The KINDRA project – towards Open Science in Hydrogeology for higher impact

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Groundwater knowledge and research in the European Union is often scattered and non-standardised. Therefore, KINDRA is conducting an EU-wide assessment of existing groundwater-related practical and scientific knowledge based on a new Hydrogeological Research Classification System (HRC-SYS). The classification is supported by a web service, the European Inventory of Groundwater Research (EIGR), which acts not only as a knowledge repository but also as a tool to help identify relevant research topics, existing research trends and critical research challenges. These results will be useful for producing synergies, implementing policies and optimising water management in Europe. This article presents the work of the project during the first two years in relation to a common classification system and an activity for data collection and training delivered by the EFG's National Associations in 20 European countries.

Les connaissances et la recherche concernant les eaux souterraines au sein de l'Union Européenne sont souvent disparates et non standardisées. KINDRA a donc comme objectif une évaluation extensive, au niveau européen, des connaissances scientifiques et pratiques touchant les eaux souterraines, basée sur un nouveau système de classification de recherche hydrogéologique dénommé HRC-SYS. La classification s'appuie sur un service web, l'Inventaire Européen de Recherche des Eaux souterraines *(EIGR) qui fonctionne non seulement comme une mine de renseignements mais aussi comme un outil d'aide à l'identification des orientations actuelles de la recherche, des thèmes pertinents de recherche, et des défis exigeants auxquels la recherche doit faire face. Ces résultats seront utiles pour réaliser des synergies, rendre effectives les politiques et optimiser la gestion de l'eau en Europe. Cet article présente le travail accompli par le projet, pendant les deux premières années, en relation avec un système commun de classification et les actions de collection de données et de formation mises en œuvre par les Associations nationales membres de la FEG, dans vingt pays européens.*

El conocimiento y la investigación de las aguas subterráneas en la Unión Europea a menudo están dispersos y no estandarizados. Por esta razón, KINDRA está llevando a cabo una evaluación a escala europea sobre el conocimiento científico y práctico relacionado con las aguas subterráneas, basado en un nuevo Sistema de Clasificación de Investigación Hidrogeológica *(HRC-SYS). La clasificación cuenta con el apoyo de un servicio digital, el* Inventario Europeo de Investigación de Aguas Subterráneas *(EIGR), que actúa no solo como un repositorio de conocimientos sino también como una herramienta para identificar temas de investigación relevantes, tendencias de investigación existentes y desafíos de investigación críticos. Estos resultados serán útiles para producir sinergias, implementar políticas y optimizar la gestión del agua en Europa. Este artículo presenta el trabajo del proyecto durante los primeros dos años en relación con el sistema de clasificación común y la actividad de recopilación de datos y formación desarrollada por las Asociaciones Nacionales de FEG en 20 países europeos.*

The objective of the KINDRA project is to help achieve a better understanding of the societal challenges relating to groundwater by providing an overall view of the scientific knowledge that exists across Europe and classifying this in an open repository. This will also hopefully raise the awareness of citizens of how science affects their daily lives.

Therefore, the KINDRA project is creating a unique knowledge inventory, i.e. a database of groundwater research results, activities, projects and programmes deemed essential for the identification of the state-of-the-art as well as future perspectives and research gaps in the groundwater field.

This project is in line with the European policy for Open Science. The deliverables for sharing scientific knowledge, research projects, articles and data represent a concrete manifestation of Open Science in practice at the European level. The same database is open for use by researchers, policy makers and the public at large. The classification of data has been elaborated in a user-friendly way in order to optimise the use of a wide range of stakeholders. It has been widely accepted and welcomed by the scientific and broader community in hydrogeology. In this sense, the KINDRA project is a reference project in implementing Open Science that could be replicated by other scientific areas.

These achievements would not have been possible without the active support of the national associations of Geology throughout Europe. These associations have connected to the community of geologists and the professionals in hydrogeology in each country. This has facilitated comparable and consistent data across Europe as well as scientific and professional peer review of the progress and the objectives of the KINDRA project. This common effort has enabled networking, mutual recognition, trust and visibility across the hydrogeology communities in European Member States.

In this sense, the KINDRA project is a concrete manifestation of a bottom-up European construction opening up for a closer collaboration between countries in Europe tackling common societal challenges such as the access to clean water.

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1. A common classification system

The KINDRA project proposes a comprehensive approach with a new classification system in hydrogeology tested and approved by the research community, the professional community in geology and the wider public at large. It is a multi-step venture from a well-defined thematic categorisation to the complete roll-out as an open searchable service (***Figure 1***).

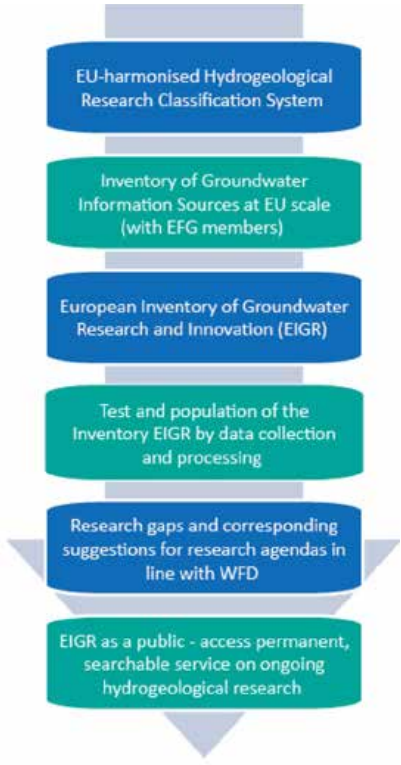

Figure 1: The methodology line.

The first year of the project focused its efforts on developing the concept of a Harmonized Terminology and Methodology for Classification and Reporting Hydrogeology-Related Research in Europe (HRC-SYS).

For classifying groundwater research and knowledge, the KINDRA project group has defined the categorisation of all groundwater research according to three main categories:

1. Horizon 2020 societal challenges,
2. Operational Actions and
3. Research Topics.

Each of these three main categories includes five overarching groups, allowing for an easy overview of the main research areas.

Horizon 2020 defines seven main Societal Challenges (SCs) for which research programmes for 2014-2020 will be defined and developed according to identified research needs. Groundwater research may be conducted under all of these SCs except for SC 4 (Smart, green and integrated transport), which is not relevant. Furthermore, we consider SC6 (Europe in a changing world - inclusive, innovative and reflective societies) and SC7 (Secure societies - protecting freedom and security of Europe and its citizens) 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 SCs 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 categorisation of groundwater research are therefore: 1. Health; 2. Food; 3. Energy; 4. Climate, environment and resources; 5. Policy, innovation and society.

The five main Operational Actions adopted as overarching actions or activities – intended to include all identified activities in the identified keywords – are based partly on literature searches in the Web of Science, Scopus (SciVal) and Google Scholar, and their results on the number of papers published in each category, and partly based on expert judgment, used to determine how the different Operational Actions are related. The five overarching activities covering all operational actions, taking into account the results of an end-user survey performed during the project, have been identified as: 1. Mapping, 2. Monitoring, 3. Modelling, 4. Water Supply, 5. Assessment & Management.

The research topics constitute by far the largest group of keywords, and it was impossible to identify five of them as overarching research topics that include all of the more than 150 identified keywords. Based on the understanding that hydrogeology or groundwater research is a natural science discipline and generally relates to one or more of the other main natural science disciplines, the following five overarching groundwater research topics have been selected: 1. Biology, 2. Chemistry, 3. Geography, 4. Geology, 5. Physics & Mathematics.

The identification of the three main categories (Societal Challenges, Operational Actions and Research Topics) and the subdivision of each of these into five overarching groups give us the tree hierarchy classification shown in ***Figure 2***. The adopted merged list of keywords consisting of about 240 terms has also been organised in a tree hierarchy, where the overarching groups represent Level 1, followed by Levels 2 and 3. Subsequently, items from the complete merged list of keywords have been distributed under pertinent categories.

The classification system depicted in ***Figure 2*** previews the interaction among the three main categories through a 3D approach, where along each axis the five overarching groups are indicated. Societal Challenges (SC) as put forward by the EC policy priorities of the Europe 2020 strategy are represented by the vertical (z) axis in ***Figure 2***, while 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), correspond to one of the horizontal axes (x). Finally, Research Topics (RT) – identified from (a) the EC policy documents, the Water Framework Directive and its daughter the Groundwater Directive, and (b) the scientific literature – are represented by the other horizontal axis (y).

This also results in a 2D representation for each of the Societal Challenges, where Operational Actions and Research Topics intersect in a 5×5 matrix. The 2D structure of each one of the five Societal Challenges allows for a 2D analysis and report of the relationships between the three main categories. Taking for instance ***Figure 3***, let us consider one of the five selected Societal Challenges, say, Health (SC1); it is then pos-

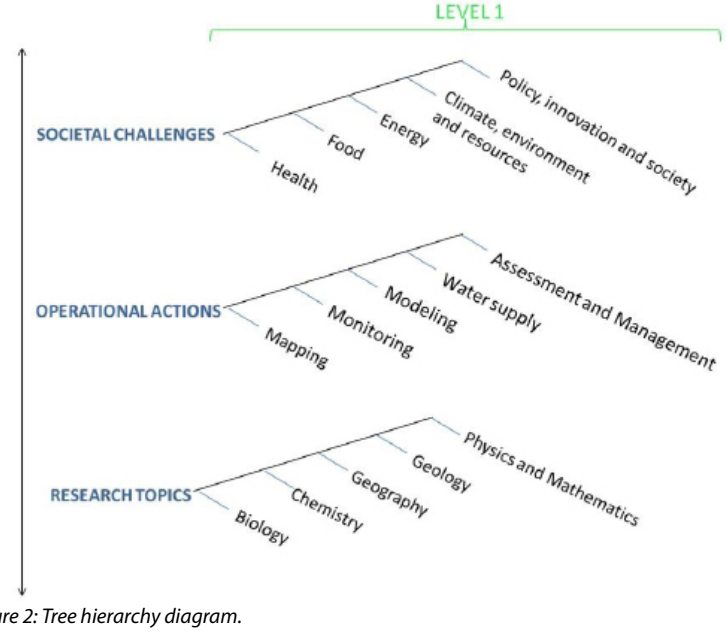

Figure 2: Tree hierarchy diagram.

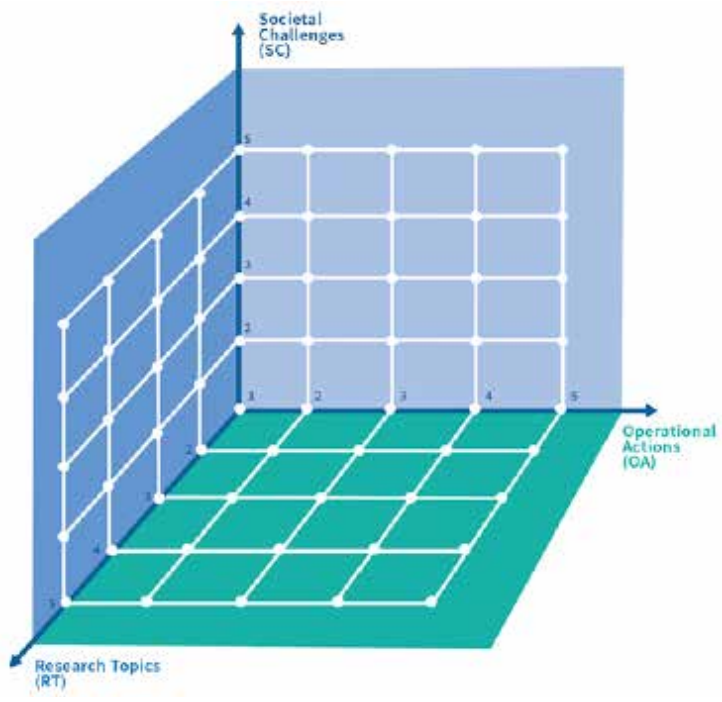

Figure 3: Three-dimensional representation of the HRC-SYS.

sible 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 a more detailed level.

2. Training and data collections

The KINDRA European Inventory on Groundwater Research (EIGR) is a tool for inventorying information sources regarding Hydrogeological Research Knowledge and Information. It follows the principles defined by the KINDRA project Harmonised Terminology and Methodology for Classification and Reporting Hydrogeology-Related Research in Europe (HRC-SYS).

The KINDRA European Inventory of Groundwater Research, EIGR, is a collection of information sources related to Hydrogeological Research Knowledge, including papers, reports, maps, databases, etc., scattered around Europe and elsewhere at international and national levels. The EIGR provides metadata identifying various information sources from which data can be collected, added and stored, to be available as open access.

The EIGR is intended to be used in three different ways:

i. for insertion of information pertaining to groundwater research and other available knowledge by experts;
ii. for consultation during and after the project by people and organisations dealing with groundwater research, but also possibly by non-experts;
iii. for analysing collected and stored information to identify trends, challenges and gaps in groundwater research, by the KINDRA partners during the project period and policy makers in the future.

The EIGR is intended to be a permanent resource, publicly available after the end of the KINDRA project.

The EIGR will not contain data itself, but rather metadata, referring and providing links to research that has been performed in Europe since 2000, and at the same time allowing their classification under the uniform proposed HRC-SYS. The EIGR allows for the insertion of different information products. In the process of inserting information in the EIGR, users are guided to classify the uploaded information and distinguish between 'research' and 'knowledge' according to four different classes of "knowledge" and "research" identified by the level of the performed quality assurance the uploaded work has received.

In order to have a quality assessment (QA) of the resources, KINDRA has classified the work according to Research and Knowledge classes. ***Table 1*** presents the definition of the 4 classes used in the KINDRA project.

The aim of the KINDRA project – to carry out a Europe-wide assessment of existing groundwater-related practical and scientific knowledge focusing on international (in EU dimensions), national and regional scientific activities – would not have been possible without the active support of professional associations in geology in EU Member States and beyond. In fact, the data collection and assessment have been implemented with the help of the member National Associations of the European Federation of Geologists. They take part in the project as EFG Linked Third Parties. Based on the data provided, the European Inventory (database) of Groundwater Research (EIGR) has been provided with data (populated) in the form using a web service.

In total there were 20 countries participating in the KINDRA Inventory population: Belgium, Croatia, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Serbia, Slovenia, Spain, Switzerland, the UK and Ukraine (see ***Figure 4***).

Table 1: Definition of research and knowledge classes 1 to 4.

Research	Knowledge
Class 1 Articles in peer reviewed journals occurring in WoS or Scopus databases only	**Class 3** Reports from research projects, maps, databases, National technical journals, etc., with internal or external QA
Class 2 Conference proceedings, monographs, book chapters, etc. Found in WoS and Scopus extended databases	**Class 4** Reports, data reports, popular magazines, newsletters, etc., with no certain QA

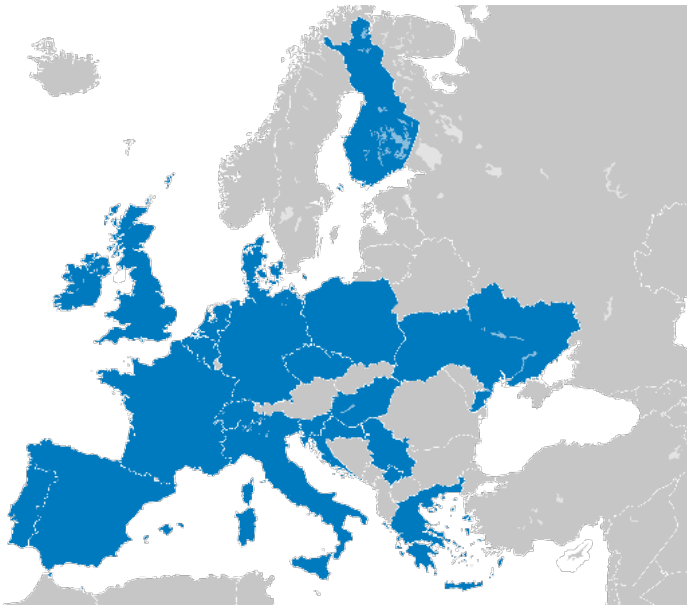

Figure 4: Countries participating in KINDRA data collection.

Before collecting data about the existing practical and scientific knowledge on groundwater research, it should be clarified where the information comes from. That is why an inventory of information sources has been created concerning national and international projects, documents, databases, initiatives, reports and scientific publications. The data were gathered by a survey in collaboration with the EFG's National Associations in 20 European countries.

An orientation workshop was organised with the participation of experts from the 20 European countries representing EFG's Linked Third Parties (National Associations) in the KINDRA project (***Fig. 5***). The aim of the workshop was to train the experts participating in data collection on groundwater research at a national level, during the second year of the project, and who will populate the European Inventory for Groundwater Research (EIGR). During the workshop the EIGR was tested and detailed guidelines for populating the EIGR were provided. The response of the participants was very positive and valuable suggestions were given to improve the EIGR's user functionalities.

The metadata insertion to the EIGR was implemented by the National Experts assigned by the European Federation of Geologists Linked Third Parties (LTPs), the 20 National Associations participating in the project.

Figure 5: KINDRA workshop for EFG's Linked Third Parties.

The National Experts used different sources on regional, national and international levels to collect the relevant information for their EIGR entries. The LTPs were asked to classify their sources of information into the following groups:

- institutions dealing with groundwater research/surveying;
- groundwater monitoring, availability of data;
- journals/archives focused on hydrogeology.

The most important sources were the national databases, reports and journals, responsible governmental bodies, universities and national geological surveys. The LTPs' experts classified the information they gathered according to the previously defined research and knowledge classes (***Table 1***). As illustrated in ***Figure 6***, most of the data from universities and research institutes were ranked as Class 1 or Class 2 and the information gathered from regional authorities usually placed into Class 3 and Class 4. In total, 45.6 % of the metadata are related to Class 4. The number of peer-reviewed articles in scientific journals (Class 1) and the number of reports from research projects and publications in national technical journals (Class 3) has a similar occurrence, 23% and 24.2% respectively. The Class 2 resources have the lowest number of EIGR records inserted by LTPs, only 7.2% were classified into Class 2. The reason for that is that the LTPs focus on publications and data sources that are not already available through the well-known and most appreciated research databases (i.e. Web of Science and Scopus).

The LTPs experts grouped the resources they entered into EIGR into the following 7 data types or resource categories. The type of the resources included in this wide range of information with different accessibility and formats are:

a. National databases
b. National and local reports containing facts and data;
c. Hydrogeological maps;
d. Technical reports, guidelines, manuals, etc.;
e. Books and book chapters;
f. Position papers and/or important papers on PR journals;
g. Others

Figure 7 shows the distribution of data type/resource category in the EIGR entries. The most dominant resource category is the "National and local reports containing facts and data" with 47.9 % of the metadata. The "Position papers and/or important papers in peer reviewed journals" data type has also a significant number of entries, with 26 %. The remaining 26.1 % is distributed between the "National databases" (2.9 %), "Hydrogeological maps" (4 %), "Technical reports, guidelines, manuals, etc."(2.9 %), "Books and book chapters" (6.4 %) and topics classified as "Other" (9.9 %).

3. Dissemination at national level

The research and methodology of the KINDRA project requires insight into past and ongoing hydrogeological research in Europe. Project dissemination on the national level is crucial. To facilitate this work, EFG Linked Third Parties (LTPs) participating in the project organised hydrogeology-related national workshops. The objective of the workshops was to facilitate interaction among stakeholders and come to a common understanding of the key research priorities in each particular country. Mapping the practical and scientific knowledge related to hydrogeology had already started before the event, while the workshops provided platforms for stakeholder interaction and the dissemination of project objectives and facilitated national-level networking.

The LTPs were encouraged to organise the workshop within the frame of a larger event (e.g. international conferences or annual meetings of the NA) or in co-organisation with other national and international organisations, if possible, in order to

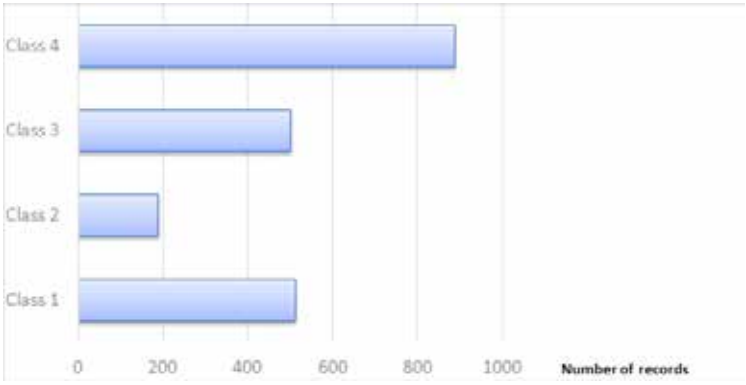

Figure 6: Quality assessment class of the records inserted in the EIGR up to January 2017.

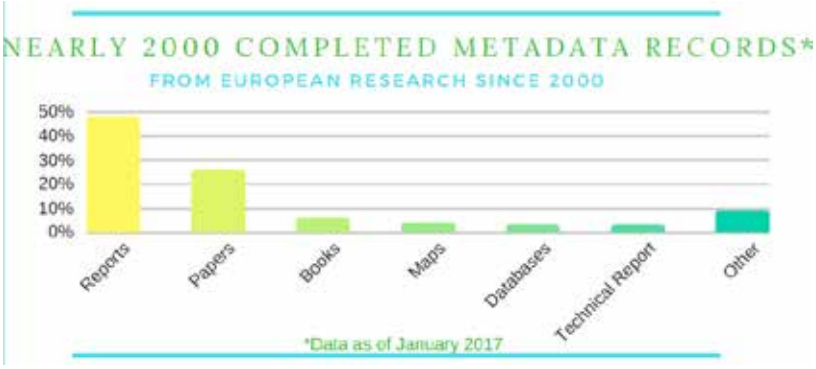

Figure 7: Metadata insertion as of January 2017.

increase the visibility of the project and have higher dissemination impact. This was the case for 10 National Associations (Greece, Serbia, Hungary, Germany, France, Poland, Belgium, Croatia, Denmark and Portugal). The rest of the workshops were organised in the National Association headquarters.

Although the overall scope was the same, the size of the workshops considerably varied, as EFG covers small and large European countries as well. The total number of the participants in the 20 European countries was over 600.

The workshops served as a platform for disseminating the project at a national level and at the same time facilitated interaction and discussion between workshop participants and KINDRA national experts. All of the participants were very interested in the KINDRA project and pointed out the importance of establishing a database of hydrogeological research and accessibility of data online on a European, but also on a national level. Participants from Denmark indicated that it would be really nice if the EIGR would be THE database with all groundwater information in Europe, including material on Research Gate, Scopus and Web of Science. Some participants were concerned about the data and platform maintenance in the future (Greece, Belgium, Spain, Serbia) and pointed out that the platform should also be communicated to the general public as a means of access to reliable scientific information on hydrogeology. The importance of pursuing roadmaps aimed at supporting policies that will enable the simplest access possible to hydrogeological knowledge by technicians, researchers and professionals was stressed (Italy), since quality and effectiveness of interventions and scientific research (aimed at both use and protection of groundwater) rely on data availability and reliability.

Participants discussed the involvement of the EU Member States related to the implementation policy according to recommendations of the Water Framework Directive in the field of works on the protection of groundwater resources and improvement of water quality. During discussion the degree of national involvement in the implementation of policy of sustainable development also was also assessed.

The general conclusions of the workshops were that the first two steps of the project (i.e. Classification and Inventory) had been completed and that the upcoming months would be mainly dedicated to the dissemination, as all technical content and results will be finally adapted into outreach materials that will help the general public to understand the relevance of groundwater in daily life. In order to achieve this, close cooperation between the public and private sector is necessary.

4. KINDRA European Inventory on Groundwater Research Open Science

On 24 April 2017 the KINDRA European Inventory on Groundwater Research (EIGR) was opened to the public. European hydrogeologists were invited to insert their data with the aim of showcasing their research to other European professionals working in the water sector.

There is a clear added value to presenting the research in the KINDRA EIGR. Three main dimensions of value can be distinguished:

1. providing visibility in the first online tool exclusively focused on groundwater research and knowledge;
2. allowing like-minded professionals to find each other;
3. classifying the research, products, papers and projects;
4. making research accessible to database analysis for EU Policy support and water directive implementation.

KINDRA EIGR has published 2,102 records from 20 countries (as of September 2017).

The record of the KINDRA inventory (EIGR), based upon the KINDRA Classification (HRC-SYS), illustrates that research and knowledge on Societal Challenge (SC) category Climate and Environment are highly represented. In total, Climate, Environment and Resource represent 87 % of the groundwater research and knowledge compilation. The societal impact of groundwater has a close relation with climate and environmental challenges. This is due to the fact that there is a close correlation between this knowledge and the daily challenges of citizens, households, industry and cities.

The Research Topic (RT) Geology has also a very high representation, 75 % of the records. In this case the explanation is the fact that most of the experts in charge of popular inventories are hydrogeologists. In the Operational Actions (OA) category, Assessment and Management is the most represented action, with 53 % of the records in this category.

Figure 8 presents a 2D representation of the research topic on Geology of the Societal Challenges, where Operational Actions and Societal Challenges intersect in the categories in each axis 5×5. This type of figures illustrates in a visible manner the societal challenges and operational actions correlate in the inventory. If the geographic areas, local, regional or national data are added, then a comparative analysis is facilitated. It becomes possible to detect which knowledge areas need additional efforts

and in which areas knowledge is already available. When a temporal dimension is added, it is also possible to visualise trends and changes over time.

Conclusions – the value of KINDRA in the broader EU policy frame

The KINDRA project has a large societal impact, given the extensive use of groundwater for our households, industry and cities. An open-science approach in the field of hydrogeology strengthens this societal impact, since it increases the quality and the relevance of hydrogeology research outcomes while allowing for the broader awareness of citizens.

The new open-science approach also increases the rate of return on public investment in hydrogeology research. First, the investment in science is gathered in a comprehensive, open and Europe-wide database of broad use and visibility. Second, the common classification enables researchers and stakeholders to detect gaps or duplication of efforts in research, while stimulating new areas of research inspired by the comprehensive state of the art provided by the open database. In this way, public investments in research in hydrogeology will have a higher return in terms of the quality and relevance of scientific outcomes.

The KINDRA project has opened up for a bottom-up European construction in the field of hydrogeology. It has created trust and reinforced networks between professionals and researchers in hydrogeology across European countries. This achievement is even more important given the relevance of groundwater and clean water to citizens and societies in Europe and beyond.

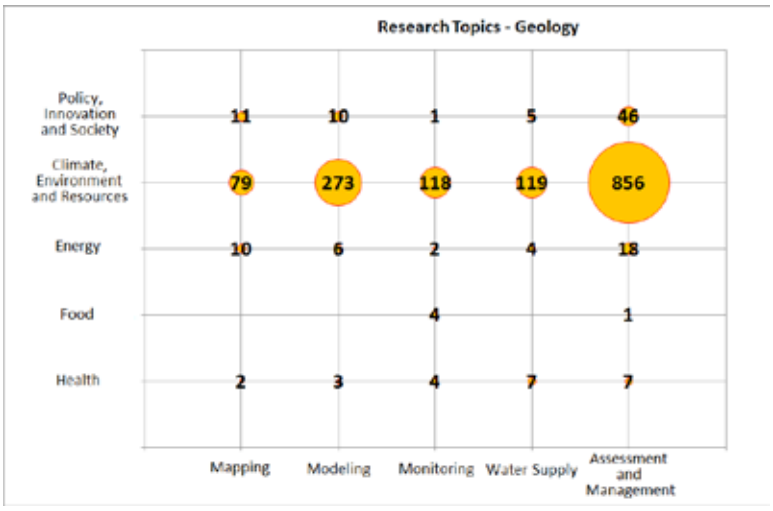

Figure 8: 2D representation of the number of resources available in the intersections of Societal Challenges and Operational Actions for the Research Topic on Geology.

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Project-related reports and publications

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