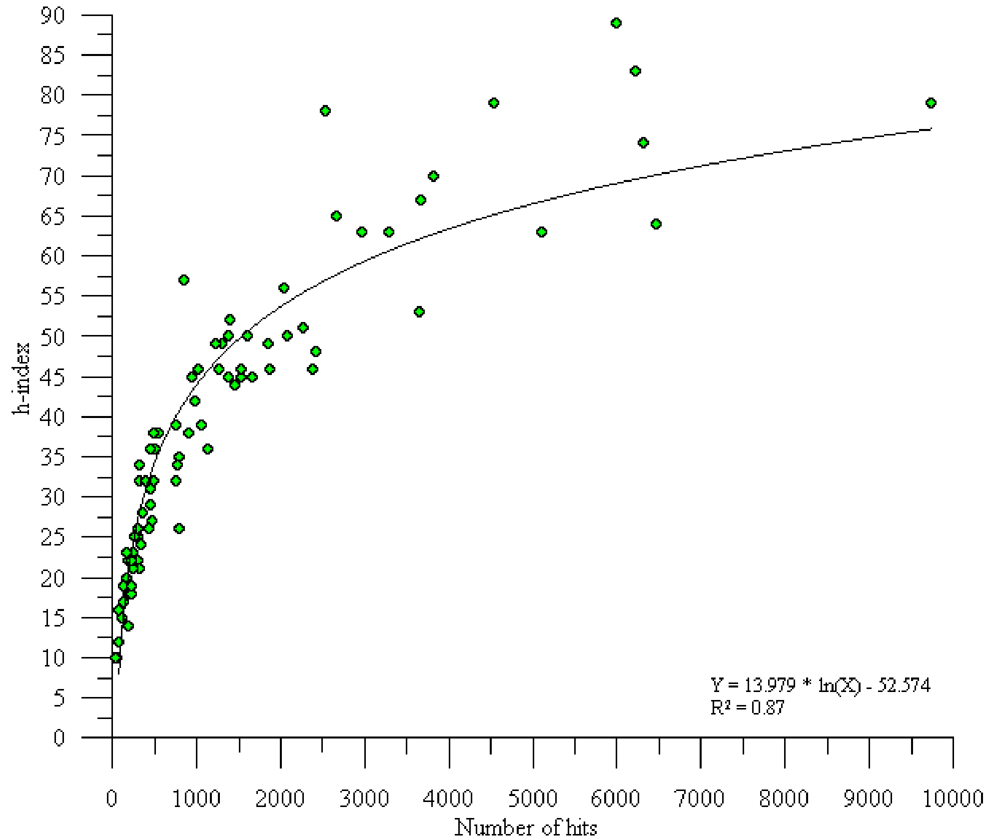

Figure 4.3.8. The correlation between the number of hits and the h-index.

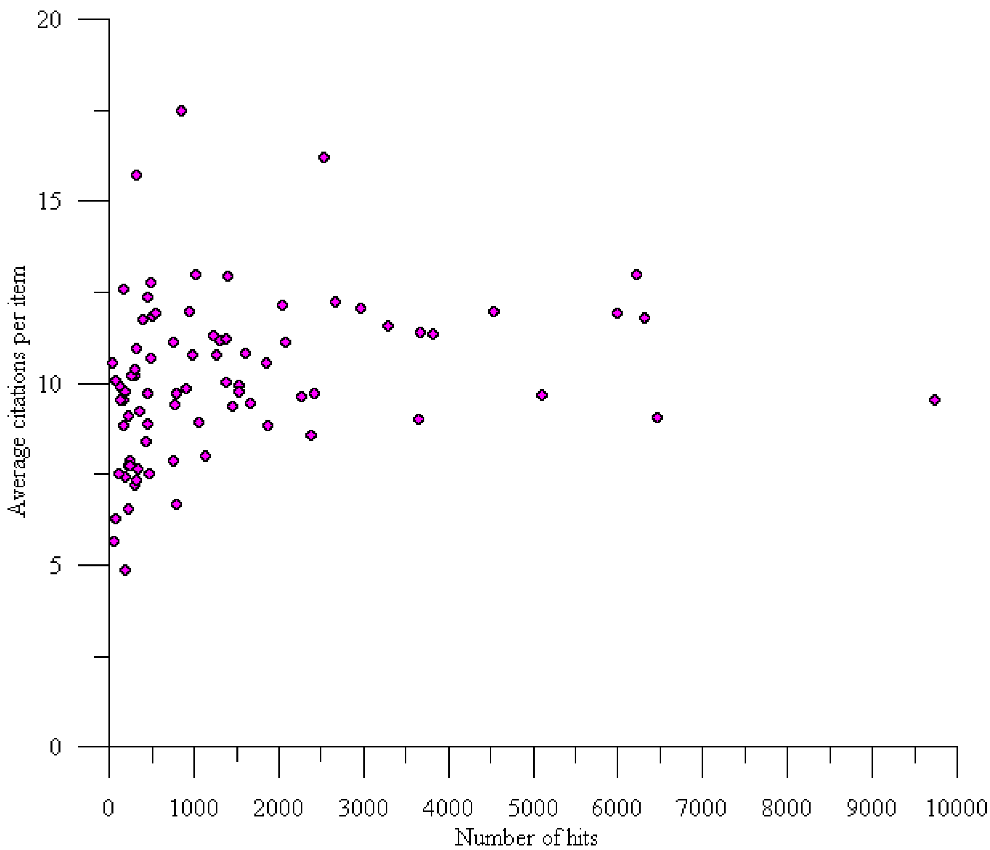

Figure 4.3.9. The correlation between the number of hits and the average citations per item.

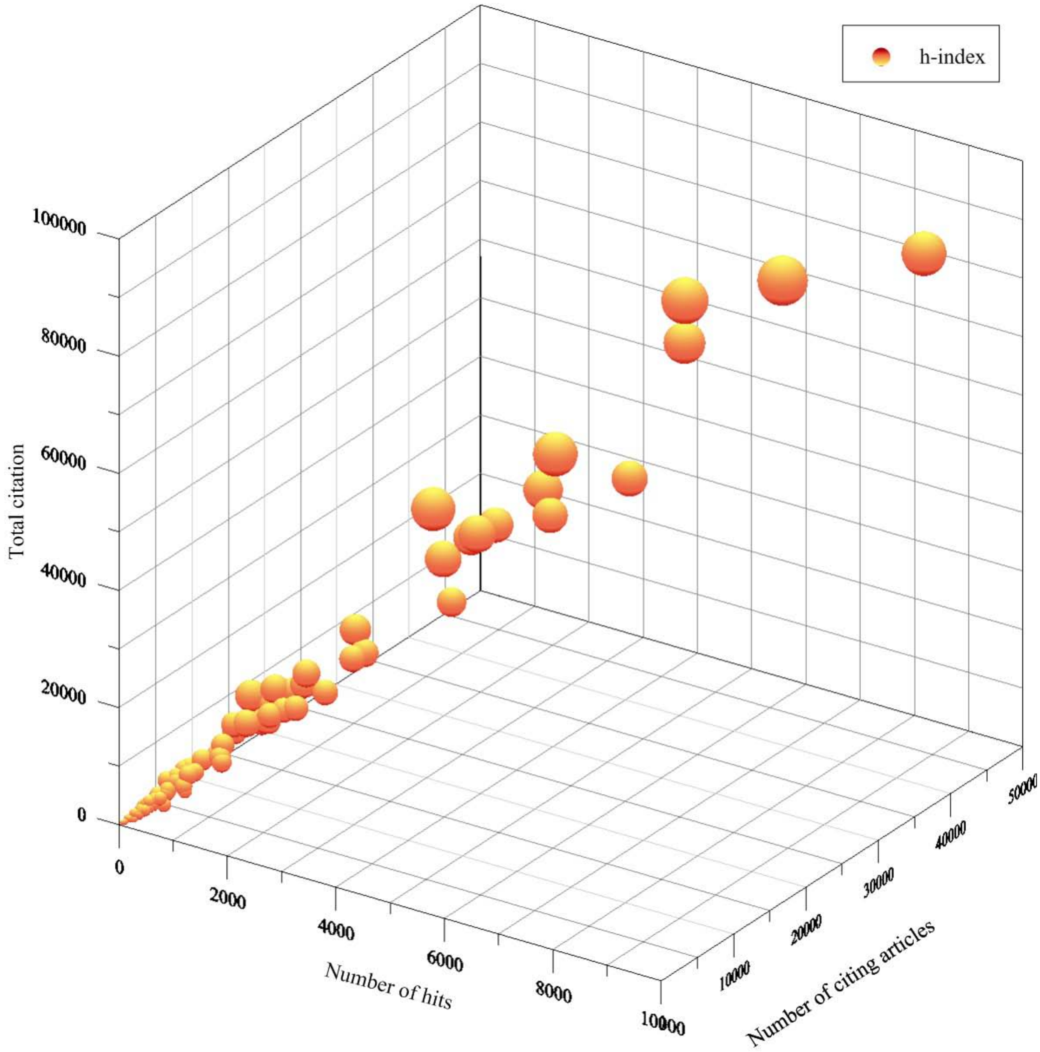

Figure 4.3.10: The 3D relationship between the elements of citation statistics in 3D.

5. PRELIMINARY HARMONIZED TERMINOLOGY AND CLASSIFICATION

The Harmonized Terminology is the knowledge infrastructure for taking stock of existing practical and scientific knowledge of hydrogeology related research and innovation activities. It is part of the Harmonized framework for reporting hydrogeology-related research and innovation (programmes, projects, results, agendas, etc) in Europe that includes both the HRC-SYS (Hydrogeological Research Classification System) and the EIGR (European Inventory of Groundwater Research).

The identification by expertise knowledge and the research of keywords (with analyses and results) are the two first steps in the building of the harmonized approach for classifying and reporting the European Groundwater R&D.

The only identification of keywords from EU Documents (WFD, GWD, Blueprint) (*Chapter 3: Groundwater keywords occurrence in international research databases*) and Scientific Journals (*Chapter 4: Keyword occurrence in international peer-reviewed journals dealing with groundwater*) cannot be considered sufficient to achieve the objective of a Harmonized Terminology, representing only the first steps, developed at this preliminary stage. It need recognize the pertinence of groundwater topics in the field of general water research and, for this scope, the identification of categories for an effective and useful classification is necessary.

The choice of categories has been done and three main categories are identified at the moment as follows: Topics, Themes and Activities. Each of these categories represent a different issue in groundwater researches (Fig.5.1): Topics (which can be also identified as Research Topics) includes branches of hydrogeological researches, while Themes express pressure and needs due to Societal and Environmental Challenges; finally, Activities (and related Actions) correspond with technical evaluations and policy decisions.

The interconnections between Topics, Themes and Activities need to be further developed, as fundamental step to achieve useful terminology and classification. Each category is directly related to the other two, and their relationships can be resumed by a two-dimensional approach, by three matrices, each one correlating two categories (Topics and Themes, Topics and Activities, Themes and Activities).

In a more comprehensive and complex way, the three main categories and their possible relationships in 3D can be evaluated using a Rubik's cube type of representation, presented in Fig. 5.1.

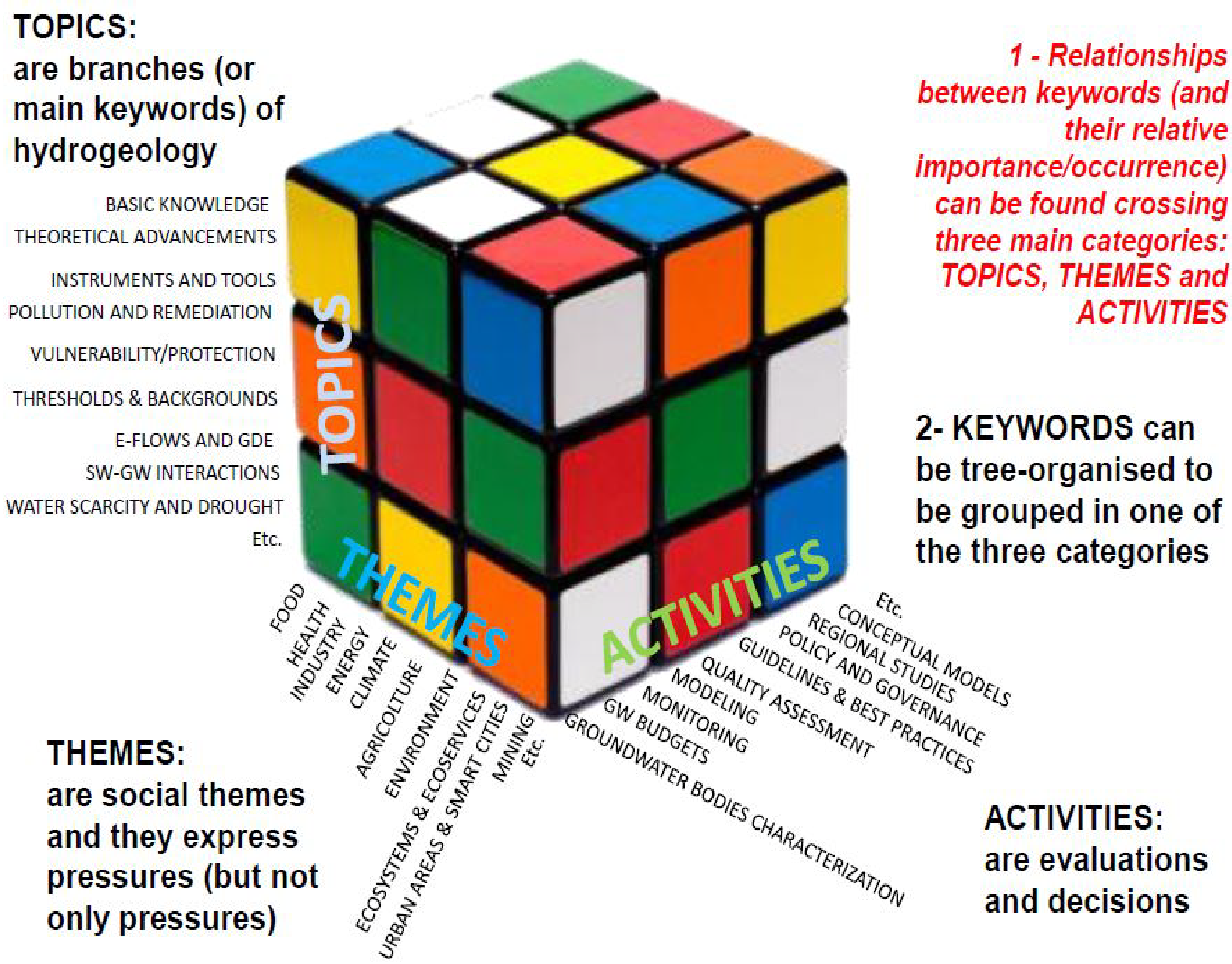

Figure 5.1: Rubik Cube for 3D representation of categories and their relationship.

Among the categories, the selected keywords can be arranged, identifying their proper allocation; this point will be developed during the following phase; at the moment, only a preliminary and incomplete list of "main keywords" is included under the three categories.

Taking into account that the keyword list is longer than the main keyword list, it is necessary to arrange the keywords in a hierarchical approach, grouping some of them under a main keyword; this can be done by a simple list, but also by a tree approach, introducing more than one level for keyword grouping; this refinement will be realized in final proposal for Harmonized Terminology and Classification (M6).

In addition, the two lists of keywords are different to some extent because they are the result of different points of departure. The list derived from the EU Directives (WFD and GWD) and Documents (Blueprint Document) has been produced by the subjective opinion of the experts considering the key issues of these documents. The list of keywords by Scientific Journals is the result of what is considered of scientific value by the scientific community, topics that address gaps in our knowledge to be addressed for the sake of advancement of science. In the present initial proposal for the identification of Harmonized Terminology and Classification, the two list are considered separately but they will be compared and merged in the final proposal for Harmonized Terminology and Classification (M6). Some keywords may be deleted and/or added accounting for the input of the JPE (Joint Panel of Experts).

The relevant Keywords are not presented in this chapter using the alphabetical order (Tab.5.1 and Tab 5.2) as in the previous chapters (Tab. 3.1.1 and Tab 4.1.2) but they are preliminary grouped considering the three main categories (Topic, Themes and Activities) identified to achieve the scope described above.

In Table 5.1 and 5.2 there are the two list of keywords. The list in Table 5.1 is that in which are reported the keywords by EU Directives (WFD and GWD) and Documents (Blueprint Document); the list in table 5.2 is by Scientific Journals.

The different colors and color tones have a specific meaning: the dark colors (dark blue, dark violet and dark orange) indicate the possible main groups inside the three identified categories (Topics, Themes and Activities) while the light colors indicate the keywords that can be contained in the main groups. This is a sub-grouping process.

Tables are a good way to show in 2D form the same concepts expressed in 3D by Rubik Cube in figure 5.1. The 3D scheme used to represent categories and their relationships is not intuitive for end-users and then a two-dimensional representation can be a way to facilitate the understanding and the exploitation of the developed methodology.

It is underlined that in Table 5.1 there is in Topics category a group including e-flow, ecological flow, environmental flow and dependent ecosystems. The first three words have the same meaning, all have been searched because the total number of hits is the sum of the numbers found for all the three words. The number of hits found by WoS related to each of the three keywords gives information about the favorite terminology in search field. The same concept has to be apply for the words overuse and over-use in Activities category inside management group.

The problem of synonyms, but also that one related to words having more than one meaning (e.g. Lead) manifested during the developing of the initial proposal for Harmonized Terminology and Classification and it´ll be solved in the final proposal.

Table 5.1: List of keywords from WFD, GWD and Blueprint Document and their grouping.

TOPICS				THEMES		ACTIVITIES	
rivers	13021	status	1327	Climate		characterisati	2092
river basins	2864	biological status	87	climate changes	2537		
transboundary	114	ecological status	160	ecoregions	14	management	26499
		quantitative status	45	hydrological cycle	406	integrated ma	1227
marine waters	1040	abstraction	557			integrated wa	595
coastal waters	2596	extraction	2219	**Ecosystems**	5648	land use	7031
territorial waters	21	chemical status	364	aquatic ecosystems	519	over-use	13
transitional waters	86	Natural background	302	ecotoxicology	41	overuse	54
salt water	437	threshold	738	stygofauna	60	sustainable w	1198
		Ammonium	905	terrestrial ecosystems	529		
groundwater bodies	1501	Arsenic	6858			measures	16947
water table decline	269	Cadmium	682	environment	13333	mitigation	497
land subsidence	384	chloride	2603			protection	1664
surface water interac	1710	Lead Pb	622	Health			
		Mercury	346	human health	2234	policy	1162
wetlands	1743	nitrate	9313	human toxicology	653	Groundwater	430
		Sulphate	5794			sustainable	1742
salinity	2480	trends	2210	Food		Water Framew	298
electrical conductivit	1198			farming		Lead	8357
intrusions	1302	ecological flows	412	agriculture	5893		
		e-flows	7	industry	1836	techniques	25622
hazards	1016	environmental flow	6183			innovations	63
indicators	1805	dependent ecosyste	281	tourism	84	mapping	2460
						models	26406
vulnerability	976	Hydrogeological cyc	58	Urban areas		monitoring	12625
				drinking water	9918	treatment	10048
deterioration	413	**Quality**	14454	storage	2682		
		Quantity	1278	water services	510	Rewies	1515
pollution	20122			water supply	7662		
pesticides	1464	droughts	1012				
pharmaceuticals	549	scarcity	427	Energy			
synthetic substance	48	floods	1699	energy production	402		
Tetrachloroethylene	192			shale gas	113		
Trichloroethylene	657						

Table 5.2: List of keywords from Scientific Journals and their grouping.

TOPICS		THEMES		ACTIVITIES	
GW bodies		***Agriculture***	1308	***Quality assessment***	
Alluvium aquifers	58	***Climate***		Laboratory experiments	1377
Aquifer	6462	Arid regions	898	Hydrochemistry	468
Aquitard	192	Climate change	4529	Vulnerability mapping	173
Carbonate rocks	321	Hydrologic cycle	320	***Monitoring***	
Artesian waters	66	Infiltration	2425	Groundwater monitoring	1455
Flow regime	1264	***Health***	2665	***Modeling***	
Crystalline rocks	225	Drinking water	2538	Analytical solutions	1127
Fracture rocks	793	***Urban areas***		Hydrochemical modeling	250
Geomorphology	320	Artificial recharge	241	Numerical modeling	3655
Groundwater	9741	Developing countries	498	Scale effects	2972
Groundwater flow	5101	Groundwater recharge	2384	***Conceptual models***	1392
Heterogeneity	1843	Landfills	445	***GW budget***	
Hydraulic properties	1534	Urban groundwater	449	Assessment	5994
Island hydrology	76	Waste disposal	398	Water budget	941
Karst	761	Water supply	2269	***Policy***	
Paleohydrology	27	Yield	3284	Groundwater management	1863
Permeability	1661	***Mining***	1521	Legislation	170
Saturation	1368	Compaction	183	Organizations	487
Volcanic aquifer	126	Subsidence	228		
Vulnerability/protection		***Ecology***	547		
Aquifer vulnerability	297				
Groundwater protection	346				
Chemical status					
Arsenic	1009				
Nitrate	2038				
Pollution and remediation					
Bioremediation	493				
Chlorinated hydrocarbons	126				
Contamination	3815				
Matrix diffusion	222				
Microbial processes	841				
Multiphase flow	298				
Solute transport	2073				
Unsaturated zone	894				
Earthquake	178				
Floods	3659				
Floodplain	748				
Rainfall	6312				
Runoff	6210				
SW-GW interactions					
Coastal aquifers	783				
Salinization	355				
Thresholds&background					
Groundwater age	440				
Wetlands	1611				
Instruments and tools					
Geographic information systems	457				
Geophysical methods	294				
Geostatistics	260				
Groundwater hydraulics	107				
Radon	159				
Remote sensing	1223				
Stable isotopes	1048				
Tracer tests	771				

6. CONCLUSIONS

In this document, corresponding to the D1.1 of Task 1.1 (WP1) of the KINDRA Project, a first step in identifying research gaps and formulating recommendations for the future has been performed, by building a harmonized approach for classifying and reporting the European groundwater research efforts. The experience of project partners has been be used to draft an initial conceptual framework of terminology and classification. The obtained results represent a preliminary approach, following general criteria, which leads to the identification of two lists of keywords, to support developing the taxonomy to be used as descriptor of groundwater scientific knowledge covering European countries. At the same time, a preliminary hierarchical structure has been established, by means of the classification of groundwater research into three main categories, with various degrees of interaction. These results are the base for the following phase (D1.2), where the harmonized Hydrogeological Research Classification System (HRC-SYS) will be finalized. The activity of Task 1.1 and 1.3 (building the HRC-SYS) will be fundamental to the structure of the European Inventory of Groundwater Research (EIGR), to be populated by each European country covered by the project partners, mainly represented by the activities of the EFG Third Parties.

This preliminary Task1.1 requires the identification of keywords and categories for an effective and useful classification, allowing the recognition of the pertinence of groundwater related topics in the field of general water research. To establish a common terminology, various academic, industrial and research classification schemes are reviewed to create a hierarchical structure from selected lists of key-words from relevant EU directive documents, i.e. the Water Framework Directive (WFD, European Commission, 2000), its daughter directive the Groundwater Directive (GWD, European Commission, 2006) and the Blueprint to Protect Europe’s Water Resources (BWR, European Commission, 2012) as well as from scientific literature that will be fundamental to identify relationships and intersections between topics, themes and activities. The comparison of keywords obtained from searches in the EU directives mentioned above and the scientific journals furthermore indicate the relevance of the European legislation on the protection of water resources and the dependent terrestrial and associated aquatic ecosystems, and whether updates of directives may be requested in revisions of these in the future (e.g. to include consideration of some emerging contaminants). Hence, they reflect the efficiency of the science and policy interface and the communication between scientists and policy-makers.

A review of groundwater related research projects, has been conducted for positioning the KINDRA project in an international context, including ongoing and previous EU funded projects and documents (as guidances and technical reports) produced by EC and International Environmental Agencies also outside EU.

Thus, summarizing, for developing the common terminology on which to base the EIGR through HRC-SYS, keywords characterizing research on groundwater related topics, themes and activities have been identified in two ways: (1) from policy documents, WFD, GWD and BWR documents, and (2) from groundwater related scientific literature. This resulted in two lists of keywords reflecting both approaches. To assess the importance and pertinence of the keyword they have been ranked by performing searches via the Web of Science and Google Scholar search engines. In the former case, search statistics have been derived reflecting the ranking of keywords, e.g. citations and H-index. For the final harmonized terminology and methodology (D1.2) additional tools and resources of WoS will be explored and applied where relevant. In addition to these analyses the geographical distribution of research has been included to map gaps and trends in groundwater related research across Europe, represented by EFG Third Parties in the KINDRA project. Finally, keywords have been grouped into categories and linked to the main categories 'topics, themes and activities' for the proposed classification scheme.

These preliminary results have been discussed with the Joint Panel of Experts (JPE) during the First Workshop (Rome, March 2015), producing a strong contribution. Contributions and comments by the JPE are not integrated in the present preliminary initial classification in this report (D1.1), but will be implemented in the final terminology and classification (D1.2) finalized by Month 6 after a final internal circulation for comments and modifications.

To sum up, the methodology and preliminary results presented in this report will be refined and checked inside the consortium, taking into account important input from the JPE members, to produce the final harmonized terminology and methodology for classification and reporting hydrogeology related research in Europe, related to Task 1.3 (D1.2 due at M6).

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