KINDRA DELIVERABLE D1.2

HARMONIZED TERMINOLOGY AND METHODOLOGY FOR GROUNDWATER RESEARCH CLASSIFICATION

Summary:

The present document details the final terminology and classification methodology on groundwater R&D results and activities with keywords derived from EU directives and 20 scientific journals publishing groundwater research with the highest impact factor. In addition, the selected keywords constituting the terminology, have been organized in a thesaurus following a hierarchical structure, with the aim of developing a harmonized methodology for classifying groundwater research. The Hydrogeological Research Classification System (HRC-SYS) has been developed by categorizing groundwater research in three main categories: 1) Societal Challenges, 2) Operational Actions and 3) Research Topics. Each of these three main categories includes 5 overarching sub-categories for an easy overview of the main research areas. These sub-categories are : A) for Societal Challenges: 1. Health, 2. Food, 3. Energy, 4. Climate-Environment-Resources, 5. Policy-Innovation-Society B) for Operational Actions: 1. Mapping, 2. Monitoring, 3. Modelling, 4. Water Supply, 5. Assessment & Management; and C) for Research Topics: 1. Biology, 2. Chemistry, 3. Geography, 4. Geology, 5. Physics & Mathematics. The complete merged list of about 200 keywords selected from the Water Framework and Groundwater directives and the selected high impact scientific journals has been organized in a tree hierarchy. The classification system maps the relation between the three main categories through a 3D approach, where along each axis the 5 overarching groups are indicated. This approach allows for a 2D representation for each of the Societal Challenges, wherein Operational Actions and Research Topics intersect in a 5x5 matrix. This 2D structure and representation renders a 2D analysis and report of the relationships between groundwater research easier to perform and comprehend than 3D analyses.

Authors:

GEUS - Geological Survey of Denmark and Greenland; SAPIENZA - University of Rome; UM - University of Miskolc

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

The following document details the final terminology and classification methodology on groundwater R&D results and activities with keywords derived from EU directives and the most relevant scientific journals dedicated to groundwater research. In addition, the selected keywords constituting the terminology have been organized following a hierarchical structure, with the aim of developing a harmonized methodology for classifying groundwater research. This document constitutes the basis of the Hydrogeological Research Classification System (HRC-SYS).

This approach is necessary and clearly stated as a preliminary step in the KINDRA project, in order to have a comprehensive understanding on the groundwater theme, by creating an overview of the 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 a direct comparison and exploitation of existing 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 report follows the preliminary one (D1.1), further developing in a structured classification the initial ideas and initial conceptual framework (keywords, categories, hierarchy) discussed between the project partners and suggestions and comments received from the Joint Panel of Experts. The synthesis of the discussions has provided the basis for the implementation of the European Inventory of Groundwater Research (EIGR), which will contain information from 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 to help position the KINDRA project in an international context. Ongoing and previous EU funded projects considered relevant to KINDRA have been analysed and direct links and collaborations have been initiated with single projects and cluster/platforms among EU projects, to better develop our activities.

For developing the common terminology on which to base the EIGR through the HRC-SYS, keywords characterizing research on groundwater have been identified following two approaches: (1) from the most important EU directives and documents, i.e. the WFD, GWD and The Blueprint to Safeguard Europe's Water Resources, and (2) from groundwater related scientific literature, which has been fundamental for identifying relationships and intersections between topics, themes and activities. To assess the importance and pertinence of the keywords, these have been ranked by performing searches via the Web of Science, Scopus and Google Scholar search engines.

Through this methodology, the KINDRA project group has defined the categorization of all groundwater research according to three main categories: 1) Societal Challenges, 2) Operational Actions and 3) Research Topics. Each of these three main categories include 5 overarching groups allowing for an easy overview of the main research areas: for **Societal Challenges**: 1. Health, 2. Food, 3. Energy, 4. Climate-Environment-Resources, 5. Policy-Innovation-Society; for **Operational Actions:** 1. Mapping, 2. Monitoring, 3. Modelling, 4. Water Supply, 5. Assessment & Management; for **Research Topics**: 1. Biology, 2. Chemistry, 3. Geography, 4. Geology, 5. Physics & Mathematics.

The complete merged list of keywords consisting of about 200 terms has been organized in a tree hierarchy, where the overarching groups represent Level 1, followed by Levels 2 and 3, as detailed in chapter 5. The classification system previews the interaction among the three main categories through a 3D approach, where along each axis the 5 overarching groups are indicated. This also results in a 2D representation for each of the Societal Challenges, where Operational Actions and Research Topics intersect in a 5x5 matrix. The 2D structure of each one of the 5 Societal Challenges, allows for a 2D analysis and report of the relationships between the three main categories. This HRC-SYS classification system will be implemented and tested in the following steps of the project, by developing the EIGR tool (D1.5) and the related EIGR guidance document (D1.3). A thorough evaluation of the HRC-SYS will be carried out during the orientation Workshop for the national EFG representatives (D2.1).

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

As stated in the Grant agreement, KINDRA has addressed previous projects which have worked under the same scope. Activities related to Deliverable 1.1 have confirmed that there already exists groundwater related research and scientific knowledge on the several domains addressed by KINDRA. Thus, in addition to the project stated in the DoW, other relevant EU Funded Projects, previously and currently under development, have been considered (see D1.1, chapter 2). The present analysis has taken into account Life, CIP Eco-Innovation, FP6, FP7 and Horizon 2020 programmes related to groundwater research. Once projects have been selected, a study and interpretation of the call topic text has been performed, pointing out the methodological approaches useful for further scientific advancements in the KINDRA project lifetime. This approach has helped identify the common aspects and possible synergies existing among all projects and helped consolidating intelligence regarding the call's project.

Additional inputs derived from a report performed by João Wang de Abreu, Blue Book Trainee at European Commission, who identified the relationship between KINDRA and past and on-going projects, have also been included (Fig. 2.1).

To sum up, KINDRA results are related to Water Framework Directive (WFD), Groundwater Directive (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. By doing so, the KINDRA research group aims to achieve the following goals:

- Applicability of research results
- Reduce unnecessary duplication of research efforts
- Raise public awareness with respect to groundwater aspects
- Promote innovation in groundwater areas.

Actions to achieve these results are carried out throughout the project. At this stage, relationships with other project groups and clusters have been established. A direct link with the Life+ project AQUALIFE currently exists. KINDRA is also part of the ICT4water cluster, a platform including 10 FP7 projects and 5 H2020 projects related to the water cycle (www.ict4water.eu); additionally KINDRA is part of the EIP marketplace, a platform dedicated to water innovation market (www.eip-water.eu/); finally, the Coordinator of KINDRA, la Sapienza, is also part of the WssTP group (wsstp.eu), the European Technology Platform for Water Innovation. Through these and other future partnerships, it is expected that KINDRA will exchange informations and communication strategies and opportunities.

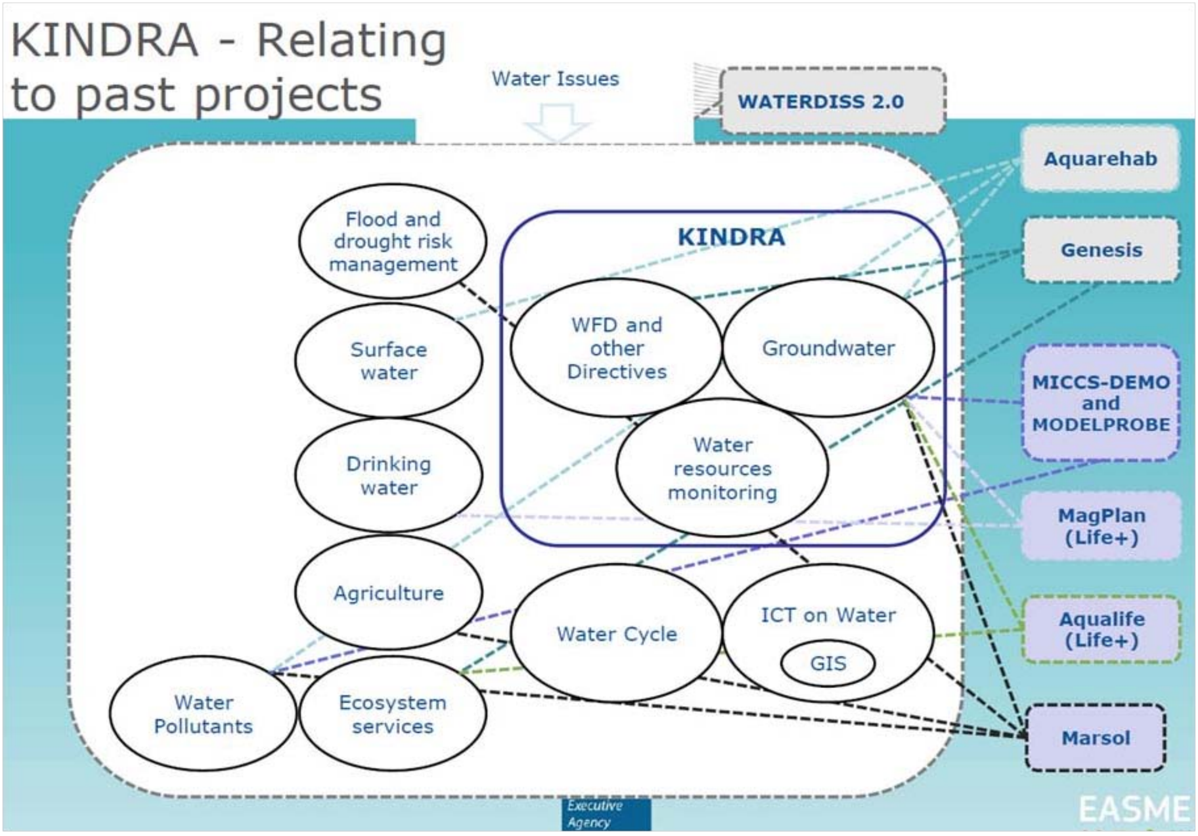

Figure 2.1 KINDRA related to past and on-going projects.From Easme meeting (February 21, 2015), João Wang de Abreu.

The presented approach matches the task related to Deliverable 1.2, "Harmonized Terminology And Methodology For Groundwater Research Classification", useful for the selection of keywords presented in next sections. The uniform EU-harmonised categorisation approach/terminology for reporting groundwater research (Hydrogeological Research Classification System – HRC-SYS) is consistent with the review of previous and current international projects related to groundwater and will strongly influence European Inventory of Groundwater Research and Innovation (EIGR).

3. SELECTION OF KEYWORDS FOR 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

Keywords are necessary for performing searches using search engines and in creating and populating the inventory (EIGR): they are the means for defining queries in the EIGR (European Inventory of Groundwater Research and Innovation). The information and the inventory need to be searchable and comparable at any given time to past and ongoing research activities, to assess the suitability and relevance of policies and research agendas, the groundwater quantitative and chemical status and the implementation of the WFD and GWD and other key directives (the nitrate directive, REF, etc.).

The use of keywords identified in the WFD and GWD, and the recent Blueprint to Protect Europe's Water Resources (BWR, European Commission, 2012), for the classification of groundwater research, covering the periods 2000-2006 and 2006-2015 for citation analyses, furthermore supports that this approach provides information that can be used for the assessment of the directives importance as research drivers.

It also helps evaluate the relevance of groundwater research in relation to the objectives of the WFD/GWD and the societal challenges defined in the EU research programme Horizon 2020, group them by categories and evaluate Science-Policy feedback within water research, policy and management. Additionally, the integrated perspective of the WFD and GWD provides good possibilities for demonstrating the important links in the water-food-energy nexus, 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 based on expert judgment by the KINDRA project group. These keywords have not been ranked nor evaluated by any statistical procedures before they were applied in further searches. Partners from the KINDRA project group have been involved in EU groundwater research projects since 1995 as well as 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 (Background CRIteria for IDentification of Groundwater ThrEsholds) 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.

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

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

According to the requirements of the WFD and GWD it is necessary to improve the understanding of the relations between groundwater quantitative and qualitative status and ecological status of groundwater dependent terrestrial and associated aquatic ecosystems.

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

The list of relevant keywords identified and extracted from the Water Framework and Groundwater Directives and the Blueprint to protect Europe's Water Resources for the development of the Hydrogeological Research Classification System - (HRC-SYS) is shown in Table 3.1.1.

Table 3.1.1 List of keywords selected from WFD (Water Framework Directive), GWD (Groundwater Directive) and BWR (Blueprint to Protect Europe's Water Resources) for the HRC-SYS.

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

3.2 IDENTIFICATION OF MOST COMMON KEYWORDS IN SCIENTIFIC JOURNALS

In scientific journals the keywords are essential, it is the second most frequently searched field after the title. The identification of main keywords in scientific literature was performed in a similar way as it was done for the policy documents (described in the Chapter 3.1.). The main keywords are identified by analyzing the data from searches on the most important international peer-reviewed journals dealing with groundwater resources.

Clearly, there are many journals dealing with hydrogeology. The most convenient approach is to identify which are the groundwater journals with the highest impact or are the most influential. Based on an international ranking comparison, a list has been made with the highest impact factor ("reputation") journals (Table 3.2.1). The right column expresses the current impact factors of each journal. Among these journals, we can for instance highlight Hydrogeology Journal, Ground Water, Journal of Hydrology and Water Resources Research as well known examples.

Table 3.2.1: 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

After having selected the most relevant scientific journals in the field of hydrogeology, detailed searches were carried out to identify the most frequently used and most relevant keywords in these scientific journals focusing on the volumes throughout the period 2006-2015. For the identification of keywords we considered the list of the most commonly used keywords adopted by Hydrogeology Journal (published by Springer). Comparing this proposed list with the search results obtained, it turned out that the 80 most relevant keywords from the scientific journals with high impact factor were also present in the keyword list of the Hydrogeology Journal. This is a very convincing match and verification of the applied approach. Therefore the following keyword list (Table 3.2.2.) is selected by the KINDRA as a reference for relevant keywords from scientific journals.

Table 3.2.2 List of keywords selected from scientific journals.

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

3.3 MERGED LIST OF KEYWORDS IDENTIFIED IN EU POLICY DOCUMENTS AND SCIENTIFIC JOURNALS

The KINDRA Deliverable 1.1 for the initial inventory framework explains in detail how the keywords have been selected from the work carried out in chapter 3.1 - Identification of relevant keywords from the Water Framework and Groundwater Directives and The Blueprint to Safeguard Europe's Water Resources – and chapter 3.2 - Identification of most important keywords selected from scientific journals –. In Deliverable 1.1, the keywords from the two different sources, i.e. policy documents and scientific literature, have been grouped in each one of the three categories identified in the KINDRA proposal Document (Topics, Themes and Activities), which represent the basic structural elements for the Knowledge Inventory for Hydrogeology Research, i.e. EIGR.

Initially six tables have been produced, with three categories for each one of the tables.

The two lists, one derived from the EU policy documents, and the second derived from the scientific journals, have been merged into one so as to build a single structure for the Knowledge Inventory including all the keywords in three tables representing the three main categories.

With the input provided by the members of the Join Panel of Experts (JPE), the Category and keyword names, used in the deliverable D1.1, have been adjusted into Research Topics, Societal Challenges and Operational Actions (initially named Technical Actions in D1.1). Observing the keywords in each one of the 3 tables linked to the three categories, the JPE members have noticed that the identified keywords were not covering all the fields related to groundwater. The initial list with keywords has been extended considering the JPE input. It is anticipated that during the lifetime of the KINDRA project additional keywords within the various 'Operational Actions' and 'Research Topics' will be identified. In the merged list new annexed keywords, relative to the initial list, are indicated.

The resulting merged list (Appendix A) is expected to be updated as new keywords will arise in the research fields dealing with groundwater, for instance as a result of continuous technological developments.

4. DEFINITION OF OVERARCHING THEMES, ACTIVITIES AND TOPICS

As described in the grant agreement, the KINDRA project will develop a uniform EU-harmonised categorisation approach / terminology for reporting groundwater research, a Hydrogeological Research Classification System – HRC-SYS, using the three main categories: themes, activities and topics. These initial categories have been developed further in collaboration with the JPE to base the main themes on the societal challenges as defined in the Horizon 2020 research framework programme, and in addition to use the overarching terms “research topics” and “technical actions” instead of “topics” and “activities”, respectively. In this report the term “operational actions” is adopted instead of “technical actions” as this is a broader term covering more than just technical actions and stressing the instrumental character. Hence, the KINDRA project group adopts the categorization of all groundwater research in the three main categories: 1) Horizon 2020 societal challenges, 2) Operational actions and 3) Research topics. The KINDRA project group adopted defining 5 overarching groups in each of these three categories for easy overview of main research areas. In the following sections it is described how we have defined these terms.

4.1 USING HORIZON 2020 SOCIETAL CHALLENGES AS MAIN THEMES

The Horizon 2020 defines seven main categories of Societal Challenges (SCs) for which research programmes for 2014-2020 will be defined and developed according to identified research needs:

1) Health, demographic change and wellbeing;

2) Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and Bio-economy;

3) Secure, clean and efficient energy;

4) Smart, green and integrated transport;

5) Climate action, environment, resource efficiency and raw materials;

6) Europe in a changing world - inclusive, innovative and reflective societies;

7) Secure societies - protecting freedom and security of Europe and its citizens.

Groundwater research may be conducted under all of these SCs, except for challenge number 4 “Smart, green and integrated transport”. Hence, this challenge is not relevant for the categorization of groundwater research. Furthermore, we consider SC number 6 and 7 similar in scope as both consider issues related to the development of secure and prosperous societies and EU policies to ensure such a development. Therefore SC number 6 and 7 are grouped into one SC with the title “Policy, Innovation and Society”.

The resulting final five societal challenges selected as overarching themes for categorization of groundwater research are therefore:

1) Health, demographic change and wellbeing;
2) Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and Bioeconomy;
3) Secure, clean and efficient energy;
4) Climate action, environment, resource efficiency and raw materials;
5) Policy, innovation and society

Or for short:

1) Health
2) Food
3) Energy
4) Climate, environment and resources
5) Policy, innovation and society.

In the following sections these five SCs will be used to establish overviews together with the defined five main operational actions and research topics. Figure 4.1.1 illustrates the number of peer reviewed research articles in the Web of Science core collection published within the field groundwater and societal challenge, e.g. “groundwater and health”, for the period 2006-2014.

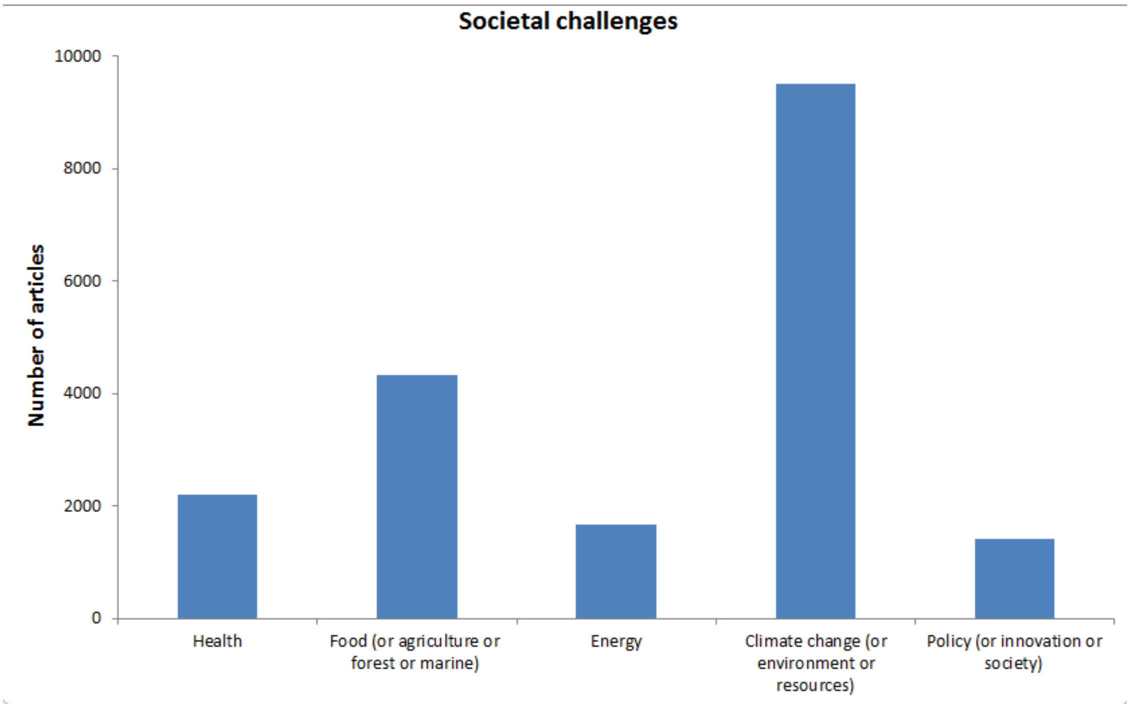

Figure 4.1.1. Number of articles in the Web of Science of Science core collection obtained by searching on the keyword "groundwater" and the keyword for the societal challenges (e.g. health) for the period 2006 - 2014. The total number of articles for all societal challenges are 19.148 or 55% of the total number of articles on groundwater (34.687) for the same period.

4.2 IDENTIFYING MAIN ACTIVITIES (OPERATIONAL ACTIONS) FROM SELECTED KEYWORDS

The five main Operational Actions adopted as overarching actions or activities, which are anticipated to include all identified activities in the identified keywords, are based partly on literature searches in Web of Science, Scopus (SciVal) and Google Scholar, and the number of papers published in each category, and partly based on expert judgment, which are used to determine how the different Operational Actions are related. The five overarching activities covering all operational actions have initially been identified as:

1) Assessment
2) Management
3) Mapping
4) Modelling
5) Water supply

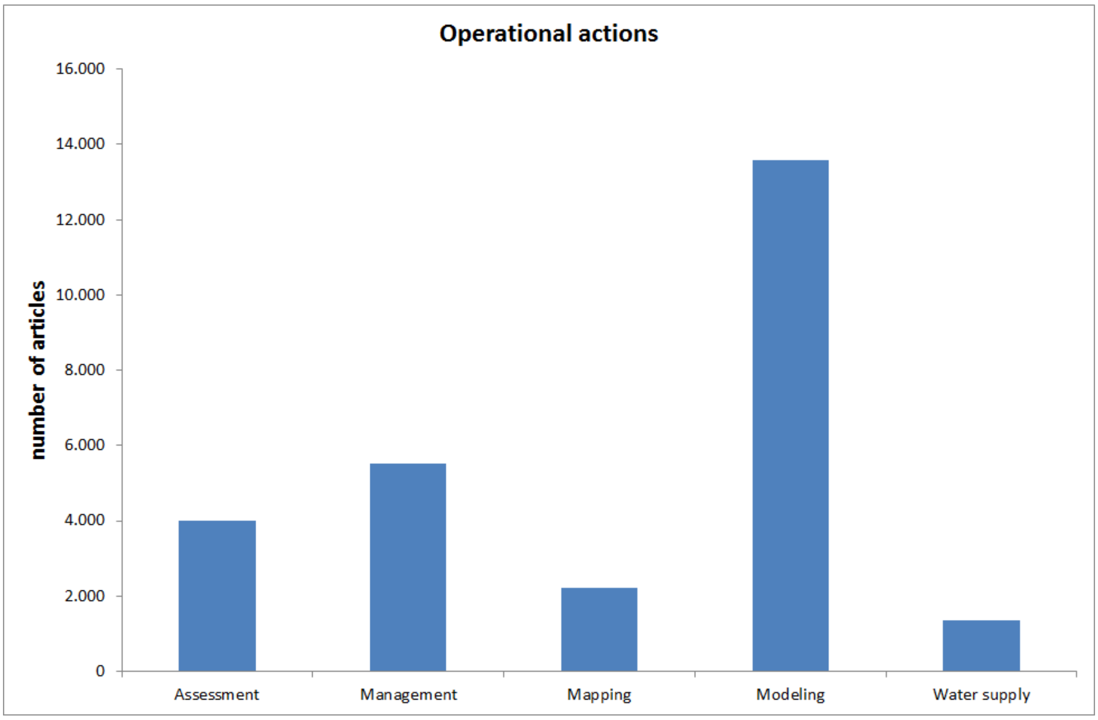

Figure 4.2.1 Number of articles in the Web of Science of Science core collection obtained by searching on the keyword "groundwater" and the keyword for the operational action (e.g. management) for the period 2006 - 2014. The total number of articles for all operational actions are 26.661 or 77% of the total number of articles on groundwater (34.687) for the same period.

All identified keywords have been categorized into one of these overarching operational actions. Monitoring is e.g. considered part of the assessment group, which included other activities than monitoring. Water supply group is intended to include the uses of groundwater, not only for drinking water, but also agricultural, industrial and energy groundwater withdrawals (for cooling and heating).

Changes in the five groups have been made considering the input of the end-users (see Deliverable 4.7). The final overarching groups are:

1. Mapping
2. Monitoring
3. Modelling
4. Water supply
5. Assessment and Management

This final grouping / categorization is described in chapter 5 (Figure 5.1).

4.3 IDENTIFYING MAIN GROUPS OF RESEARCH TOPICS

The research topics constitute by far the largest group of keywords, and it was impossible to identify five of the selected research topics as overarching research topics that include all of the more than 150 identified research topics. Based on the understanding that hydrogeology or groundwater research is a natural sciences discipline and generally relates to one or more of the other main natural science disciplines such as biology, chemistry, physics and mathematics, we propose the following five overarching groundwater research topics, into which we anticipate all previous, on-going and future groundwater research can be related to:

1) Biology
2) Chemistry
3) Geography
4) Geology
5) Physics & Mathematics.

However, the keywords groundwater and the main research topics above only attracts few hits, and it is therefore more illustrative to include major sub-topics or sub-levels of keywords in each group such as shown below, when comparing the research output from each group:

1) Biology (or ecosystems or ecology)
2) Chemistry (or geochemistry or hydrochemistry)
3) Geography (or hydrology or climate)
4) Geology (or hydrogeology or geohazards)
5) Physics & Mathematics (or geophysics or hydrogeophysics or geostatistics)

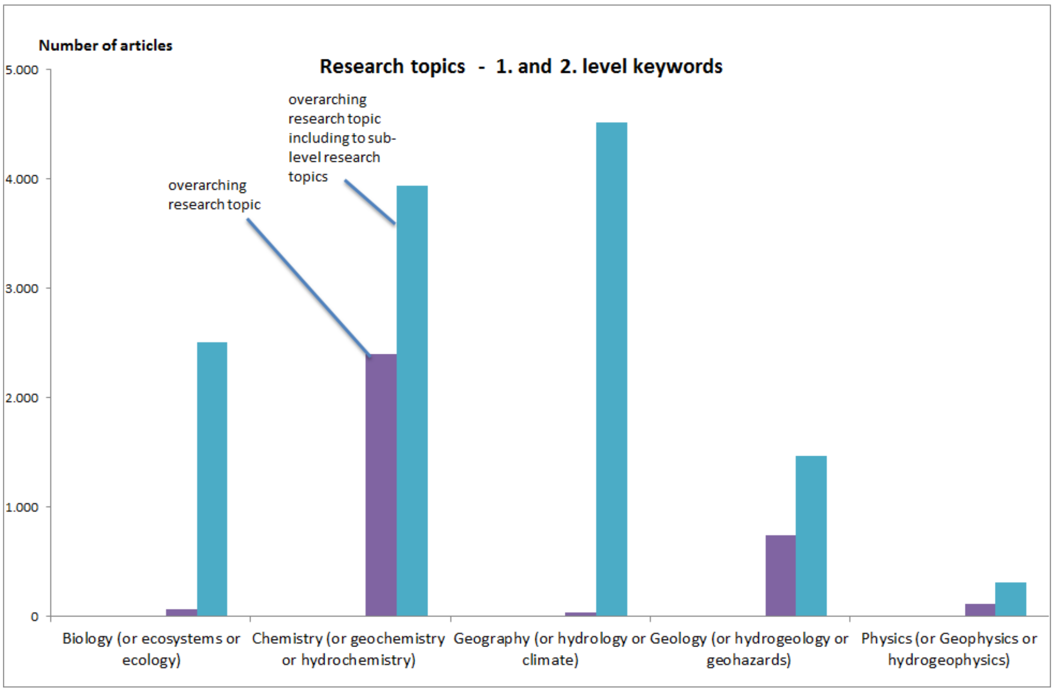

Figure 4.3.1 Number of articles in the Web of Science core collection obtained by searching on the keyword "groundwater" and the keyword for research topic (e.g. chemistry) for the period 2006 - 2014. The total number of articles for all overarching operational actions (purple columns) are 3370 or approx. 10% of the total number of articles on groundwater (34.687) for the same period. By including two sub-level (2nd level) keywords (e.g. hydrogeology and geohazards for the main topic geology) in the search (i.e. searching on e.g. groundwater and geology or groundwater and hydrogeology or groundwater and geohazards) the number of hits i.e. published articles (blue columns) increases to 12.747 (or 37% of total number of groundwater articles).

NOTE! Searches for peer reviewed scientific articles on the topic groundwater and one of the overarching topics listed above in the research databases generally applied by groundwater scientists (Web of Science and Scopus) attract in total few hits compared to searches on major research topics such as e.g. pollution or nitrate. As an example, the total number of hits for searches on the topic groundwater and the sum of searches on all the above listed main research topics for the period 2006-2014 is 3370, while for this period a total of 34.687 peer reviewed groundwater research papers have been published according to searches on groundwater articles (topic=groundwater) in the core collection of Web of Science. In comparison the number of hits (peer reviewed journal papers) for {topic=groundwater and topic=bacteria} or {topic=groundwater and topic=nitrate} are 2071 and 3596, respectively.

In other words, sub-level research topics such as “bacteria” and “nitrate”, which are categorized as part of overarching Research Topics (in this case Research Topic 1 and 2 – biology and chemistry, respectively) may receive many more hits for published papers than the main topics.

The total number of articles obtained from searching the Web of Science core collection for the period 2006-2014 for groundwater and all the overarching themes, activities and topics (societal challenges, operation actions and research topics) is 49.179, 40% more than the total number of articles published for the period. As the same article may appear in several groups it is by no means a certain indicator, but it does indicate that the selected overarching keywords represent most of the conducted groundwater research, and that the most published articles are covered when all sub-levels of the operational actions and research topics are included in the searches.

The overall categorization of Societal Challenges, Operational Actions and Research Topics in five overarching main groups of keywords is shown in Figure 5.1 in chapter 5.

We anticipate that all the keywords found within the EU directives and the groundwater journals as described in chapter 3 can be grouped within the five overarching groups in each category. This hypothesis is tested and confirmed in the following chapter.

5. GROUPING OF MERGED KEYWORD LIST IN SELECTED MAIN THEMES, ACTIVITIES AND TOPICS

After the initial search on and analysis of keywords from the considered sources (EU policy documents and scientific journals) as described in chapter 3, and defining the overarching themes (Societal Challenges), activities (Operational Actions) and topics (Research Topics), the KINDRA project group focused on making the compiled results easy to use in order to establish a solid basis for the Hydrogeological Research Classification System (HRC-SYS). A crucial step in this process has been the identification of the three main categories (Societal Challenges, Operational Actions and Research Topics) and the sub-division of each of these in five overarching groups (or sub-categories as explained in chap. 4). These are the basis for the tree hierarchy classification, as shown in Fig. 5.1.

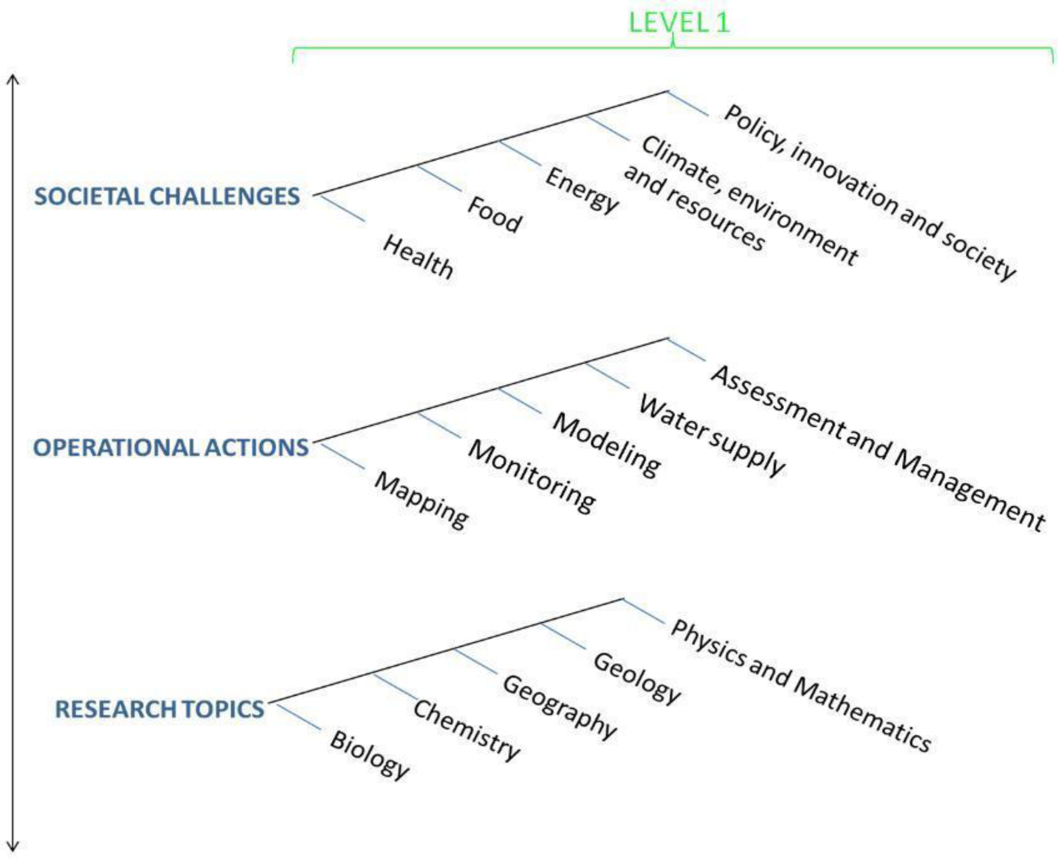

Figure 5.1 Tree hierarchy diagram.

5.1 Grouping of keywords into sub-levels of Operational Actions (OA) and Research Topics (RT)

Subsequently, items from the complete merged list of keywords (Tab. 3.3.4) have been distributed under each category of pertinence. Results from the grouping activities are presented in three different tables, for Societal Challenges (Tab. 5.1), Operational Activities (Tab. 5.2) and Research Topics (Tab. 5.3) respectively.

For a better performance of this classification, the KINDRA project group considered worthwhile to recognize several levels of keywords (up to four). Looking at the first category, Societal Challenges, it represents LEVEL 0 in the hierarchy; following in the list of the grouped keywords, Level 1 is characterized by the five sub-categories (Tab. 5.1), i.e. (i) Health, (ii) Food, (iii) Energy, (iv) Climate, environment and resources and (v) Policy, innovation and Society.

For Societal Challenges (Tab. 5.1), however, no further sub-categories have been inserted, to highlight the independency of this category respect with the other two main categories. This approach allows to consider the Societal Challenges for main comparison after identifying the relationships between the two technical categories.

Table 5.1: Grouped keywords into the Societal Challenges category.

Societal Challenges			
LEVEL 1	**LEVEL 2**	**LEVEL 3**	**LEVEL 4**
Health			
Food			
Energy			
Climate, environment and resources			
Policy, innovation and society			

In contrast, Operational Actions (Tab. 5.2) and Research Topics (Table 5.3a and b) include for each of the five keywords of level 1, sub-categories in up to three levels (levels 2,3 and 4) where appropriate.

Table 5.2: Example of keywords grouped into sub-levels of the five fixed Operational Actions
(Note! the keywords list and sub-level grouping are not fixed - it will develop and expand through time)

Operational actions

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Mapping	Remote sensing		
	Airborne measurements		
	Borehole logging or Well logging OR Geophysical logging		
	Surface geophysic		
	Electromagnetic methods		
	Geophysical methods		
	Cone penetration tests		
	Geographyc information Systems Or GIS		
	Survey		
Monitoring	Qualitative monitoring network	Tracer test	
		Investigation well	
		Multi-screen wells	
	Quantitative monitoring network	Investigation well	
		Multi-screen wells	
Modeling or modelling or Model	Hydrochemical modeling OR Hydrochemical modelling		
	Numerical modeling OR Numerical modelling		
	Integrated hydrological modeling		
	Coupled groundwater surface water modeling		
	Salt water intrusion modeling		
	Solute transport modeling		
	Density dependent modeling		
	Conceptual model		
	Scale effect Or Scaling effect		
Water supply	Energy production	Abstraction	
		Extraction	
	Food Production	Abstraction	
		Extraction	
	Drinking water	Abstraction	
		Extraction	
	Mining	Abstraction	
		Extraction	
	Industry	Abstraction	
		Extraction	
	Farming	Abstraction	
		Extraction	
	Agriculture	Abstraction	
		Extraction	
	Tourism	Abstraction	
		Extraction	
Assessment and Management	Characterisation	Technique	Slug test
			Geostatistic
			Pumping test
			Laboratory experiments
			Laboratory measurements
			Analytical solution
	Status assessment	Geophysics	
		Quality	
		Baseline	
	Review		
	Measure	Remediation	Treatment
			Containment
			Removal
			Bioremediation
			Capping
			Chemical oxidation
			Excavation
			Incineration
			Natural attenuation
			Pump & Treat
			Permeable Reactive Barrier
			Soil Vapor Extraction
		Mitigation	Intrusion
			Salinization
			Artificial recharge Or Managed aquifer Recharge
		Protection	
		Adaptation	Trend
	Legislation	WFD	
		GWD	Overuse Or Over-use
			Groundwater resources
	Governance	Sustainable	Sustainable water use
			Land use
	Organization	Water services	
		Integrated management	
		Integrated water resources management	
	Patent		

Table 5.3a: Example of keywords grouped into sub-levels of the overarching fixed Research Topic categories (level 1: Biology, Chemistry and Geography)

(Note! the keywords list and sub-level grouping are not fixed - it will develop and expand through time)

Research Topics

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Biology	Ecosystem	Aquatic ecosystem	Stygofauna
		Terrestrial ecosystem	Wetland
		Dependent ecosystem	Wetland
	Ecology		
	Ecohydrology	e-flow OR ecological flow OR environmental flow	
	Ecotoxicology	Status	Microbial processes
			Biological status
			Chemical status
			Ecological status
			Quantitative status
	Human toxicology	Human health	
Chemistry	Geochemistry	Contamination	
		Natural background or Pollution	Nitrate
			Ammonium
			Arsenic
			Cadmium
			Chloride
			Lead OR Pb
			Radon
			Mercury
			Sulphate or Sulfate
			Metals OR "Heavy metals"
			Pesticide
			Pharmaceutical
			Emerging contaminants
			Chlorinated Hydrocarbons
			Tetrachloroethylene OR Perchloroethylene OR PCE
			Trichloroanisole OR TCA
			Trichloroethylene Or TCE
			Deterioration
	Hydrochemistry	Multiphase flow	
		Matrix diffusion	
		Synthetic substance	
		Solute transport	
		Threshold	Drinking water
		Indicator	Electrical conductivity
			Salt water or saltwater
			Salinity
	Tracer	Environmental tracer	Groundwater dating
		Stable isotopes	Groundwater dating
		Noble gases	Groundwater dating
Geography	Europe		
	N. America		
	S. America		
	Asia		
	Russia		
	Australia OR New Zeland		
	Middle east		
	Transboundary	River	River basin districts
			River basin OR Catchment basin OR Watershed
			Surface water interaction
			Ecoregion
		Marine waters	Coastal waters
			Transitional waters
			Territorial waters
			Shale gas
	Climate	Climate Change	
	Hydrology	Island hydrology	
		Water budget	
		Artesian water	

Table 5.3b: Example of keywords grouped into sub-levels of the fixed Research Topics category (level 1 - Geography, Geology, Physics & Mathematics)

(Note! the keywords list and sub-level grouping are not fixed - it will develop and expand through time)

Research Topics			
LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Geography (cont'd)	Hydrological cycle Or Hydrologic cycle	Rainfall OR rain fall	
		Recharge	
		Runoff	
	Paleohydrology	Paleowater OR Palaeowater	
		Flood	
		Drought	Arid region
			Scarcity
	Urban areas	Urban groundwater	
		Waste	Landfill OR Land Fill OR Dump site
			Waste disposal
		Developing country	
	Geomorphology	Floodplain	
Geology	Groundwater body	Aquiclude	
		Aquitard	
		Karst	
		Aquifer	Volcanic aquifer
			Karst aquifer
			Carbonatic aquifer
			Sand aquifer
			Alluvium or Alluvial aquifer
			Coastal aquifer
			Artesian
			Carbonate rocks
			Crystalline rocks
			Fractured rocks
			Sandstone
			Unsaturated zone
			Aquifer vulnerability
			Vulnerability
			Heterogeneity
			Saturation
			Physical conditions
			Groundwater age
	Geothermal energy		
	Geohazard	Hazard	
		Earthquake	
Phisycs and Mathematics	Quantity	Water table	Flow regime
			Flow
		Hydraulic Parameters	Porosity
			Permeability
			Storage
			Yield
			Hydraulic conductivity
		Hydraulic properties	Subsidence
			Compaction
			Fracture
			Fault
			Saturation

6. FINAL PROPOSAL FOR A GROUNDWATER RESEARCH CLASSIFICATION SYSTEM: HRC-SYS

The groundwater research classification system HRC-SYS is built on a three dimensional representation of:

(1) Societal Challenges (SC) as put forward by the EC policy priorities of the Europe 2020 strategy and described in this document in chapter 4.1. (represented by the vertical (z) axis in Figure 6.1).

(2) Operational Actions (OA), which are instrumental actions required for implementing groundwater related activities, e.g. implementation of the Water Framework directive and the development of river basin management plans, in Figure 6.1 represented by one of the horizontal axes (x).

(3) Research Topics (RT), identified from (a) the EC policy document, Water Framework Directive and its daughter Groundwater Directive, and (b) the scientific literature, refer to section 4.3, and in Figure 6.1 represented by one of the horizontal axes (y).

The selection of five overarching Societal Challenges, Operational Actions and Research Topics were described in chapter 4 and further detailed into additional sub-categories (level 2-4) in chapter 5.

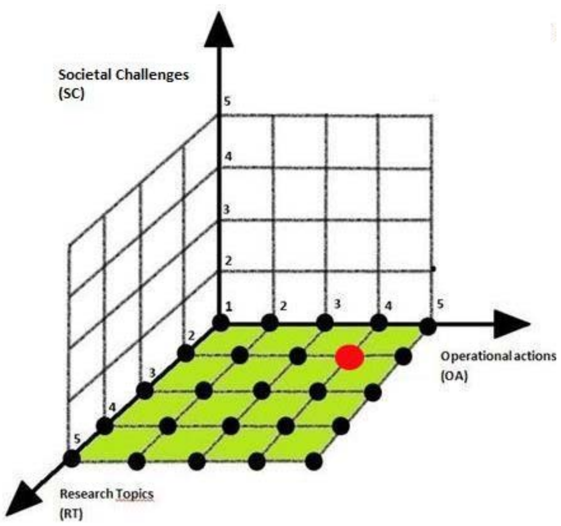

Figure 6.1. Two and three dimensional representation of the HRC- SYS. In green the 2D level corresponding to SC1 Health. The red dot shows the intersection of OA4 (Water supply) with RT2 (Chemistry), see Fig.6.2

The HRC-SYS is populated by considering for each of the 5 overarching categories included in 'Societal Challenges, the intersections between 'Research Topics' and 'Operational Actions', through a 3D approach (CUBE), where along each axis the 5 overarching groups are indicated (Fig. 6.1).

Taking for instance Figure 6.1, let's consider one of the five selected 'Societal Challenges", say, Health (SC1); it is then possible to identify all possible intersections for 'Operational Actions' and 'Research Topics' within this layer. Each sub-category on Research Topics and Operational Actions for the same Societal Challenge SC1 Health, can be represented and analysed at more detailed level. At this point it becomes easier, as well as more end-user friendly, to use two dimensional representations, i.e. tables, to study intersections on different levels (1, 2 & 3).

For each of the five 'Societal Challenges Themes' layers such tables (Figure 6.2) can be constructed by detailed 2D representation for all levels, e.g. for 'Societal Challenge Theme' Health, 'Research Topics' (RT) and 'Operational Actions' (OA) at all levels (1, 2 & 3) can be deployed to populate the HRC-SYS and at a later stage identify gaps for each layer and RT-OA intersections.

In the case of Figure 6.2, the keyword "tracer" in combination with the keyword(s) "energy production" have less than 50 published papers for the investigated period, while the RT "Hydrochemistry" in combination with the OA "Tourism" has more than 150 papers for the same period. The illustrated example just demonstrate the concept and does not represent real data. All combinations of RTs and OAs in this diagram will belong to one of the three groups >50, 50-100 and > 50. The grouping of the number of papers varies between the different combinations of Societal Challenge, Research Topic and Operational Activity some combinations will have many (e.g. > 1000 papers) others only few (e.g. < 10)

To sum up, for each vertical layer (Societal Challenges), a first-order table is built intersecting the five Operational Actions with the five Research Topics. Each of these intersections, also at lower levels (2, 3 and 4) facilitates summarizing the state of the art of the corresponding groundwater research and knowledge.

By this way, each one of the 2D graphs related to a single Societal Challenge, will include research and knowledge attributed to one RT and one OA. From each of these points (e.g. the red dot in Fig.6.1), a subordinated 2D graph representing the second order of keywords classified in the HRC-SYS can be carried out (see Fig.6.2), where along the axes the subordinated keywords for each RTs and OAs are identified, to provide additional information. The 2D approach renders the analysis and reporting of the relationships between groundwater research easier to perform and more comprehensible than a 3D analysis.

The adoption of the above mentioned classification system allows comparison of bibliometric and other indicators for each sub-field of research and knowledge, for trend and gap analysis.

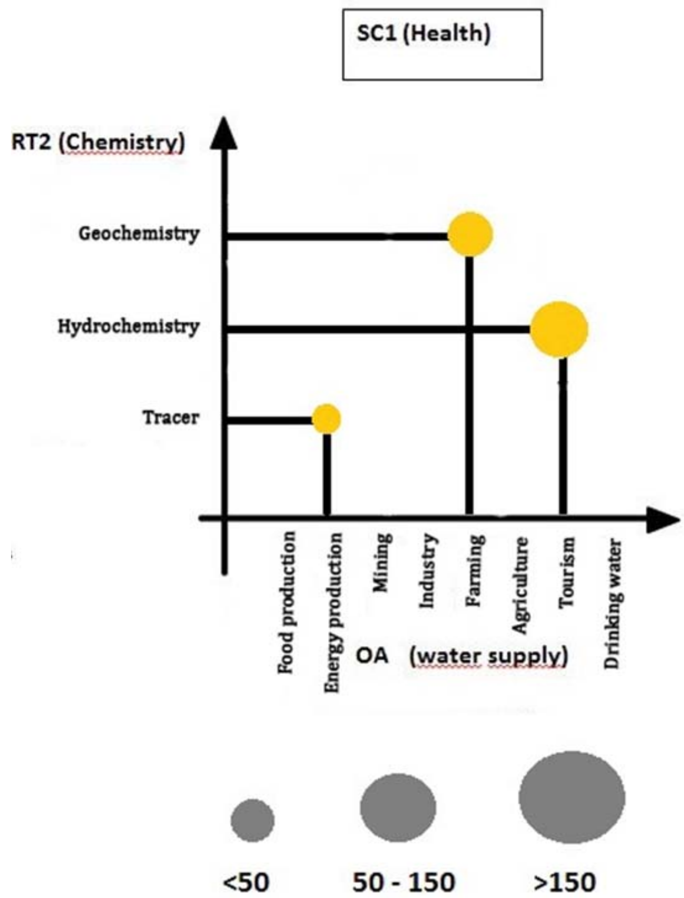

Figure 6.2. Two dimensional representation of the HRC- SYS for SC1-Health. Example of a 2D presentation of the performance of selected sub research topics (RTs) within RT2 "Chemistry" in combination with operational actions of OA4 "Water Supply" and Societal challenge 1 (SC1) "health" (see Figure 6.1).

As mentioned before, the core of the proposed classification system is the Level 1, corresponding to the five sub-categories identified among the three main categories. Consequently, the inventory EIGR needs to immediately identify these categories, allowing an immediate comparison and analysis among them. To identify gaps and trends, specific analytical tools will be adopted during the project (WP3), but their preliminary development (by query functions for data evaluation and production of statistics, diagrams, etc.) has been based during the classification adoption. This approach allows to test the significance of the proposed HCR-SYS into the groundwater topic. Specific tools will be selected in the following phases of the project, but similar approaches exist into the scientific bibliometric tools; for example, the SciVal tool, developed from the Scopus database, allows to extract information by different criteria. Some examples are shown in Appendix 2. Similar approaches will be followed for selecting analytical tools to be adopted for gaps and trend analysis.

7. REFERENCES

European Commission, 2000. Directive 2000/60/EC (Water Framework Directive) of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. OJ L 327, 22.12.2000, pp 1- 51.

European Commission, 2006. Directive 2006/118/EC (Groundwater Directive) of the European Parliament and of the Council, Official Journal of the European Union L 372/19.

European Commission, 2008. http://ec.europa.eu/environment/integration/research/newsalert/pdf/115na2_en.pdf.

European Commission, 2012. Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions – A Blueprint to Safeguard Europe's Water Resources, COM(2012) 673, SWD (2012) 381-382.

APPENDIX

A1. Merged Keywords´ list

1	Abstraction				
2	Adaptation				
3	Agriculture				
4	Airborne measurements				
5	Alluvial aquifer	or	alluvium aquifer		
6	Ammonium				
7	Analytical solution				
8	Aquatic ecosystem				
9	Aquiclude				
10	Aquifer				
11	Aquifer vulnerability				
12	Aquitard				
13	Arid region				
14	Arsenic				
15	Artesian				
16	Artesian water				
17	Artificial recharge	or	managed aquifer recharge		
18	Asia				
19	Assessment				
20	Australia	or	New Zealand		
21	Baseline				

22	Biological status				
23	Biology				
24	Bioremediation				
25	Borehole logging	or	Well logging	Or	Geophysical logging
26	Cadmium				
27	Capping				
28	Carbonate rocks				
29	Carbonatic aquifer				
30	Characterisation				
31	Chemical oxidation				
32	Chemical status				
33	Chemistry				
34	Chloride				
35	Chlorinated hydrocarbons				
36	Climate				
37	Climate change				
38	Coastal aquifer				
39	Coastal waters				
40	Compaction				
41	Conceptual model				
42	Cone penetration test				
43	Containment				
44	Contamination				
45	Coupled groundwater-				

	surface water modelling				
46	Crystalline rocks				
47	Density dependent modelling				
48	Dependent ecosystem				
49	Deterioration				
50	Developing country				
51	Drinking water				
52	Drought				
53	Earthquake				
54	Ecohydrology				
55	Ecological status				
56	Ecology				
57	Ecoregion				
58	Ecosystem				
59	Ecotoxicology				
60	E-flow	or	Ecological flow	or	Environmental flow
61	Electrical conductivity				
62	Electromagnetic methods				
63	Emerging contaminants				
64	Energy				
65	Energy production				
66	Environment				
67	Environmental tracer				

68	Europe				
69	Excavation				
70	Extraction				
70	Farming				
71	Faults				
72	Floodplain				
73	Flood				
74	Flow				
75	Flow regime				
75	Food	or	Food Production		
76	Fracture				
77	Fractured rocks				
78	Geochemistry				
79	Geographic information systems	or	GIS		
80	Geography				
81	Geohazard				
82	Geology				
83	Geomorphology				
84	Geophysical methods				
85	Geophysic				
86	Geostatistic				
87	Geothermal Energy				
88	Governance				
89	Groundwater Age				

90	Groundwater body				
91	Groundwater dating				
92	Groundwater Directive				
93	Groundwater resources				
94	Hazard				
95	Health				
96	Heterogeneity				
97	Human health				
98	Human toxicology				
99	Hydraulic property				
100	Hydraulic parameter				
101	Hydraulic conductivity				
102	Hydrochemical modeling	or	Hydrochemical modelling		
103	Hydrochemistry				
104	Hydrogeological cycle				
105	Hydrologic cycle	or	Hydrological cycle		
106	Hydrology				
107	Incineration				
108	Indicator				
109	Industry				
110	Infiltration				
111	Innovation				
112	Integrated hydrological modelling				
113	Integrated management				

114	Integrated water resources management				
115	Intrusion				
116	Investigation well				
117	Island hydrology				
118	Karst				
119	Karst aquifer				
120	Laboratory experiment				
121	Laboratory measurement				
122	Land use				
123	Landfill	or	land fill	Or	dump site
124	Lead	or	Pb		
125	Legislation				
126	Management				
127	Mapping				
128	Marine waters				
129	Matematics				
130	Matrix diffusion				
131	Measure				
132	Mercury				
133	Metals	or	Heavy metals		
134	Microbial processes				
135	Middle East				
136	Mining				
137	Mitigation				

138	Modeling	or	Modelling	or	Model
139	Monitoring				
140	Multiphase flow				
141	Multi-screen well				
142	Natural attenuation				
143	Natural background				
144	Nitrate				
145	Noble gases				
146	North America				
147	Numerical modeling	or	numerical modelling		
148	Organization				
149	Overuse	or	Over-use		
150	Paleohydrology				
151	Paleowater	or	Palaeowater		
152	Patent				
153	Permeability				
154	Permeable Reactive Barrier				
155	Pesticide				
156	Pharmaceutical				
157	Physics				
158	Physical conditions				
159	Policy				
160	Pollution				
161	Porosity				

162	Protection				
163	Pumping test				
164	Pump & Treat				
165	Qualitative monitoring network				
166	Quantitative monitoring network				
167	Quality				
168	Quantitative status				
169	Quantity				
170	Radon				
171	Rainfall	or	rain fall		
172	Recharge				
173	Remediation				
174	Remote sensing				
175	Removal				
176	Resources				
177	Review				
178	River Basin District				
179	River basin	or	catchment	or	watershed
180	River				
181	Runoff				
182	Russia				
183	Salinity				
184	Salinization				

185	Salt water	or	salt water		
186	Saltwater intrusion modeling	or	Saltwater intrusion modelling		
187	Sand aquifer				
188	Sandstone				
189	Saturation				
190	Scale effect	or	Scaling effect		
191	Scarcity				
192	Shale gas				
193	Slug test				
194	Society				
195	Soil Vapor Extraction				
196	Solute transport				
197	Solute transport modeling	or	Solute transport modelling		
198	South America				
199	Stable isotopes				
200	Status				
201	Status assessment				
202	Storage				
203	Stygofauna				
204	Subsidence				
205	Sulphate	or	sulfate		
206	Surface geophysics				
207	Surface water interaction				
208	Survey				

209	Sustainable				
210	Sustainable water use				
211	Synthetic substance				
212	Technique				
213	Terrestrial ecosystem				
214	Territorial waters				
215	Tetrachloroethylene	or	perchloroethylene	Or	PCE
216	Threshold				
217	Tourism				
218	Tracer test				
219	Tracer				
220	Transboundary				
221	Transitional waters	or	estuary		
222	Treatment				
223	Trend				
224	Trichloroethane	or	TCA		
225	Trichloroethylene	or	TCE		
226	Unsaturated zone				
227	Urban areas				
228	Urban groundwater				
229	Volcanic aquifer				
230	Vulnerability				
231	Waste				
232	Waste disposal				
233	Water budget				

234	Water Framework Directive				
235	Water services				
236	Water supply				
237	Water table				
238	Wetland				
239	Yield				

A2. Examples and perspectives for the application of the groundwater research classification system / HRC-SYS.

In the Initial Proposal for a Harmonised Terminology and Methodology (deliverable D1.1) the occurrence of Groundwater related keywords in international research databases has been evaluated by performing searches using two search engines: Web of Science (WoS) and Google Scholar (GS). In addition to Google Scholar and WoS/InCites there are other tools available for statistical analyses, therefore in deliverable D1.2 Scopus/SciVal is also evaluated.

WoS/InCites, Scopus/SciVal and Google Scholar are tools that are anticipated to be useful at a later stage in KINDRA, especially in WP3 on Research Gaps and Recommendations that have relevance for the implementation of the Water Framework (WFD) and Groundwater Directives (GWD) including a sound understanding of groundwater-surface water interactions and climate change impact, mitigation and adaptation.

Interestingly, the comparison between WoS, Scopus and Google Scholar is a research field itself (i.e. Meho and Yang, 2007; Falagas et al., 2008; Jacso, 2005).

Google Scholar has become a popular tool to make scholarly searches across a wide range of scholarly and related research. It allows to search across many disciplines and sources: articles, theses, books, abstracts and court opinions, from academic publishers, professional societies, online repositories, universities and other web sites. It finds both citations and full documents. Google Scholar metrics is a tool with which you can browse the top 100 publications in several languages, ranked by five-year h-index and h-median metrics.. Browsing by research area is available only for English publications. In addition, a search can be performed for specific publications in all languages by words in their titles. Available metrics in GS are: The h-index of a publication, i.e. the largest number h such that at least h articles in that publication were cited at least h times each. The h-core of a publication is a set of top cited h articles from the publication.. The h-median of a publication is the median of the citation counts in its h-core. For example, the h-median of the publication above is 9. The h-median is a measure of the distribution of citations to the articles in the h-core. Finally, the h5-index, h5-core, and h5-median of a publication are, respectively, the h-index, h-core, and h-median of only those of its articles that were published in the last five complete calendar years.

The Web of Sciences engine refers to ISI publications only and includes various statistics, among which: numbers of papers (or hits), total citations, average citations, H – index, Highest citations. The option to extract statistical analyses using the Citation Report is the strength of WoS but more extensive analyses can be performed using the WoS associated tool InCites, which uses WoS content records back to 1956. InCites constitutes a customized, web-based research evaluation tool that allows to analyze institutional productivity and benchmark the output against peers worldwide.. InCites is a comprehensive environment for research and bibliometric assessment and evaluation to better support the long term vision and to identify the latest trends with a multifaceted analytics view.

In the Initial proposal for HRC-SYS (Deliverable 1.1) WoS has been used to define the most important keywords among the scientific community, researching for peer-reviewed journals dealing with groundwater while the search engine Google Scholar has been used as source of knowledge for publications without any prior quality assurance. The use of both WoS and Google Scholar has allowed, and allows including both white literature (peer-review papers) and gray literature, e.g. abstracts, reports, book chapters,low-impact journals and conference proceedings (Meho & Yang, 2008). The ratio between the number of results on a given keyword in Google Scholar (GS) and WoS provides information on the relevance of the topic for management and research. Scopus is an Elsevier product and similar to WoS, but with a broader content. It is a large abstract and citation database of peer-reviewed literature: scientific journals, conference proceedings and trade publications, book series, and stand-alone books. It delivers a comprehensive overview of the world's research output in the fields of science, technology, medicine, social sciences, and arts and humanities. Scopus features smart tools to track, analyze and visualize research. Scopus indexes about 50 million publications. Reference lists are captured for the 29 million records published from 1996 onwards but no for the additional 21 million pre-1996 records reach as far back as the publication year 1823.

SciVal, a tool based on Scopus data, offers a broad range of metrics, as illustrated in Table B1.

Table B1: Groups of metrics in SciVal.

	Productivity	Citation Impact	Collaboration	Disciplinarity	Snowball Metric	"Power metric"
Scholarly Output	●				●	●
Journal Count				●		●
Journal Category Count				●		●
Citation Count		●			●	●
Cited Publications		●				◐
Citations per Publication		●			●	
Number of Citing Countries		●				●
Field-Weighted Citation Impact		●			●	
Collaboration			●		●	◐
Collaboration Impact		●	●			
Academic-Corporate Collaboration			●			◐
Academic-Corporate Collaboration Impact		●	●			
Outputs in Top Percentiles		●			●	◐
Publications in Top Journal Percentiles		●				◐
h-indices	●	●			●	●

SciVal offers many tools to make bibliometric analyses; in Figures B1, B2 and B3 examples are provided. All the diagrams shown deal with the keyword search for Groundwater OR "Ground water". The referring time period is 2010-2015 (5 years plus current year); it is the longest period that can be considered by SciVal in the production of such kind of diagrams. There is also the possibility to use much long time period but this is available only in the "Benchmarking" sheet.

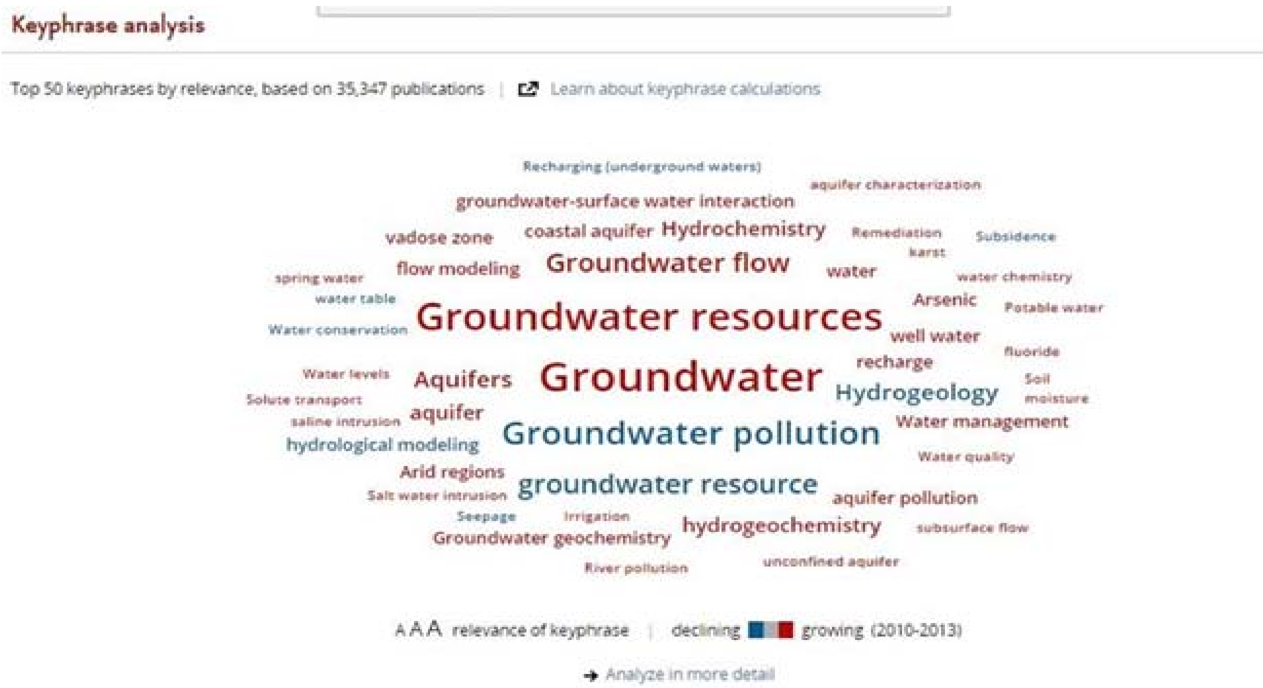

Figure B1: Keyphrase analysis performed by SciVal for the keyword Groundwater OR "Groundwater" (time period 2010-2015). The size of the words represents the relevance of keyphrase while the colour means the trend for the publications related to the word: blue-declining interest; red-growing interest.

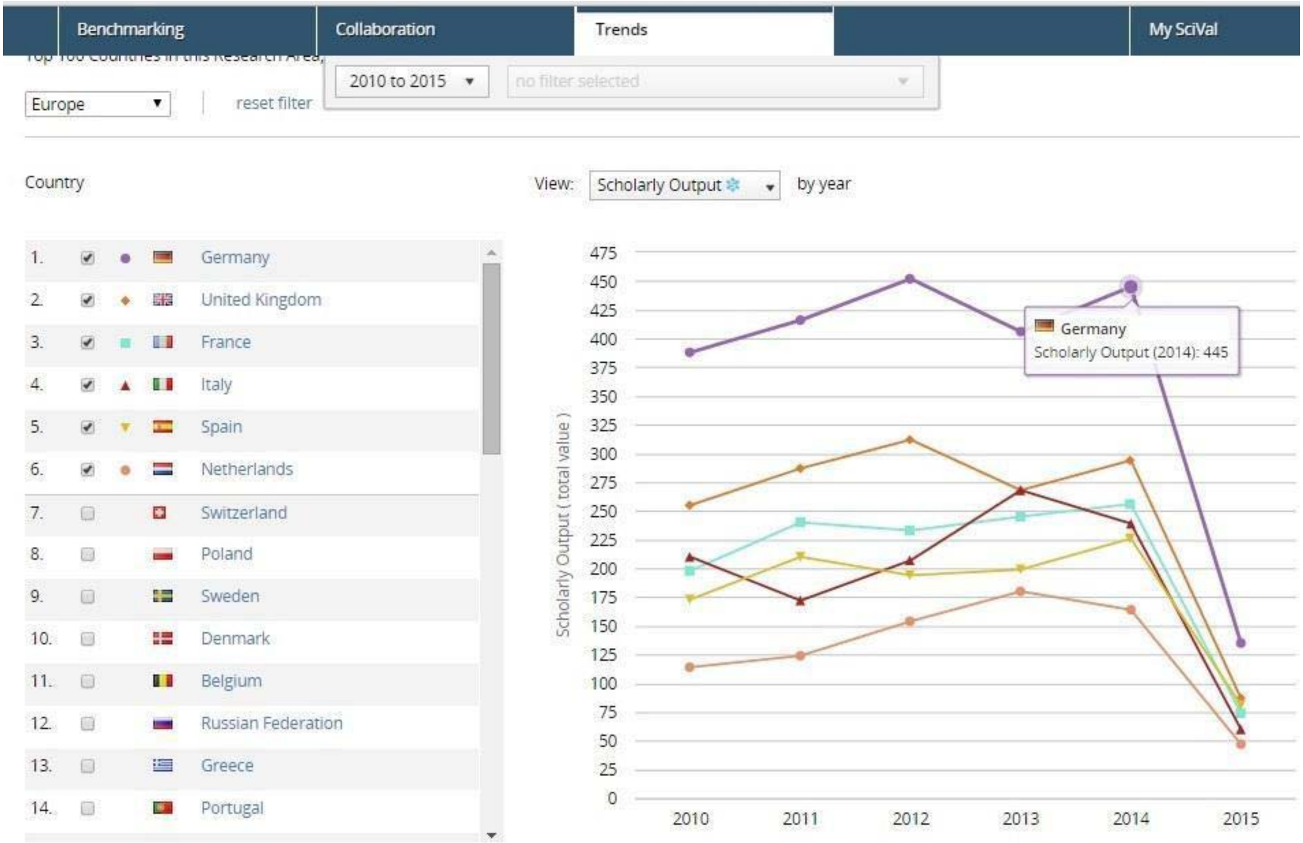

Figure B2: Scholarly output in Europe related to the keyword Groundwater OR "Ground water" for the period 2010-2015. The diagram shows different trends for the six countries in Europe with the highest number of publication for the performed research.

Figure B3: The ten most active research institutions or organisations within the groundwater OR "ground water" research area in the period 2010-2015.

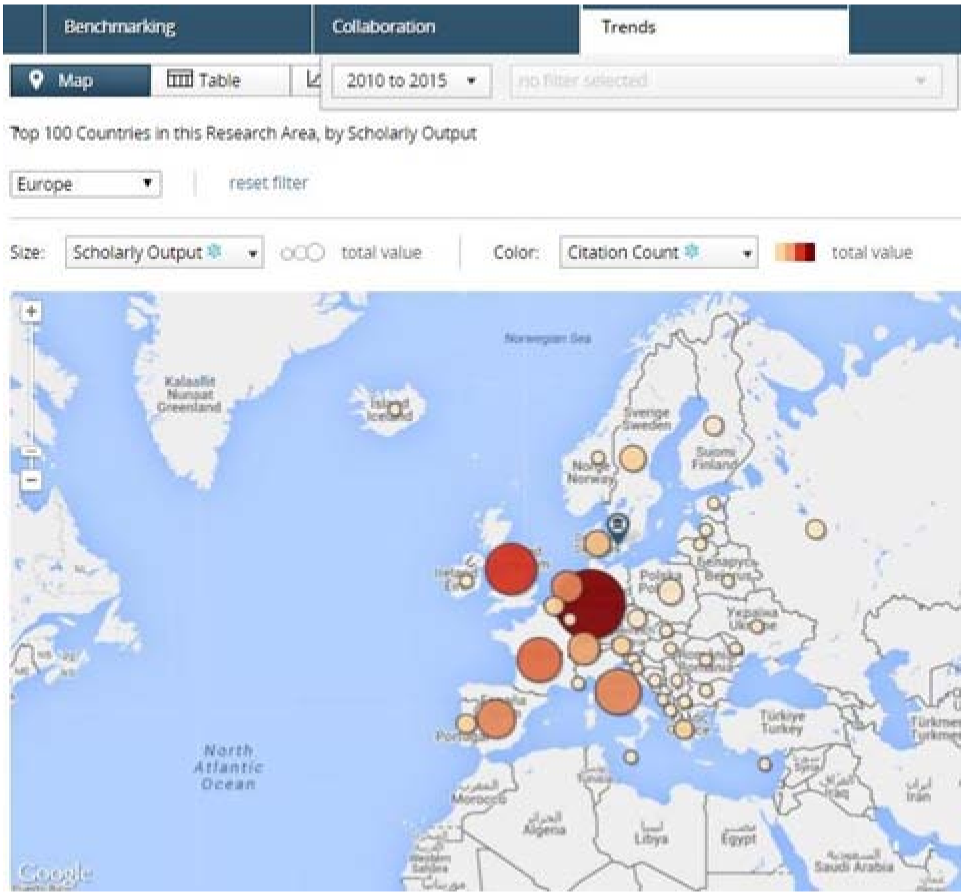

Figure B4: Bubble Diagram showing on the european map the relevance of the Scholarly output in the different countries (size) and the citation count (colour). The size of the bubbles is directly proportional to the Scholarly output while the strength of the colour indicate the number of citation counts (strong colours = many citations).

These are only a few examples of how SciVal can be used. It is a powerful tool that provides many possibilities regarding the evaluation of current research and identification of research gaps (WP3).

In order to carry out the most comprehensive evaluation of current research gaps and trends it is important to use a combination of WoS/InCites; Google Scholar and Scopus/SciVal because they are complementary tools