Natural-Hazard-Related Web Observatory as a Sustainable Development Tool

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Abstract

Using the Internet and wealth of data and knowledge available on the Web, so-called web observatories have been developed in the last decade—in very different fields of use. The article discusses the use of such observatories to support the implementation of sustainable development at different scales. The focus is on landslides as risk to society, and since they are related to water and soil, a web-based observatory on natural hazards, including landslides, can draw upon water- and soil-related observatories that are used worldwide as a sustainable development tool. A new landslide observatory may support major global initiatives to adapt to climate change. The Observatory's vision, structure and use can be built upon the experiences gathered by developing a global water observatory for smart water management, using Artificial Intelligence tools. UNESCO Chair on Water-related Disaster Risk Reduction of the University of Ljubljana, Slovenia, and the UNESCO International Research Institute on Artificial Intelligence at the Institute Jožef Stefan, Slovenia, have joined efforts and knowledge to develop a new global web observatory (tentatively first as the Landslide Observatory) to be used by different stakeholders when implementing global climate adaptation policies and relevant European Union strategies. The information gathered on the internet is structured, and shown using geolocators for different regions and/or countries. For interpretation of world-wide web data, landslide expert knowledge is used.

Keywords

Artificial intelligence • Earth observations • International consortium on landslides • International programme on landslides • Sendai framework on disaster risk reduction • Sustainable development goals • World wide web

1 Introduction

Landslides are frequent natural hazards globally, and their understanding and research are needed for landslide risk reduction. In many ways understanding is achieved by observing natural phenomena such as land sliding in all its variety of forms (Hungr et al. 2014). For intense and focused observations scientists are using observatories, according to the Miriam-Webster Dictionary i.e. a building (as in astronomy) or a place given over to or equipped for observation of natural phenomena. Diverse in-situ (field) observatories have been developed and are running over years to monitor and understand landslide dynamics and/or develop early warning systems. Using the internet and wealth of data and knowledge available on the Web, new types of so-called

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web observatories have been developed in the last decade—with very diverse purposes in mind. They are based on Open Data and Big Data, and any other Web data, and by crawling prepare a raw data collection from the Web, then by mapping of data do the pre-processing, converting, indexing, tagging, and integrating, to finally do the visualization and analysis of collected data (Aljohani et al. 2019). A proposed web Landslide Observatory is not a replacement of existing on-site landslide observatories and/or landslide-related Earth Observatories, but rather a web platform to provide structured data, tools, and knowledge to help stakeholders better understand landsliding as natural and social phenomena and their consequences and impacts on the environment and humankind, support sustainable development, and stimulate risk dialogue and increasing society resilience.

Landslides are mentioned in the Operational Implementation Plan for the UNESCO Intergovernmental Hydrological Programme Phase IX (IHP-IX OIP). In its February 2022 draft for the Priority Area 1: Scientific Research and Innovation, rainfall-induced landslides are mentioned in the proposed activity on Research and knowledge generation on the scientific advances in addressing and timely forecasting of water-related disasters and on additional impacts of synchronous and/or cascading water-related hazards.

The Kyoto Landslide 2020 Commitment for Global Promotion of Understanding and Reducing Landslide Disaster Risk (KLC2020) was launched on 5 November 2020 by the International Consortium on Landslides (Sassa 2021a). Earlier, the 2017 Ljubljana Declaration on Landslide Risk Reduction (Sassa 2017) endorsed a plan for the preparation of the KLC2020 as a global alliance which aims, in the medium- and long-term, to accelerate and incentivize actions for landslide disaster risk reduction to 2030 and beyond. The KLC2020 is thus a framework aimed at providing key actors and diverse stakeholders concerned with landslide risk at all levels and in all sectors with tools, information, platforms, technical expertise and incentives to globally promote landslide risk reduction.

KLC2020 supports the implementation, any follow-up and review of several global initiatives: the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR 2015), the 2030 United Nations Agenda for Sustainable Development (UN 2022a) and its 17 Sustainable Developments Goals, the New Urban Agenda, and the Paris Climate Agreement. The KLC2020 is also a contribution to the ISDR-ICL Sendai Partnerships 2015–2025 for global promotion of understanding and reducing landslide disaster risk with a subtitle "Tools for Implementing and Monitoring the Post-2015 Framework for Disaster Risk Reduction and the Sustainable Development Goals"' (Sassa 2015). The ISDR-ICL Sendai Partnerships 2015–2025 was a voluntary commitment to the United Nations World Conference on Disaster Risk Reduction, Sendai, Japan, 2015. Today, there are many Voluntary Commitments to SFDRR, not all at global scale (UNDRR 2022).

KLC2020 accounts for ten priority actions in research and capacity building, coupled with social and financial investment, among them, the following priority actions are of interest for discussion in this paper:

– Action 5: Promote open communication with local governments and society through integrated research, capacity building, knowledge transfer, awareness-raising, training, and educational activities, to enable societies and local communities to develop effective policies and strategies for reducing landslide disaster risk, to strengthen their capacities for preventing hazards from developing into major disasters, and to enhance the effectiveness and efficiency of relief programs.
– Action 9: Foster new initiatives to study research frontiers in understanding and reducing landslide disaster risk by promoting joint efforts by researchers, policy makers and funding agencies.

The basic idea behind this paper is to discuss a state-of-the-art on diverse global observatories related to sustainable development and its goals, and how this knowledge can be used to develop a natural-hazard-related web observatory that would help to strengthen the discourse among relevant stakeholders focused on risk dialogue in order to increase resilience and support the implementation of sustainable development goals (SDGs) related to natural hazards. Water has an important role in the 2030 Agenda for Sustainable Development (Casale and Cordeiro Ortigara 2019), as it is directly or indirectly related to all SDGs (Fig. 1).

The University of Ljubljana (UL) Faculty of Civil and Geodetic Engineering (FGG) is a full member of the ICL since 2008, and has actively contributed to different ICL and IPL activities in the years there after (Mikoš and Petkovšek 2019), most notably by organizing the 4th World Landslide Forum in Ljubljana in 2017 (Mikoš et al. 2017).

UL FGG has been since 2008 consecutively recognized five times as the World Centre of Excellence on Landslide Risk Reduction, and is hosting UNESCO Chair on Water-related Disaster Risk Reduction (WRDRR), established at University in Ljubljana in 2016. UL FGG and UNESCO WRDRR Chair are supporting KLC2020, and its two Priority Actions: #5 and #9. In this sense, ULFGG proposed in 2022 a new IPL project entitled "World-wide-web-based Landslide Observatory (W3bLO)". The project, if approved by the Global Promotion Committee of the International Programme on Landslides and the Kyoto Landslide Commitment 2020 (GPC/IPL-KLC), will be executed in collaboration with the UNESCO International

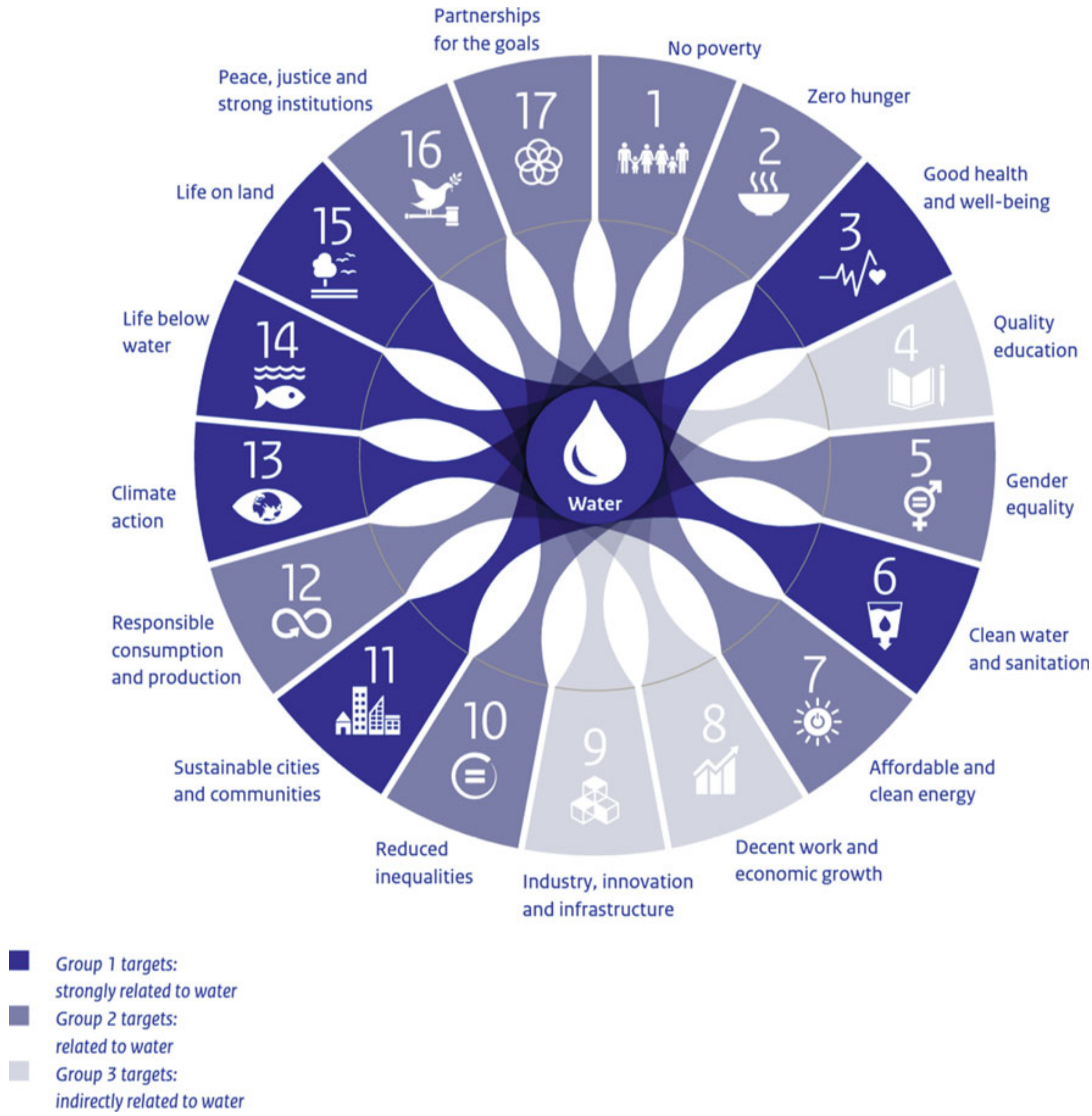

Fig. 1 Importance of Water in 2030 (from PBL 2018, *source* Casale and Cordeiro Ortigara 2019, Fig. 4)

Research Institute on Artificial Intelligence (IRCAI), hosted by Institute Jožef Stefan, Ljubljana. The IRCAI was inaugurated and virtually launched in March 2021, and is regarded as a coordination point, founding route and exploitation accelerator for approaches to the UN SDGs that make use of Artificial Intelligence. Due to the proximity of the both institutions, located in the City of Ljubljana, Slovenia, and excellent experiences in the past in the field of the joint research cooperation, it was quite natural to try to combine the expertise in the two fields: Artificial Intelligence (IRCAI) and landslide research and risk reduction (ULFGG), for the implementation of sustainable development. The joint idea was to start developing a web-based observatory to be applied in the field of disaster risk reduction.

The first phase of the project work will be based on the experiences of the IRCAI team while developing a web-based water observatory for smart water management for sustainable development. Before a more focused and in-depth description of a water observatory under construction for smart water management, a short overview of already developed natural-hazard-related observatories will be shown to see what information they offer. A confrontation of the two, and having in mind the SFDRR 2015–2030 targets, a way further in preparing a web-based Landslide Observatory will be paved.

Landslides and mass movements were also recognized as one of the main threats to soil health in the EU Soil Thematic Strategy (Montanarella and Panagos 2021), thus being relevant for target SDG 15.3 for achieving land degradation neutrality. Landslides are related to the EU Biodiversity Strategy for 2030 (European Commission 2022a) that was published on 20 May 2020, and EU Soil Strategy for 2030 (European Commission 2022b), adopted by the European Commission on 17 November 2021. As a tool for the implementation of the latter strategy, the EU Soil Observatory was launched on 4 December 2021 (ESO 2022). Its vision, mission, operational principles, organization, functions and activities are laid down in a concept note (European Commission JRC 2021). Sustainable soil management and the restoration of degraded land is critical if biodiversity protection targets are to be achieved. The reader can easily understand how landslides are involved in water and soil issues concerning sustainable development at all scales. Potentially, a web-based Landslide Observatory will help to implement different international strategies and policies, foremost several SDGs.

Different institutions/entities are offering tools or data for water-, soil-, and natural-hazard-related observatories. For example, Copernicus Emergency Management Service (EMS) Early Warning and Monitoring offers critical geospatial information on emergency response and disaster risk management at European and global level through continuous observation and forecasts for floods, droughts and forest fires (Table 1).

The Dartmouth Flood Observatory was founded in 1993 by Dartmouth College, Hanover, New Hampshire, USA, and moved in 2010 to University of Colorado, USA. It offers diverse space-based data, images, maps, and tools for surface waters, including floods (Kettner et al. 2021).

The NASA Earth Observatory (NASA 2022a) is bringing together images, global maps, articles, blogs, stories, and discoveries on a variety of natural events, including flooding and landslides. For landslides as for other natural disasters it is important to develop robust inventories of events. NASA has developed Global Landslide Catalog (GLC) and expanded it by Landslide Reporter Catalog (LRC) to the so-called Cooperative Open Online Landslide Repository (COOLR) (NASA 2022b). The COOLR project contains *Landslide Reporter*, the first global citizen science project for landslides, and *Landslide Viewer*, a portal to visualize data from COOLR and other satellite and model products (Juang et al. 2019). In the first 13 month of the project, 162 landslide events were added to the inventory (NASA 2022c)—a good start.

In 2010, the International Consortium on Landslides (ICL) started its ICL World Report on Landslides (ICL 2022), a platform for a global repository on landslides for

Table 1 A selection of natural-hazard-related observatories

Observatory	Information	References
AGU–Blogosphere	A community of earth and space science blogs, hosted by the American Geophysical Union, including The Landslide Blog	AGU (2022)
DFO–Darmouth flood observatory	Space-based measurement, mapping, and modeling of surface water for research, humanitarian, and water resources applications	DFO (2022)
EDO–European drought observatory	Drought-relevant information and early-warning for Europe	EDO (2022)
EFAS–European flood awareness systems	Complementary regional and national flood forecast and monitoring information	EFAS (2022)
EFFIS–European forest fire information system	Forest fire activity in near-real time. Useful for wildfire management at national and regional level	EFFIS (2022)
EUSO–European union soil observatory	Collecting high-resolution, harmonized and quality-assured soil information (showing status and trends) to track and assess progress by the EU in the sustainable management of soils and restoration of degraded soils	EUSO (2022)
GDACS—Global disaster alert and coordination system	GDACS is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve alerts, information exchange and coordination in the first phase after major sudden-onset disasters. The system covers earthquakes, tropical cyclones, floods, volcanoes, droughts, and forest fires	GDACS (2022)
GDO–global drought observatory	Drought-relevant information and early-warnings globally	GDO (2022)
GloFAS–global flood awareness systems	Complementary global flood forecast and monitoring information	GloFAS (2022)
NASA earth observatory	Images, global maps, articles, blogs, stories, discoveries on natural events such as floods, landslides, fires, drought and other natural events	NASA (2022a)

Fig. 2 The approach used leading from data sensing to the digital twin and its approximation to local priorities

landslide experts, researchers and practitioners alike. Later, detailed instructions were prepared on the web site with a ranking system depending on the details submitted to the Report. In 2017, forty reports were submitted (Abolmasov et al. 2017). In early 2022 it is sadly only added a few more.

2 A Data-Driven Global Observatory

The world's globalization phenomena unveiled the awareness of world-wide problems, such as the climate crisis and its consequences, but also the common efforts to find solutions to water-related problems (e.g. floods) through collaborative actions. There are many obstacles still today on such global strategies to which innovative technology and data-driven solutions can help. In this section, we describe a novel concept of a global observatory based on text mining algorithms that is able to answer the wide range questions that are core to global solutions, using Big Data analytic methods over the layered information it is ingesting in real-time.

The main perspectives of this global observatory fall on: (i) the monitoring and exploration of news articles and social media feeds; (ii) the analysis of combinations of indicators through time and what stories can they tell; and (iii) the exploration of published scientific knowledge and patented innovation; and (iv) the exploration of historical data on natural resources and weather, allowing to forecast tendencies in a medium/long-term time horizon of ten years. All of these perspectives can be combined to provide complementary answers to main landslide-related topics.

2.1 Methodology

Observing events both at global and local scales requires firstly the sensing capability and then the interoperability between the knowledge that was sensed. That sensing is translated by the acquisition of heterogeneous data that can provide us with a multitude of perspectives over what is being observed.

As illustrated by the schema in Fig. 2, we consider the construction of the Global Water Observatory into phases going from lower to higher complexity. We start by putting together data sources that are meaningful to a range of stakeholders that are targeted, from engaged citizens to decision makers that can leverage the information provided to established evidence-based policies.

At the data collection phase, we must be concerned with properly addressing the challenges in the heterogeneous nature of Big Data in all of its Vs dimensions (Song and Zhu 2016), their different frequency and size, as well as the levels of access to it established by data providers. These parameters take into consideration to ensure the appropriate data ingestion into the system. The selection of data sources is done manually, but their ingestion is automated, when the frequency of the update is high (e.g. weather).

In the case of yearly updates, the data is ingested manually (e.g. MEDLINE or statistical aggregated data feeding indicators). This Observatory collects data from many different data sources (e.g., the Worldwide news, the Microsoft Academic Graph, the Word Bank, the United Nations Sustainable Development Goals) in their global scope, according to their relation to the focus topics and priorities (see Table 2). Complementary to this, the local installation of the Observatory is also ingesting local data originated mostly from national open data initiatives, national statistics agencies or open datasets produced in the context of projects that relate to the priorities that are being observed (collected from global repositories, e.g., Schweizerische Eidgenossenschaft 2022).

The next stage is the data cleaning, data processing and data integration prior ingestion. This step is very important to allow for the data quality that is needed in order to obtain useful insights from it. In this step, we include the data curation, where the most meaningful datasets are selected and parsed. The Observatory also includes exploratory data analysis and some data visualization for the purpose of prototyping the data visualization modules that are then available at the Observatory.

The Observatory phase is then possible when the curated data streams of a selection of dynamic data sources are live in the system and can be used to obtain insight on particular topics of interest, monitor Key Performance Indicators associated with business priorities, and allow for a global and local perspective on related topics. These include interactive data visualizations of indicators and statistical data, the dynamic view of the news sources over priorities,

Table 2 Data sources feeding the observatory

Name	Source	Short description
Worldwide news	Event registry	News articles with timestamp, title and URL
Facebook impact	Event registry	Number of posts in Facebook mentioning a certain article
UN open dataset	UN portal	Global indicators on water resource management
World Bank open data	World Bank	Global indicators on the access to clean and drinkable water
SDG	SDG6 web portal	Global indicators of progress on the achievement of SDG6
JRC	Global surface water	The volume of available water by GIS coordinates over time
Statistical water data	Eurostat	Different statistical time series on water-related aspects
European water data	EU open data portal	A range of water-related topics described by time series
Twitter feed	Twitter	The historical data of a part of the global Twitter feed
Weather data	ECMWF	The current data and forecasts on the weather conditions
MEDLINE	USA national library of medicine	The 26 + million biomedical research article abstracts and titles
Microsoft academic graph	Microsoft academic	Published research articles and patents (including MEDLINE)

or the user query over a scientific research topic. This allows for insight on topics in analysis (such as water topics like water scarcity and water quality, and public health topics like Ebola or the new coronavirus) that will be put into the context of local data when sourced from the shared interest of users.

The path ahead is a novel concept of a meaningful Digital Twin (i.e., a dynamical model which given a current state of an observed system, is capable of a digital partial reconstruction of such a system) that builds over the Global Water Observatory to rise above data complexity towards data interoperability. This is usually difficult to achieve in full due to the heterogeneity of the data, the different characteristics of the data sourced (frequency, data types, etc.) and the domain knowledge needed to identify new challenges covering a wide range of business intelligence priorities. Nevertheless, useful aspects of it can be achieved, some of which are already evident from the implementation available at (NAIADES Water Observatory 2022) and discussed in the following sections. An example of this is to track a topic in the news, its impact in the social media, and explore the range of the problem in the published scientific research, as well as extract good practices to deal with this problem.

A final stage to this diagram, and usually forgotten in a theoretical framework, is the adaptation of the system to the needs and priorities on the user's side. Here, we consider the ingestion of local data, the customization of news streams, the availability of exploratory dashboards, the shareable instances for policy makers, and the APIs for 3rd party integration.

Altogether these five phases run simultaneously to have the Observatory running as a live system that can support real-time decision-making. A typical example of the aimed outcome of such an intelligent system is the following sequence of events:

(i) a new technology is identified in scientific research;
(ii) the patents around it multiply, alerting its importance;
(iii) new mentions of its usage arise in the market landscape;
(iv) companies relating to it are now able to guarantee new investment; and
(v) news media is more and more aware of the importance of the technology (unknown in (i)).

The system that is able to access the data sources that relate to the items above, is also able to track the term throughout the several phases of popularization. It is also able to show the current status of a particular topic of interest, and optimally alert for potentially trendy topics in the future.

The analysis of indicators in pair with other data-driven perspectives can put the problem into a global context. In the visualization of Fig. 3 we consider five dimensions—x-axis, y-axis, bubble size, bubble color, and time—to represent the many aspects of the representation of the information. The explorations based on this analysis lead us to aspects of the causality inherent to the problem itself, in the sense that some of the answers to the problem in analysis lie in the analysis of the causes of that problem.

2.2 An Observatory for Water Events

Water is fundamental to all human activity and ecosystem health, and is a topic of rising awareness in the context of the recent discussions on climate change. Water resource management is central to those concerns, with the industry accounting for over 19% of global water withdrawal, and agricultural supply chains are responsible for 70% of water stress (Our World in Data 2020). In 2015 the UN established

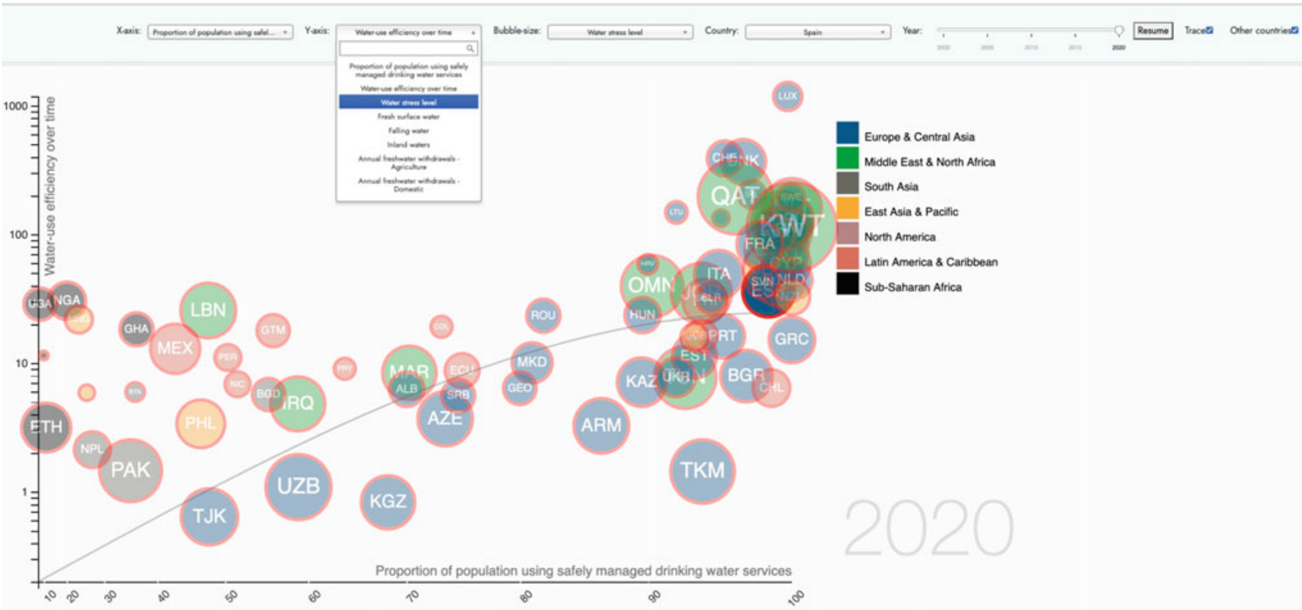

Fig. 3 Animated visualization of indicators and their relation

"clean water and sanitation for all" as one of the seventeen Sustainable Development Goals, aiming for eight targets to be achieved by 2030 (UN 2022b). The UN secretary-general points out in April 2020 that SDG 6 is "badly off track" compromising the progress on the 2030 Agenda (UN 2020). As noted by the Organization for Economic Co-operation and Development (OECD), the 'water crisis' has often proven to be a crisis of governance (OECD 2011), where water scarcity is largely caused by mismanagement of resources, leading to a global prioritization (Akhmouch et al. 2018).

Added to this, climate change is a global problem that in recent years has been in the focus of European and World-wide strategies. The priorities in the European Union are rapidly changing towards sustainability and environmental efficiency, covering most domains of action. The European Commission's Green Deal (European Commission 2019a) aiming for a climate neutral Europe in 2050, and boosting the economy through green technology provides a new framework to understand and position water resource management in the context of the challenges of tomorrow (European Commission 2019b).

In this context, the NAIADES project (NAIADES 2022) aims to improve the water resource management in a global context, including European regions where water scarcity is predicted, also dealing with concerns such as saline intrusion and groundwater contamination. The current implementation of the Water Observatory in the context of the European Commission's-funded Horizon 2020 project NAIADES on "Smart Water Management for Sustainable Development Goals" (Pita Costa et al. 2021) allows users to have a global perspective on water-related events (e.g. floods), but also to address specific conditions and priorities. It is ingesting water-related data both from global agencies (e.g. UN and World Bank) and local entities (e.g. Swiss open government data opendata.swiss (Schweizerische Eidgenossenschaft 2022)) to activate an intelligent system distributed through the following "views":

- Indicators: adding to the global indicators fed on statistical data provided by the United Nations, the world bank and other trustworthy agencies, the local installation of the observatory is ingesting curated open datasets that have regional information about water topics of interest to the stakeholder.
- Media: each location has its own news and social media streams configured to priorities and aspects of the news that stakeholders define as topics of interest (e.g., floods).
- Research: similar to the media sources, the research topics allow for some customization to better fit to the needs of the local user.
- Resources: the natural resources information provided for exploration is geolocated to the regions of interest to the user of the platform.

These views change when a new location is selected to better reflect the priorities of its users. This observatory allows the user to achieve a multitude of perspectives aligned with objectives fed by data sources of different nature, as follows:

- Explore the details of the best practices identified in global and local news on water-related topics, with a worldwide coverage through multilingual capability configured to the user priorities;
- Assess the impact of the events of interest from the reshares on social media (Facebook), as well as explore the real-time feed of social media itself (e.g., Twitter);
- Observe the evolution in time of local and global indicators related to the usage of water resources to understand the relations and possible implications in own business;
- Explore the global information of water contamination from trusted scientific sources and news articles, complemented by the social media input, and the good practices to deal with local similar problems in focus;
- Reuse open datasets on weather and water levels to have an assessment on the impact of climate change in available resources in a window of ten years;
- Align with the input of the observatory with the data provided by other data platforms and the proprietary data, enriching the business intelligence.

The NAIADES Global Water Observatory does not only contribute to the improvement of European sustainability in water-related matters, but will also provide the local actors on the water resource management an active role in that. The typical three main groups with different workflows that can be users of this technology belong to supported by the developed technology:

- water resource management: using the provided information in the resolution of problems related to weather events, to understand how their actions are perceived by the consumers, and to explore successful scenarios in similar cases.
- local government: to help evidence-based decision-making using open data, better sync to the Sustainable Development Goals and other guidelines, and evaluate commitments in time.
- general public: for water education with a local context, in aspects that matter to the local population, based on parts of the Water Observatory that can be open to the public.

The intention to globally monitor water resources is not new, and by the late 1960s (Freeze and Harlan 1969) the first spatially-distributed water resources model appeared, with first operational uses of satellite observations in water resources developed in the early 1980s (Ramamoorthi 1983). The reliable management of water resources is only possible under the condition of availability of adequate qualitative and quantitative information about the state of the water body at any moment of time.

Taking advantage of the recent technological progress enabling much innovation that was unthinkable a few years ago, the concept of the Digital Twin is increasingly entering the water sector as an innovation driver. Due to the rapidly growing awareness of the sustainability challenges that we are facing in Europe and worldwide in the context of water resource management, there has been much work done to develop systems that are able to collect information about the available water and even simulate and forecast that in the near future. These are usually geolocation-based systems ingesting water-related data to enable real-time monitoring of resources and usage (Idrica 2018). The other typical approach is the systems focused on workflows in the water sector, including the management of water distribution networks, hydraulic efficiency or leak/fraud detection, better suited to those companies that already have their infrastructure in place and know well what they want to monitor (Idrica 2019).

The approach proposed in this section is novel in many ways. It brings a dimension of media and social media to the analysis of global water events, made possible by the recent advances in text mining and machine learning to capture appropriate insight from the data collected worldwide.

As shown in Fig. 3, the user can select over a variety of indicators each of which represents a time-series of ingested statistical data that can describe progress on a certain topic over the years. Moreover, the analysis of the open data ingested allows us to identify causality relationships between those indicators (Neuman and Grobelnik 2022) and to compare regions and countries on resources and measures to build evidence-based policy-making over data that is often freely accessible but is not always easy to explore.

The media is also a rich dataset that can be used to monitor the water-related events in real-time. NAIADES is using the Event Registry News Engine (Leban et al. 2014) to analyze more than 300 thousand new articles per day over more than 60 languages. The NAIADES Water Observatory is monitoring flood and water contamination events at a worldwide scale (in Fig. 4, we show the news dashboard exhibiting the most recent topics on a selected specific focus in media every second), allowing us to use advanced text mining capabilities to explore the main concepts and categories when addressing water-related events (in Fig. 5, we show the distribution of news categories on a certain water-related topic over a time window).

This news monitoring perspective is also including a Twitter observatory that adds a social media perspective covering the main discussions taking place in related topics, or the sentiment of those social media posts over time that can help us to achieve another perspective on the water event. The current implementation is based on an easily configured dashboard feeding on the collected data that can

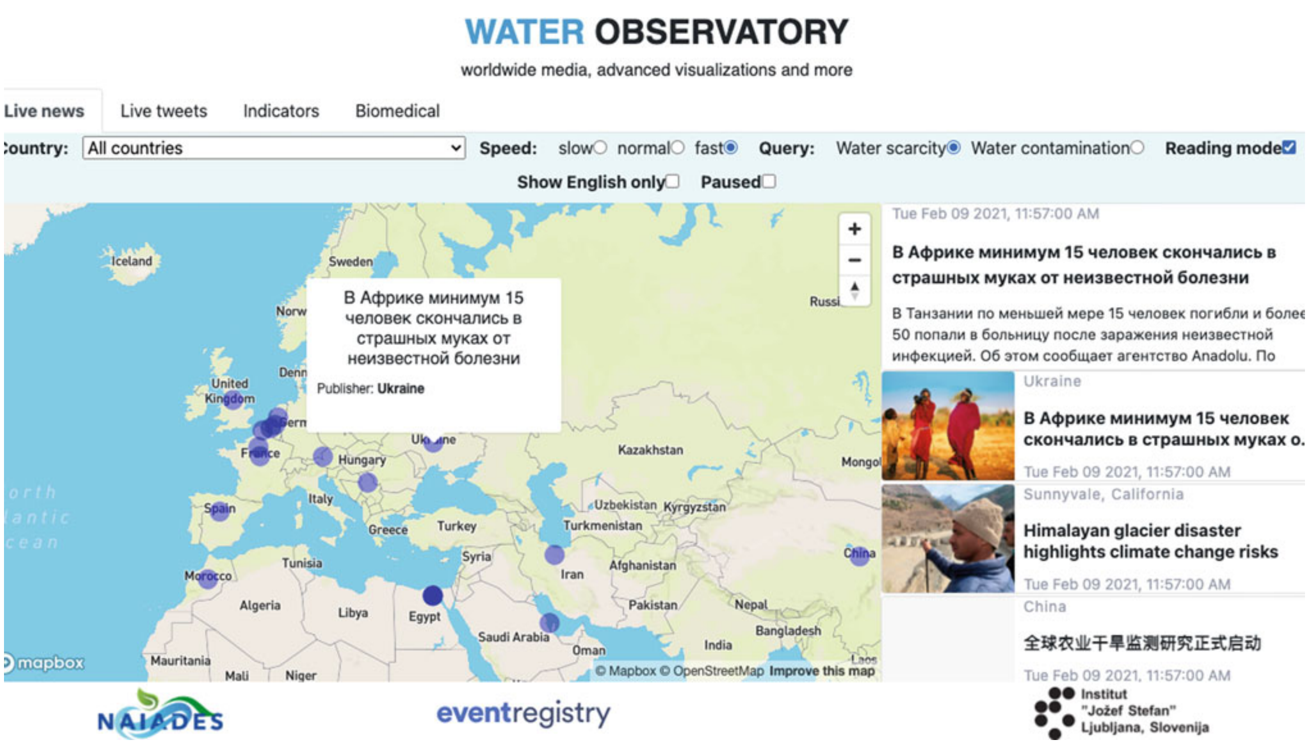

Fig. 4 SDG 6-focused NAIADES water observatory collecting worldwide news on water-related events

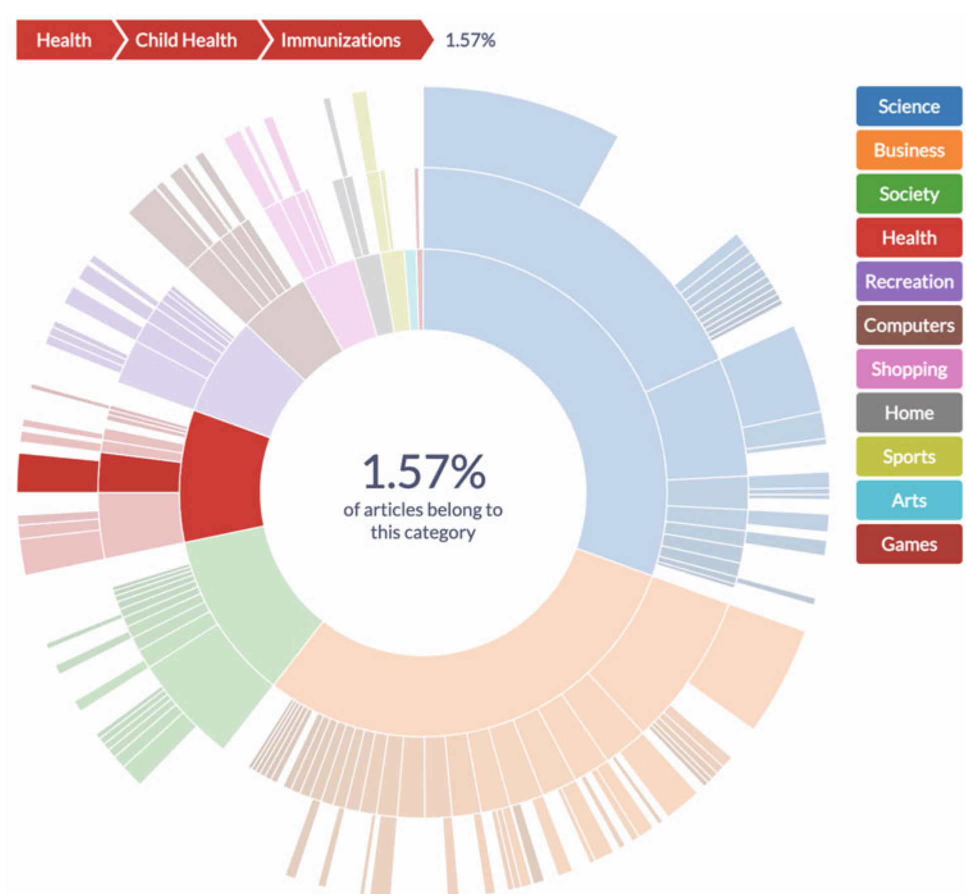

Fig. 5 Weight of news categories in the context of "wastewater" during 2021

also serve as a prototype tool to explore potential and build useful data visualization dashboards.

One of the valuable aspects of the usage of social media data is the possibility of using it in order to nowcast public opinion about the actions taken in a certain water-event, or to establish customized alerts to monitor those events. The latter is a much more difficult task due to the noise and low frequency/amount of data. For those, we can use data from collected news on similar events covering the main features to take into consideration.

The important role of scientific research in this context is revealed by the trends and findings on certain water-related topics (e.g. water contamination or wastewater) and the best practices that can be extracted from this data. The observatory is also using other text mining and data analytics algorithms to analyze simultaneously multiple time-series providing interactive exploration tools to understand trends in research over time and how concepts are related with each other over time (see Fig. 6).

The localization of this global system entails the customization of its functionality in news monitoring, ingestion of local indicators and exploration of scientific research on observed problems in, e.g., groundwater contamination. In that, the observatory is synchronizing with the priorities of regional water providers. These agencies (e.g. Aguas de Alicante) are collecting data on their water resource management services to improve the customer satisfaction and optimize their system.

2.3 Addressing Other Landslides Problems

The development of a Landslide Observatory, refocusing some of the technologies used in the earlier described NAIADES Water Observatory, are mostly due to the acquisition of appropriate data and to the definition of monitoring priorities. When analyzing the worldwide news and social media, the usage of appropriate terms, and eventually the ingestion of news venues that are not yet considered is fundamental to cover well the topics of interest and better capture the dynamic perspective they provide. The Observatory is using Wikipedia terms to activate its multilingual potential (e.g., "Landslide" is an existing term in Wikipedia covered by 81 languages, while "Mudslide" does not exist having to be substituted by "Mudflow" as noted by Wikipedia).

Following the unfortunate mudslide disaster event in the Shizuoka Prefecture in Japan on July 7, 2021, the news monitors ingested 2165 related news articles covering the event and its consequences. Figure 7 shows the entities and concepts extracted from the sample of news based on the query defined by the user that will activate other data analytics algorithms and data visualization modules (as above in Fig. 5).

When learning over historical data collected on a topic, the Observatory can leverage text mining methods to automatically classify news records based on labeled text, and identify related events that the user can recur to in order to

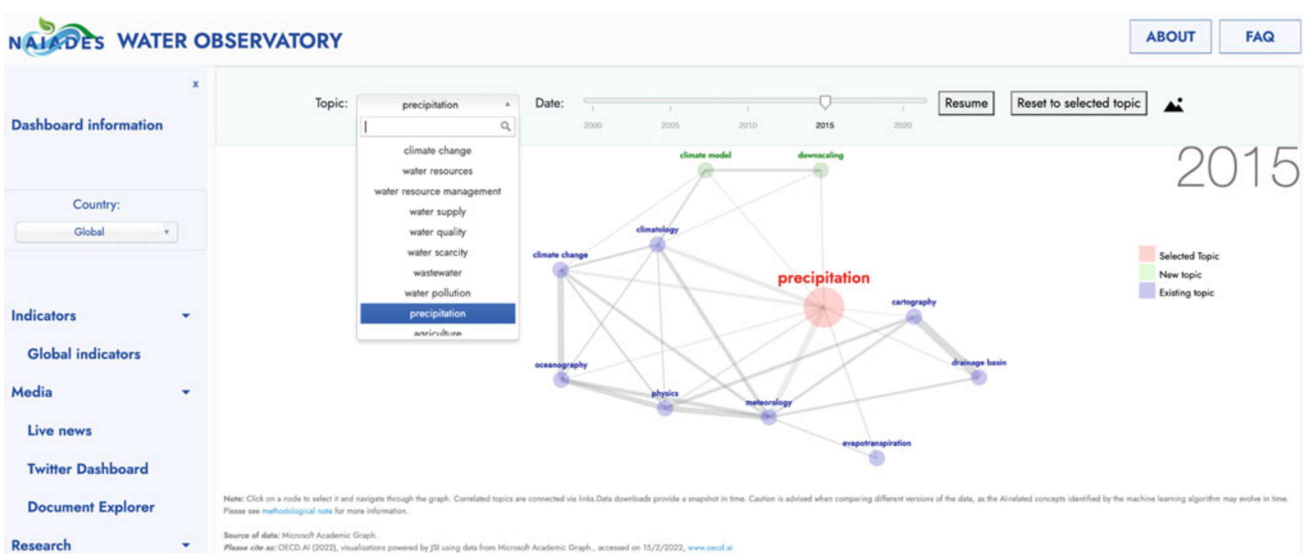

Fig. 6 Main topics in research relating to "precipitation" across time

explore a certain event. By ingesting a stream of Twitter data, we are also able to reuse some of these extracted entities in monitoring similar events in social media, and relating the frequency of mentions with the intensity of the media coverage on such events.

Moreover, with the computation of the news sentiment, they can grasp the perspective of the media on, e.g., the governmental actions to the event. Figure 8 shows the news sentiment overview on news regarding the current mudslide disaster in Ecuador, in a suburb of Quito on January 31, 2022. Although most of the sentiment is negative as expected due to the nature of the event, part of it is positive showing some appreciation for, e.g., the reevaluation of scientists and engineers in the water distribution in Ecuador, or the reopening of public discussions on the bargain power of indigenous groups in mining and drilling disputes (New York Times 2022).

The existing observatory identifies 927,847 articles collected over eight years on the topic of "Landslides" (see Fig. 9). It allows the user to explore the phases of each event based on the available news articles and explore constructive scenarios from other experiences and methodologies, leveraging the capabilities of text mining technologies made available by the Jožef Stefan Institute (e.g. NewsFeed and Wikifier (Leban et al. 2014)) allowing the use of Wikipedia terms to perform complex queries across languages, and that can better acquire detail and reasoning.

Allied with the exploration in media and social media, the user of the Observatory can explore published research and patented innovation through a complex data visualization technology that makes it easier to perform literature review over a certain topic, allowing for powerful Lucene-based queries over the article's metadata aiming to refine search by moving a pointer over clusters of related topics (see Fig. 10). Considering that the MEDLINE dataset ingested into the system includes "Landslides" as one of its descriptor categories (USA National Library of Medicine 2019), the exploration of scientific articles covering landslide-related topics can be explored using the following Lucene query: *MeshHeadingList.desc: "Landslides"*.

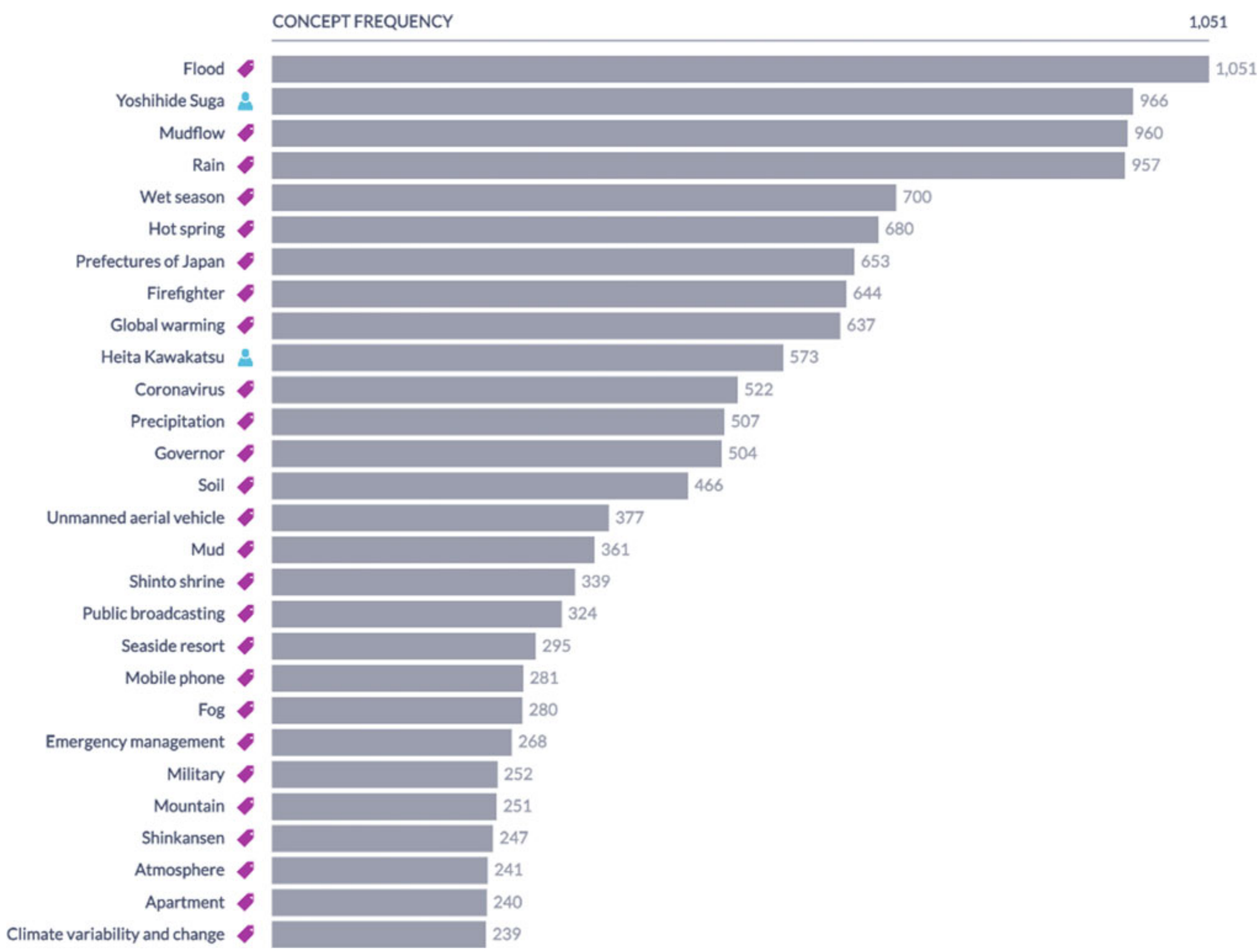

Fig. 7 Main concepts related to the mudslide disaster in Japan on July 15, 2022

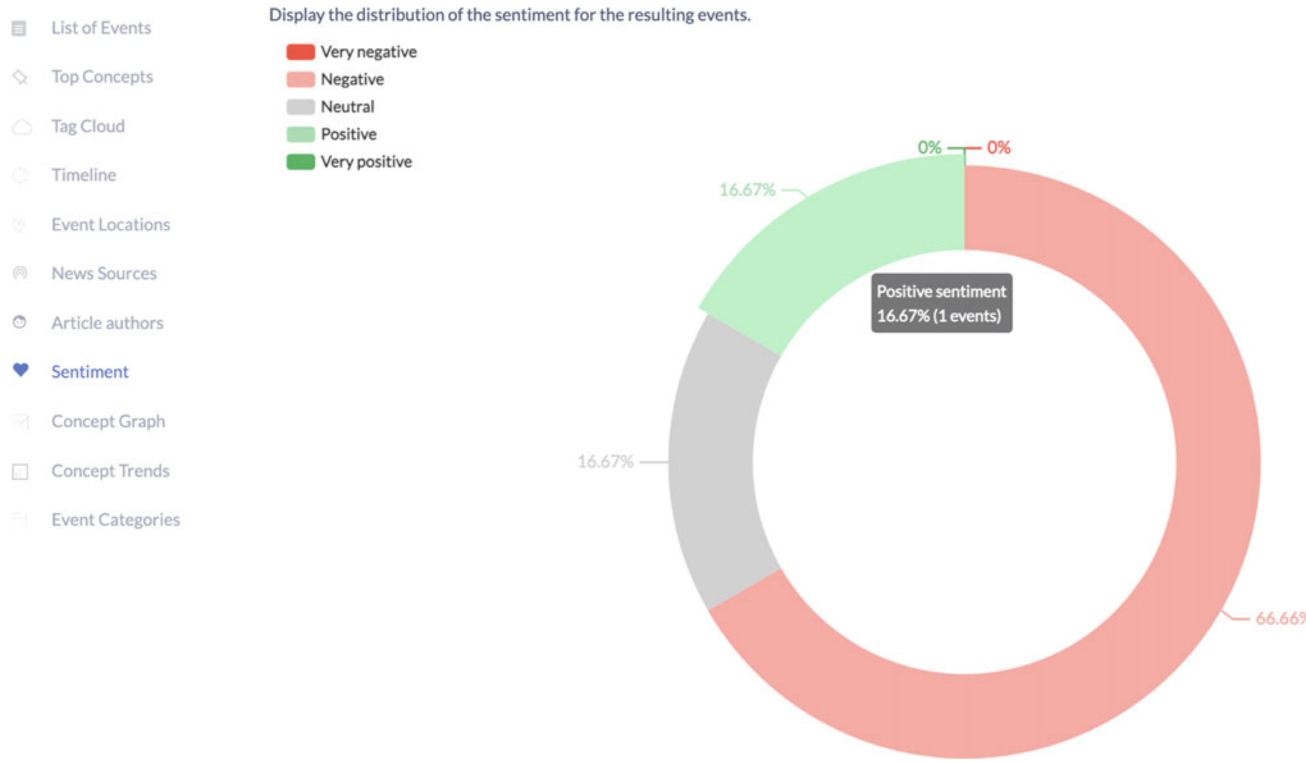

Fig. 8 News sentiment captured from the mudslide

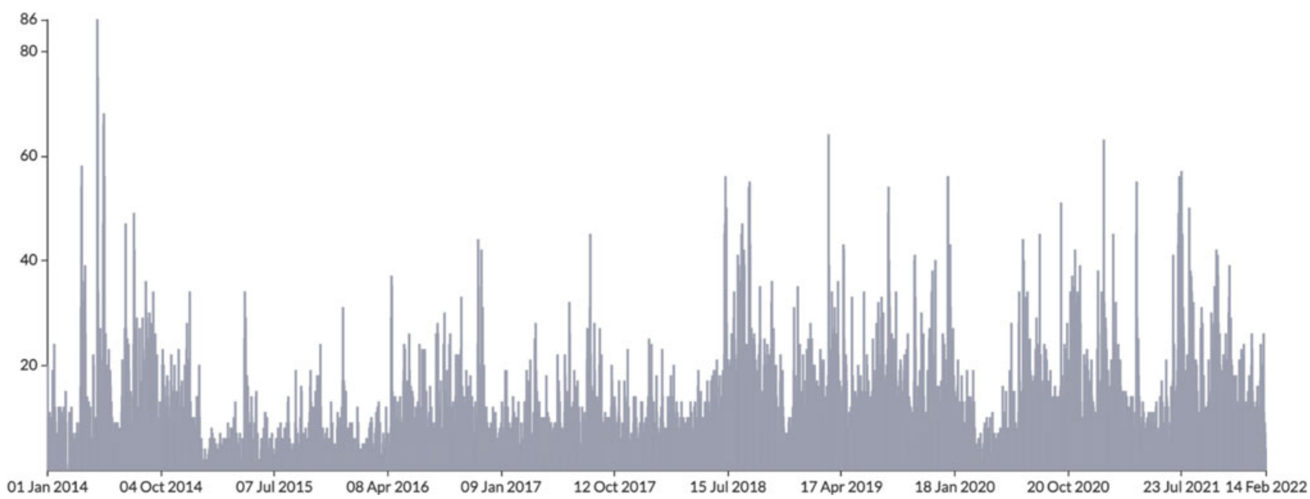

Fig. 9 Exploring a timeline of worldwide news on landslide events throughout 927,847 articles in eight years of collected data

Finally, the access to the indicators view as a data visualization tool to make sense of the ingested statistical data, complements this analysis workflow allowing the user to investigate on different aspects related to landslides, from the "water stress level" to the "water exploitation index", to name a few of the time series already cleaned and ingested.

3 Conclusions and Further Work

The results discussed in this article show the potential impact of the proposed data-driven global observatory in contexts like water resources and climate change preparedness (already including a focus on floods as water-related events),

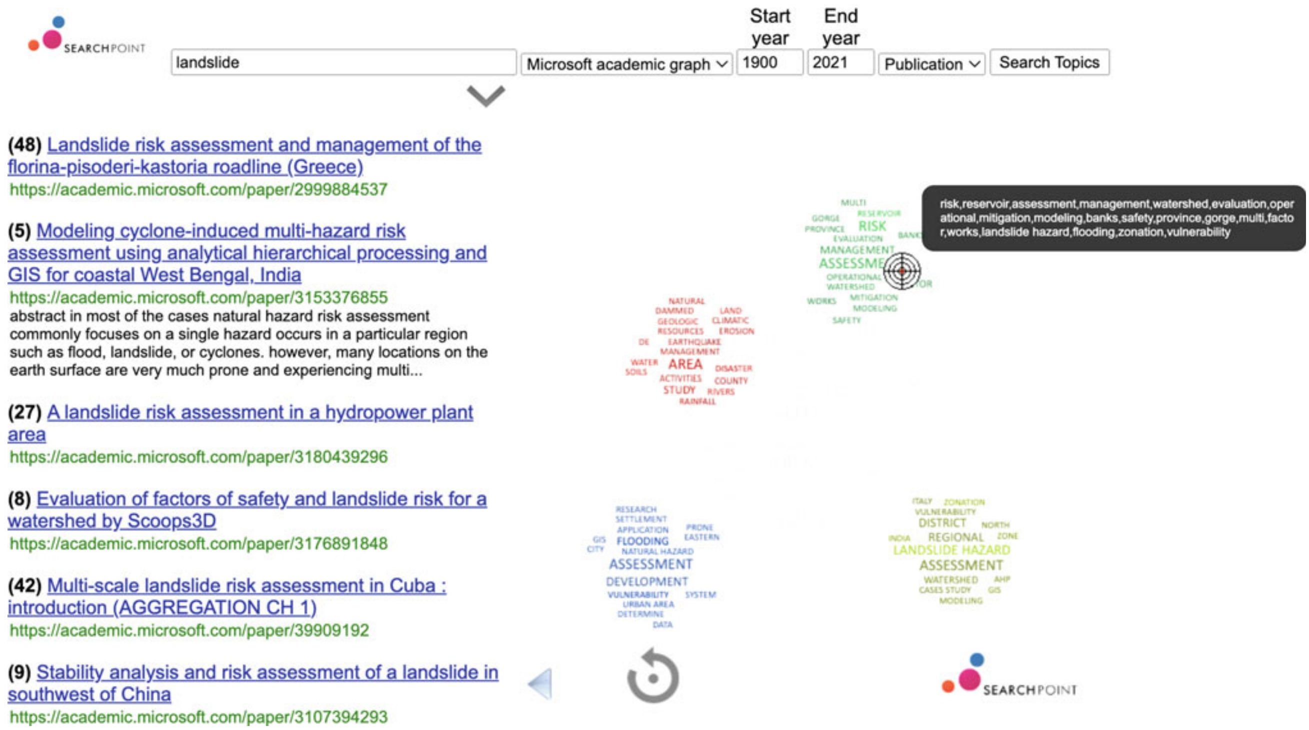

Fig. 10 Exploring scientific research on landslide assessment and management

and the scaling potential to address landslides, as already demonstrated with the results shown. This integrated system is capable of monitoring in real-time worldwide news and social media, statistics, published science, weather and many other data streams that are identified as useful and can provide complementary value to those considered already. The scaling capability of this intelligent system allows it to be deployed in the context of other global problems where there is enough data to provide useful and meaningful contribution, either in other aspects of the climate crisis to better plan response, in addressing other epidemiological concerns to serve as early warning, or in addressing a new focus in the context of data science for social good.

We are now working on extending this system to further integrate the information retrieved with the focus on landslide-related topics. The user will be able to explore a wide range of indicators and compare trends on a global and local level throughout a meaningful timeline. We will also be reusing EC-funded open datasets and initiatives in order to ingest this information as European-level indicators to complement the analysis.

Moreover, we are investigating the optimal long-term forecasting and data visualization that can contribute to climate change preparedness, integrating the knowledge obtained from the appropriate application of text mining methods to indicators, research and news, and elaborating on the impact of that change in landscape monitoring-specific problems.

Furthermore, we will be further investigating the validity of the localization of this Observatory, integrating some of the local data that can be provided by the user, and customizing news sources to their own priorities, as well as making available data exploration dashboards that allow for further insight and evidence-based policy.

The gained expertise on how to build a web observatory in the field of water management in order to support the implementation of the SDG6 “Clean water and sanitation” will be used to develop a web landslide observatory that may be used for the implementation of the SDG13 Climate Change and other SDGs, where landslides are seen as threatening factor, and other international strategies and policies, including the Kyoto Landslide Commitment 2020 for Global Promotion of Understanding and Reducing Landslide Disaster Risk. The observatory development can also be seen as a contribution to UNESCO Intergovernmental Hydrological Programme Phase IX (IHP-IX OIP).

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